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Mine Site Cleanup for Brownfields Redevelopment:

A Three-Part Primer

The Brownfields and Land Revitalization
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U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Brownfields and Land Revitalization Technology Support Center
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The color photos on the cover illustrate the transformation possible when mine sites are cleaned up and redeveloped. They depict reclaimed mine sites in Montana and Pennsylvania. Source: Chuck Meyers, U.S. Office of Surface Mining. The sepia photo depicts a coal breaker at a mine in Shenandoah, PA. It was obtained with permission from the website

Mine Site Cleanup for Brownfields Redevelopment

Foreword

It is estimated that more than 500,000 abandoned mine sites are located throughout the United States. Cleanup of mine sites for redevelopment provides an opportunity to turn these sites into land that has beneficial uses. Mine sites have a variety of potential reuses, including recreation, wildlife habitat, rangeland, historic and scenic preservation, and, depending on location, conventional residential, commercial, and industrial construction. Complex economic, social, and environmental issues face communities planning to redevelop these sites. Challenges to redeveloping mine sites include finding the resources to characterize and remediate sites with potentially significant environmental issues; addressing federal, state, and local regulatory requirements; and working through redevelopment issues with the local community and other stakeholders.

To help address these challenges, the U.S. Environmental Protection Agency (EPA), through its Brownfields and Land Revitalization Technology Support Center (BTSC – see box on page iii) has prepared this primer on *Mine Site Cleanup for Brownfields Redevelopment* to provide information about the cleanup aspects of mine site redevelopment, including new and innovative approaches to more efficiently characterize and clean up those sites. The use of these approaches to streamline characterization and remediation of mine sites offers the potential for redevelopment at a lower cost and within a shorter timeframe.

Brownfields

Section 101 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) defines brownfields as "real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant."

The U.S. Environmental Protection Agency (EPA) established its Brownfields Economic Revitalization Initiative to empower states, communities, and other stakeholders to work together to accomplish the redevelopment of such sites. With the enactment of the Small Business Liability and Brownfields Redevelopment Act in 2002, EPA assistance was expanded to provide greater support of brownfields cleanup and reuse. Many states and local jurisdictions also help businesses and communities adapt environmental cleanup programs to the special needs of brownfields sites.

With the enactment of the Small Business Liability Relief and Brownfields Revitalization Act (commonly referred to as the “brownfields law”), the definition of brownfields was expanded to include mine-scarred lands, making these properties eligible for the benefits of the brownfields program. EPA defines mine-scarred lands as “lands, associated waters, and surrounding watersheds where extraction, beneficiation (crushing or separating), or processing of ores and minerals (including coal) has occurred" (EPA, 2004a). The inclusion of mine-scarred lands in the brownfields program strengthens existing mine reclamation programs administered by DOI's Office of Surface Mining (OSM).

This primer is divided into three parts:

> **Part 1, Overview,** summarizes the basic issues surrounding mine site cleanup for brownfields redevelopment, including innovative characterization and remediation approaches.
>
> **Part 2, Coal Mine Sites,** includes detailed technical information about the characterization, remediation, and redevelopment of coal mine sites, focusing on sites in the eastern United States. It is intended for those with an interest in and knowledge of the technical details of redevelopment of coal mine sites.
>
> **Part 3, Hard Rock Mine Sites,** contains detailed technical information about the characterization, remediation, and redevelopment of hard rock mine sites. It is designed for an audience with knowledge of and interest in the technical aspects of hard rock mine redevelopment.

The primer also includes appendices containing regional points of contact for the EPA Brownfields Cleanup and Redevelopment Program, state and tribal points of contact for Abandoned Mine Lands Programs, references used in the preparation of the document and additional information resources, a glossary of terms, and a list of acronyms used in the document.

Many of the resources cited in this primer and other relevant resources about redevelopment of mine sites are available through BTSC at *www.brownfieldstsc.org/miningsites.cfm*.

Brownfields and Land Revitalization Technology Support Center

The BTSC was established to ensure that brownfields and land revitalization decision-makers are aware of the full range of technologies available for conducting site assessments and cleanup in order to make informed decisions about their sites. The BTSC can help decision-makers evaluate strategies to streamline the site assessment and cleanup process, identify and review information about complex technology options, evaluate contractor capabilities and recommendations, explain complex technologies to communities, and plan technology demonstrations. The BTSC, coordinated through EPA's Office of Superfund Remediation and Technology Innovation, offers access to experts from EPA's Office of Research and Development, the Department of Defense, the Department of Energy, and other federal agencies. Localities can submit requests for assistance directly through the EPA Regional Brownfields Coordinators, online, or by calling toll free 1-877-838-7220.

Other publications developed through the BTSC:

- Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Cleanup, Fourth Edition
- Brownfields Technology Primer: Using the Triad Approach to Streamline Brownfields Site Assessment and Cleanup
- Directory of Technical Assistance for Land Revitalization
- Assessing Contractor Capabilities for Streamlined Site Investigations
- Brownfields Technology Primer: Requesting and Evaluating Proposals that Encourage Innovative Technologies for Investigation and Cleanup
- Understanding Procurement for Sampling and Analytical Services under a Triad Approach
- Use of Dynamic Work Strategies Under a Triad Approach for Site Assessment and Cleanup – Technical Bulletin

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1.1 INTRODUCTION

A major challenge in cleaning up and redeveloping mine sites is finding the resources that are needed to assess and address potential contamination at these large complex sites. However, innovative approaches that streamline the assessment and cleanup of mine sites have the potential to reduce the amount of resources needed by saving time and decreasing overall project costs.

While a formal inventory of abandoned or inactive mine sites in the United States has not been completed, the Mineral Policy Center estimates that there are 557,000 abandoned mines, located primarily in the western part of the country (Earthworks, 2005). These sites have potentially significant environmental issues that would need to be addressed as part of a redevelopment strategy. Environmental contamination can come from mine drainage, waste rock, tailings (rock discarded from milling processes), and industrial activities. In addition, mine sites are typically characterized by abnormally low pH (i.e., highly acidic), acute toxicity of the metals in the soil, nutrient deficiencies, and lack of vegetation.

Part 1 of this primer provides information about innovative approaches to assessing, cleaning up, and redeveloping mine sites. It covers:

- General information about mine sites, including types of mines, and types of contamination found at mine sites
- An overview of cleanup considerations for these sites (discussed in more detail in Parts 2 and 3)
- Potential sources of funding for mine site redevelopment
- Examples of mine sites where innovative approaches have been used for site assessment and remediation

This primer also includes appendices containing regional points of contact for the EPA Brownfields Cleanup and Redevelopment Program (Appendix A), state and tribal points of contact for Abandoned Mine Lands Programs (Appendix B), references used in the preparation of the primer and additional resources (Appendix C), and a glossary of terms and list of acronyms used in the primer (Appendix D).

1.2 MINE SITES AND ASSOCIATED ENVIRONMENTAL CONCERNS

This section summarizes the types of mines used to remove an ore from the ground and the methods used to process the extracted ore at the mine site. The types of contaminants found at mining sites are also summarized.

1.2.1 Mines and the Mining Process

Extraction of the mineral or ore from the ground is the first step in mining. There are three general approaches to extraction:

- **Underground mining**—in which ore is extracted without removal of the overburden (the topsoil and rock above the ore). Underground mining has been the major method for the production of certain metals, but in recent years it has been increasingly less common in the United States. It has significantly less impact on the surface environment than do the surface methods described below, because there is less surface disturbance and a much lower quantity of non-ore materials that must be removed and disposed as waste (EPA, 2000a).

- **Surface mining**—in which overburden is first removed in order to reach and remove the ore. Surface mines include:

    - **Open-pit mines** are those in which a small amount of overburden is present relative to the amount of ore removed. The small amount of overburden is insufficient to recreate the original contour of the land. When abandoned, open-pit mines are sometimes left to fill with water, forming deep man-made lakes (Younger, et al., 2002).

    - **Open-cast mines**, also known as ”strip mines” or “highwall mines,” are those in which a large amount of overburden is present relative to the amount of ore removed. It is feasible to backfill (“cast”) the removed overburden in place as mining operations advance further into the hill. Thus, more of the original contour of the land is maintained (Younger, et al., 2002).

    - **Dredge mines** have been used to mine placer deposits, which are concentrations of heavy metal minerals that occur in alluvial deposits associated with current or ancient watercourses. Commercial dredging has not been widely practiced in the United States in recent years, although placer mining is still an important industry in Alaska (EPA, 2000a).

- **In-situ solution mining**— a method of extracting minerals from an orebody that is left in place rather than blasted and excavated. It entails drilling a series of wells into the orebody. A solvent is circulated through the formation by injection into some wells and withdrawal from others. This form of mining is used in some parts of the southwestern United States for copper mining and in other areas with salt mines for fertilizers like potash (EPA, 2000a).

The second step in mining is beneficiation, which involves crushing or milling the ore to separate the rock waste or concentrate the ore for use as a final product or in preparation for further processing. Beneficiation also can involve leaching—separating a soluble metal or mineral from the orebody by selectively dissolving it in a suitable solvent, such as water, sulfuric acid, or a sodium cyanide solution, and removing it from the leaching solution chemically or electrochemically (EPA, 2000a).

Following beneficiation, the processing step further refines the ore and prepares it for specific uses. Processing may incude a variety of operations such as smelting (melting or fusing), refining, roasting, or digesting. Both processing and beneficiation can be performed at facilities co-located with the mine or at a separate location offsite that may serve one or more mines.

1.2.2 Definition of Mine-Scarred Lands

Mine sites include abandoned or inactive mines and associated lands. EPA considers mine-scarred lands (MSL) to be “lands, associated waters, and surrounding watersheds where extraction, beneficiation, or processing of ores and minerals (including coal) has occurred (EPA 2004a).”

Examples of coal MSL include:

- Abandoned surface and underground mines
- Abandoned coal processing areas
- Abandoned piles of mine spoils (waste rock removed to extract and process coal)
- Acid or alkaline mine drainage
- Local water bodies (including streams, ponds, and lakes) and watersheds affected by mine drainage

Examples of hard rock MSL include:

- Abandoned surface and underground mines
- Abandoned waste rock or spent ore piles
- Abandoned roads constructed wholly or partially of waste rock or spent ore
- Abandoned tailings, tailings piles, or disposal ponds
- Abandoned smelters
- Abandoned heap leaches (engineered piles on which ore is placed before applying the leaching solution)
- Abandoned dams constructed wholly or partially of waste rock, tailings or spent ore
- Abandoned dumps or dump areas used for the disposal of waste rock or spent ore

- Acid or alkaline rock drainage
- Local water bodies (including streams, ponds, and lakes) and watersheds affected by mine drainage

1.2.3 Contamination Associated with Mine Sites

The sources and types of contamination at mine sites vary and can affect soil, ground water, and surface water (see Table 1.1). Mine drainage, waste rock, tailings, heap leaches (where ore is placed on lined pads in engineered lifts or piles before applying the leaching solution), and dump leaches (where ore is placed on the ground before applying leaching solution) are among the major sources of contamination. Surface-water runoff from open pits, tailings ponds and ore stockpiles can carry both toxic and nontoxic materials (e.g., silt) to streams and lakes. Seepage from impoundments or from water-filled pits and mine openings also can release contaminants to surface water and ground water.

Waste from associated operations is another source of contamination at mine sites. Operations that may result in contamination include machine maintenance, vehicle repair, or other activities in which solvents, petroleum, lubricants, or other industrial chemicals may have been used. In addition, contamination may result if electrical transformers and capacitors, which can contain polychlorinated biphenyls (PCBs), were used to supply electricity to the site.

Table 1-1. Sources and Types of Contamination at Mine Sites

Source	Type
Waste rock or spoil	Acid mine drainage (AMD), metals
Tailings and tailings piles	AMD, radionuclides
Pits	AMD
Machinery	Solvents
Transformers/capacitors	PCBs

Although the activities associated with coal mining and hard rock mining are similar, the characteristics and nature of the sites and the environmental effects differ.

At coal mines, extracted coal is separated from non-coal materials before it is distributed. This process includes sorting the coal and removing any waste rock and disposing it in spoil piles, washing the coal in water to remove sulfur and other impurities, and drying the coal. Some waste rock removed from the coal during the sorting phase still contains small portions of coal and is referred to as coal refuse. Historically, fires were common in coal refuse piles. Now, however, many of these coal refuse piles are re-mined to extract the remaining coal.

Historically, waste from the wash step was discharged into adjacent water bodies. This practice has become less common, however, and the waste now is disposed in other ways onsite

(Younger, et al., 2002). A common way is to dispose of the waste behind dams constructed from coarser waste materials. Failures of these waste dams have caused large pollution events in water bodies throughout the world.

For many years, remediation of mine spoil piles was advanced by revegetating the piles. However, revegetation alone did not solve the problem of acid mine drainage (AMD). AMD is water with a pH generally less than 4 that drains from mine workings and mine wastes. The low pH is due to the formation of acids resulting from the oxidation of sulfide minerals (e.g., pyrite) in the host rock when exposed to air and water. Due to its acidity, AMD tends to contain elevated levels of metals leached from the ore and host rock. More detailed information about contamination issues at coal mining sites is presented in Part 2 of this primer.

In hard rock mining, extracted ore typically is processed by grinding the ore, extracting the minerals containing the metal(s) of interest from the ground material, and refining the metals into marketable products. Refining primarily involves separating one metal from another after they have been extracted and concentrated. Extracting the minerals from the ore can be accomplished in various ways, including:

- Leaching with acids or cyanide
- Gravity concentration using jigs, screens, sluice boxes, and water
- Amalgamating using mercury
- Floatation separation using chemicals (or water slurry) and rising air bubbles
- Magnetic separation
- Solution extraction - electrowinning

Typical contamination concerns at hard rock sites include the mobility of the contaminants and their bioavailability—i.e., the degree or ability of the contaminant to be absorbed by an organism and interact with its metabolism. Hard rock mine sites are typically large non-residential areas denuded of vegetation and covered with mine tailings and waste rock. More detailed information about contamination issues at hard rock mining sites is presented in Part 3 of this primer.

1.3 CONSIDERATIONS FOR CLEANUP AND REDEVELOPMENT OF MINE SITES

This section describes the considerations for identifying cleanup and redevelopment approaches for mine sites. These considerations, which also are applicable to other types of contaminated properties, include technical, regulatory, and stakeholder requirements, , as well as financial issues, including potential sources of funding. It is important to recognize that the considerations and the relative importance of those considerations will vary depending on site-specific conditions and requirements. Parts 2 and 3 of this primer provide more detail about site-specific conditions for coal mine sites and hard rock mine sites, respectively.

1.3.1 Technical Considerations

Identifying the specific contamination at a mine site and cleaning it up efficiently is critical to success in redeveloping a site. One of the approaches that can be used for assessment and cleanup of mine sites is the Triad. This is a dynamic, collaborative approach to site characterization and cleanup that helps site stakeholders work toward cleanup that is faster, better, and cheaper and sets the stage for appropriate redevelopment.

The Triad approach minimizes the likelihood of mistakes by cost-effectively supporting the development of an accurate conceptual site model (CSM). Briefly, a CSM is any graphical or written representation (or "conceptualization") of site contamination concerns: how it got there, whether or not it is migrating or degrading, how variable concentrations are across the site, what receptors might be exposed, and what risk-reduction strategies are most feasible. An accurate CSM is a primary work product of the Triad approach, and it is continually refined over the course of an investigation.

Use of the Triad approach at mine sites requires three important elements:

- systematic project planning (sometimes called “strategic planning”) to provide a roadmap and benchmarks for the stakeholder team to measure progress;
- dynamic work plan strategies that guide the course of the project but maintain the flexibility to make decisions and adapt in real-time, as data are analyzed, which helps achieve significant cost and time savings; and
- the use of real-time measurement technologies to enable real-time gathering, interpreting, and sharing of data to support real-time decisions.

The CSM and the individual components of the Triad approach will be referenced throughout this primer and discussed at some length in Parts 2 and 3. Technical considerations that could be used to build a CSM for mine sites include an understanding of:

- Contamination due to past activities or disposal practices that may limit the suitability of a site or a portion of a site for redevelopment.

- Types and volumes of media (e.g., soil, ground water, surface water, and sediment) to be remediated.
- Type of technology— conventional technology, innovative technology, or a combination of technologies—needed to address the contamination at the site.
- Time frame and budget available for the cleanup.
- Whether contamination is treated onsite or excavated for treatment and disposal offsite. (The large volume of wastes and the often remote locations of mine sites can make offsite treatment and disposal costly.)
- Whether physical barriers such as fences or institutional controls (such as zoning restrictions or restrictions on building permits) are appropriate, alone or in combination with a treatment or containment technology.
- Intended end use of the site, which may impact the levels that need to be achieved for the cleanup, and the ability to leave wastes in place.
- Current topography of the land (For example, steeply sloping land may be inappropriate for use as an industrial site without extensive regrading or geotechnical work.).
- Understanding the site characteristics (e.g., soil types and properties) and nature and extent of contamination that may effect the location and movement of contaminants as well as impacts on possible redevelopment scenarios.
- Presence of mine shafts, openings, and high walls that can be safety hazards.
- Hydrogeologic connections or interactions with other and or larger subterranean systems, such as mine pools, mine shaft breakthroughs, relief borehole discharges, etc.

There are several cleanup approaches commonly used at mine sites. For example, contaminated soil or buried equipment can be excavated for disposal at an offsite landfill. In addition, containment technologies, such as engineered caps or vertical barrier walls (e.g., slurry walls) have been used where there are threats due to direct contact or concerns about leaching of contaminants to ground water. Containment also might include technologies used to collect or divert contaminants to reduce or minimize releases, such as detention or sedimentation basins, or interceptor trenches.

Conventional treatment technologies for soil, ground water, or surface water include chemical treatment (such as use of lime to neutralize AMD and to precipitate metals), stabilization, solidification, and vapor extraction. For contaminated buildings, conventional decontamination often is performed using pressure washing. In addition, some structural elements, such as any saturated wooden components, may need to be removed.

Innovative and emerging treatment technologies include phytoremediation and amended bioremediation. Residuals from waste-water treatment can be used as a soil amendment to add organic matter and nutrients to the soil to recreate a fertile soil horizon with a reestablished microbial community, invertebrates, and plants. Amendments can also address metals toxicity and acidity. These types of technologies are discussed further in Part 3.

1.3.2 Regulatory Considerations

With regards to federal regulations, coal mine sites generally fall under the jurisdiction of the Surface Mining Control and Reclamation Act (SMCRA). In addition, the Small Business Liability Relief and Brownfields Revitalization Act (commonly known as the "brownfields law" *http://www.epa.gov/brownfields/sblrbra.htm*) has been interpreted to cover abandoned mine sites (both coal and hard rock), which increases the potential sources of grants and assistance available to stakeholder teams. Hard rock mine sites that fall on the National Priorities List are regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund.

The following paragraphs summarize the major federal laws governing the restoration of mine sites. Reders should refer to the statutes and relevant regulations themselves for a full understanding of the requirements under each. In addition, it is important to recognize that there are many other federal, state, and even local ordinances that may be relevant to a particular site restoration project.

Surface Mining Control and Reclamation Act (SMCRA): SMCRA governs surface coal mining activities and established the Abandoned Mine Land (AML) Reclamation Fund. A surcharge is levied on all coal mined in the United States to support the AML fund, and the monies are used to reclaim mined lands abandoned prior to 1977. SMCRA established the OSM to administer the provisions of SMCRA and to distribute AML fund monies. A total of 23 states and three Native American tribes have approved abandoned mine reclamation programs that administer annual OSM grants from the AML fund. Once a state has certified to the OSM that certain requirements have been met in regards to clean up of abandoned coal mines, money from the OSM grants can be used to fund reclamation of eligible abandoned hard rock mine sites. Further information is available at *http://www.thecre.com/fedlaw/legal26/smcra.htm*.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA): CERCLA created a tax on the chemical and petroleum industries and provided broad federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment.

Section 106 of CERCLA grants EPA the authority to compel persons to conduct cleanup activities if there is a release of a hazardous substance that presents an imminent and substantial danger to human health or the environment (pages 43-44 at *http://www.epa.gov/superfund/resources/remedy/pdf/cercla.pdf).* Section 106 allows EPA to use administrative orders and judicial actions to direct a potentially responsible party (PRP) to conduct a cleanup. CERCLA response actions include removal actions to remove sources of contamination in emergency and non-emergency situations, and remedial actions that are typically long-term responses performed at sites placed on the National Priorities List.

CERCLA authorities are often used to compel cleanup of mine sites. If both CERCLA and SMCRA authorities are applicable, EPA generally defers to OSM and allows cleanup to proceed under SMCRA provisions.

Clean Water Act (CWA): Mining often results in discharges to U.S. waters subject to regulation under the CWA. The National Pollutant Discharge Elimination System (NPDES) permit requirements set forth in section 402, (*http://www.epa.gov/owow/wetlands/laws/section402.html*) and dredge and fill permit requirements set forth in section 404 (*http://www.epa.gov/owow/wetlands/facts/fact10.html*) are most relevant to mine sites.

The NPDES permit program establishes specific requirements for discharges from industrial sources, including mine sites. Depending on the type of industrial or commercial facility, more than one NPDES program may apply. Stormwater that runs off the property of an industrial facility may require an NPDES permit under the stormwater program. The industrial facility may also discharge waste water directly to a surface water and require an individual or general NPDES permit. Finally, many industrial facilities, whether they discharge directly to a surface water or to a municipal sewer system, are covered by effluent limitation guidelines and standards. Many mining projects involve some filling of U.S. wetlands or other waters, which requires authorization under section 404 of the CWA. Further information about the CWA is available at *http://www.epa.gov/region5/water/cwa.htm*.

Resource Conservation and Recovery Act (RCRA): RCRA created a framework for the management of hazardous waste, solid waste, underground storage tanks, and medical waste. The hazardous and solid waste management programs authorized by RCRA are most relevant to mine sites. RCRA Subtitle C establishes a system for controlling hazardous waste from its point of generation to its final disposal *(http://www4.law.cornell.edu/uscode/html/uscode42/usc_sup_01_42_10_82_20_III.html*). The program under RCRA Subtitle D encourages states to develop comprehensive plans to manage primarily nonhazardous solid waste, such as household and industrial solid waste, and mandates certain minimum technological standards for municipal solid waste landfills (*http://www4.law.cornell.edu/uscode/html/uscode42/usc_sup_01_42_10_82_20_IV.html)*.

RCRA contains specific exclusions from the definitions of solid waste and hazardous waste that include specific aspects of mining activities and waste. EPA regulations affecting solid and hazardous waste exclusions are codified in 40 CFR 261.4 *(http://frwebgate.access.gpo.gov/cgi-bin/get-cfr.cgi?TITLE=40&PART=261&SECTION=4&TYPE=TEXT*). The mining waste exclusion, referred to as the Bevill amendment, was congressionally mandated by §3001(b)(3) in the 1980 amendments to RCRA *(http://www.epa.gov/compliance/assistance/sectors/minerals/processing/bevillquestions.html).* Under the current provisions of the RCRA mining waste exclusion, solid waste from the extraction and beneficiation of ores and minerals, and 20 specific mineral processing wastes are exempt from regulation as hazardous waste under RCRA. Solid waste not subject to regulation as hazardous waste may be regulated under RCRA Subtitle D. Materials exempted from the definition of solid waste may be subject to regulation under other statutory authorities.

Toxic Substances Control Act (TSCA): TSCA provides EPA with authorities to regulate the manufacture (including import), processing, distribution, use, and disposal of chemical substances. Under Section 6 of TSCA, the EPA Administrator may take a variety of actions to control or mitigate the risk posed by a chemical, including prohibiting the manufacture, import, processing, or distribution of a chemical substance. Chemicals regulated under Section 6 include chlorofluorocarbons (prohibiting their use as aerosol propellants), asbestos, and certain substances in metalworking fluids. The mining industry has traditionally used high levels of PCBs as the dielectrics in transformers and capacitors. These items are commonly found wherever there is a high electrical power demand. Transformers and capacitors, either single units or in banks, can be expected in any phase of surface or underground mining operations and the ore beneficiation process. EPA uses TSCA authorities in limited instances to address PCB contamination at mine sites when other authorities are not sufficient or applicable to address the risk.

Additional federal regulations: Other federal regulations that may apply to mine sites include the Clean Air Act (CAA), the Emergency Planning and Community Right-to-Know Act (EPCRA), the National Environmental Policy Act (NEPA), and the Safe Drinking Water Act (SDWA).). For more information on these reulations, please see Appendix D of the Abandoned Mine Site Characterization and Cleanup Handbook (EPA, 2000a).

1.3.3 Stakeholder Considerations

A major goal for systematic project planning is to include all of the stakeholders in the decision-making process for the redevelopment of the property, including the local community, regulators, financial entities, site owners, technical and engineering professionals, and other interested parties. A crucial part of reclamation and redevelopment is active involvement by all stakeholders, including the members of the communities in the mine vicinity. This up-front involvement will curtail suprises and costly changes to projects later. Community stakeholder involvement creates a sense of support for the project that is not possible otherwise.

Example 1: Collaboration Among Stakeholders Leads to Innovative Treatment Approach

Remediation efforts at two mine sites are examples of how important collaboration and creativity are to success in mine site reclamation and redevelopment. Underground mining began in the 862-square-mile Patoka River Watershed region (Indiana) in the 1830s, and had been replaced by surface mining by the 1920s. When sites were abandoned, damage from acid mine drainage affected 60-75% of the South Fork watershed. A collaborative effort of local agencies, volunteers, and the U.S. Department of Interior Office of Surface Mining led to an innovative application of anoxic treatment to acid mine drainage on the watershed's Lick Creek. The partners created a limestone dam in one of the lakes in the area, using the anoxic properties of the lake itself to allow the metals to settle out of solution at one end of the lake before passing the water into the wetland. The area now looks like a park, and the water flowing into the wetland is clear (Comp and Wood, 2001).

Community stakeholder considerations at mine sites may include:

- Community values and culture can impact how area residents react to cleanup efforts. It is important to recognize and appreciate the historical significance of the mining industry to the community.
- Residents' perceptions of the health risks posed by the site vary. At some sites, the perceived contradiction between EPA's assessment of potential risk and residents' input on health risks, such as blood lead tests, can cause area residents to be skeptical of EPA's contention that mining sites pose a threat to human health.
- Liability concerns usually are an issue. The uncertainty about who will be responsible for cleanup costs weighs heavily on communities and can impact residents' willingness to participate in cleanup discussions and activities.
- Cleanup and redevelopment have economic impacts. Since many mine sites have been abandoned for some time, the attention that cleanup and redevelopment brings to the site can cause both real and perceived economic concerns to a currently thriving community (EPA, 2000a).

Development of a CSM using Triad ensures that all stakeholders are offered the opportunity to review a consistent set of information as they participate in the decision-making process. Involvement in CSM development by all levels of regulators provides important insight to the stakeholder team and avoids many potential problems after the project is well underway when it becomes more difficult or expensive to change.

Additionally, the CSM helps all stakeholders understand the various viewpoints that exist regarding a site restoration and to focus on areas where uncertainties and data gaps exist. For example, a family living near a potentially hazardous site may have an entirely different understanding of risk than does a regulatory official working in a distant city. However, input from both parties are important and consensus must be reached for credible restorations to be completed.

Example 2: TAG Involves Residents in Developing Cleanup Plan

The Eagle Mine site (Colorado) includes the Eagle Mine Workings; the town of Gilman; the mine tailings pond areas of Rex Flats, Rock Creek Canyon, and waste rock; and roaster pile areas. Mining operations at the site began in the 1870s. In the early 1900s, the New Jersey Zinc company consolidated a number of these workings and operated them as Eagle Mine. In 1966, the company merged with Gulf Western. Mining operations were abandoned in 1984. Residues from the roasting process were left in five waste piles. Mine tailings from the milling process and polluted surface and ground water from the site affected several nearby wetlands. EPA added the site to the National Priorities List in 1986. EPA has worked with the Colorado Department of Public Health and Environment, the responsible party, and the affected community since 1988 to clean up the site. EPA provided a technical assistance grant (TAG), which allowed residents to hire a technical advisor for independent review of the cleanup.The collaboration in implemeting the cleanup plan has resulted in the elimination of public health risks and significant recovery of the Eagle River trout fishery (EPA, 2004e).

1.3.4 Financial Considerations and Funding Sources

Financial considerations are an important component of redevelopment. With the large size and complexity of most mine sites, the availability of resources to assess, clean up, and redevelop a mine site can be considerable.

In addition to the Abandoned Mine Land fund administered by Office of Surface Mining and mentioned in Section 1.3.2, a number of funding programs are available for restoration of mine-scarred lands. The Directory of Technical Assistance for Land Revitalization, available at *http://www.brownfieldstsc.org/directory/directory.cfm*, has additional information on these types of funding sources. Most federal funding available from EPA for mine-scarred brownfields sites is administered under authority of CERCLA, Section 104(k) (EPA, 2004b). Brownfields grant funds may be provided to state and local governments and community organizations. Additional money may be used by these organizations to capitalize a brownfields revolving loan fund (RLF). Non-government organizations are eligible to apply only for cleanup grants. For-profit organizations are not eligible for brownfields grants, although they may borrow from a brownfields RLF. Appendix A provides a list of EPA Regional Brownfields Coordinators who may be able to assist in obtaining cleanup funds.

EPA is one of the agencies that participates in the Brownfields Federal Partnership. Other participants that may be able to provide financial assistance and/or expertise include the DOI's OSM and Bureau of Land Management, the U.S. Army Corps of Engineers (USACE), Forest Service, Fish and Wildlife Service, Department of Commerce, Department of Transportation, and Department of Health and Human Services.

Not all abandoned mine sites are reclaimed using federal funds. Where the location of a site is advantageous and potential benefits of reclaiming and reusing the land exceed the costs of cleanup and redevelopment, state and local governments, industry, land developers, environmental groups, or private citizens may fund improvements or complete reclamation. Funding may be available from state, tribal, and local agencies based on the specified reuse of the area. These may include sport fisheries grants, wetlands grants, and wildlife habitat creation grants. Obtaining these types of grants may be beneficial to organizations seeking to obtain brownfields grants from EPA by making the grant application more attractive to agency officials.

A list of federal, state, and tribal points of contact for abandoned mine lands programs is available online at *http://www.osmre.gov/statefeddirectory.htm*. In addition, a list of state and tribal AML Programs is provided in Appendix B.

Mine-Scarred Lands Initiative – As an extension of the Brownfields Federal Partnership, a MSL working group was established to collaboratively address the challenges of MSL cleanup and revitalization. The MSL working group consists of the following six federal agencies: EPA, DOI, Department of Agriculture, Department of Housing and Urban Development, USACE, and Appalachian Regional Commission. The group is co-chaired by EPA's Office of Brownfields Cleanup and Redevelopment and DOI's OSM.

The MSL working group has begun work on demonstration projects that represent the variety of challenges facing mining communities across the country. Working group members are assisting projects as needed to identify community redevelopment needs, facilitate local visioning and action plan development, locate experts, share information, and involve the private sector. Demonstration projects cover both coal and hard rock mine sites. Each requires the collaboration of multiple federal agencies and offers the potential for valuable lessons that will help improve future redevelopment of MSL. Demonstration projects are being conducted at the:

- Barrick Bullfrog Mine in Beatty, Nevada—a former gold mine being considered for redevelopment. Renewable energy production is at the forefront of reuse options.
- CAN DO Innovations Site in Hazleton, Pennsylvania—an 82-acre anthracite coal mine, which is part of the larger 366-acre Cranberry Creek Gate Corridor project. The project illustrates the challenge of integrating cleanup, compaction, infrastructure, and other site development activities.
- Eureka Townsite in San Juan County, Colorado—an approximate one-mile segment of the Upper Animus River Valley contaminated by tailings from abandoned gold, silver, lead, and zinc mines. The stakeholders are providing input on cleanup strategies and water quality standards applied to mine reclamation. They are discussing diverse and sustainable reuse options.
- Kelly's Creek Watershed in Kenawha County, West Virginia—a watershed with poor drinking water supplies affected by historic coal mining activities and improper sewage disposal. The project involves innovative approaches to development of waste-water infrastructure, remediation of AMD, and collaboration with a mineland owner to redevelop a large tract of privately-owned land.
- Pennsylvania Mine in Summit County, Colorado—a site with a creek that discharges to the Snake River that is contaminated by metals requiring cleanup. Stakeholders hope to delist the creek and river from the CWA list of impaired waters as well as facilitate economic growth and establish a trailhead and trout fishery.
- Stone Creek Tipple Site in Lee County, Virginia—a 1.5-acre abandoned coal loading facility that poses a health and safety hazard due to stream bank erosion and possible PCB contamination. Hundreds of tipple sites exist in Appalachia, and stakeholders hope this demonstration serves as an example of cleanup and reuse of these sites.

Progress on these demonstrations is documented in *Mine-Scarred Lands Revitalization – Models through Partnerships* (EPA, 2005a).

Mine Site Cleanup for Brownfields Redevelopment:

Part 2–Coal Mine Sites

2.1 INTRODUCTION

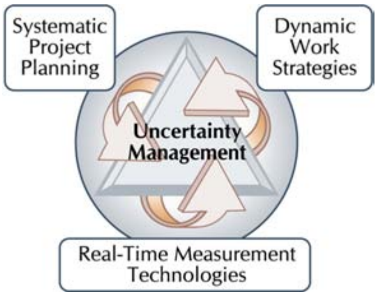
Thousands of surface and underground coal mines occupying millions of acres of land across the eastern and central United States were mined prior to the 1980s and were abandoned or were reclaimed and closed with a minimal degree of restoration (EPA, 2000a). This legacy of abandoned mines includes an enormous amount of public safety, engineering, and environmental problems affecting their cleanup and reuse. Part 2 of this primer provides technical information about the characterization, remediation, and redevelopment of coal mine sites, with a focus on coal mine sites in the eastern United States. Part 2 is designed for an audience with some knowledge of and interest in the technical aspects of coal mines and redevelopment and includes:

- Specific characteristics and problems associated with coal mine sites
- Potential reuse scenarios for coal mine sites
- Approaches for assessment and cleanup of these sites, including use of the Triad approach
- Specific technologies for coal mine site remediation
- Additional information about coal mine site redevelopment, including case studies and resources

Common issues that hinder the cleanup and redevelopment of coal mines (discussed in more detail in Section 2.2) include abandoned highwalls, subsidence, and acid mine drainage (AMD). As an example of the extent of these issues, coal mining in Pennsylvania prior to 1965 left 2,400 miles of streams impacted by AMD, 252 miles of dangerous highwalls, over 1,200 open portals and shafts, 38 underground mine fires, and 200,000 acres of subsidence-prone land (*http://www.dep.state.pa.us/dep/deputate/minres/BMR/BMRhome.htm*).

Part 2 of the primer presents the potential for cleaning up and redeveloping abandoned, unused coal-mined lands for a variety of purposes, including recreation and wildlife habitat, as well as commercial, industrial, and residential development. Challenges to redeveloping coal mine sites include characterizing and remediating their health and safety and environmental issues; meeting federal, state, and local regulatory requirements; and working together with local communities, environmental groups, and other stakeholders. One obstacle to the redevelopment of abandoned mine lands (AML) is often the lack of money and tools available to characterize and remediate the site. As discussed in Part 1, the EPA has several initiatives underway to address these challenges and to promote the redevelopment of AML. The use of the Triad approach is one way to streamline site cleanup. Triad, explained in more detail in Figure 2-1, is a dynamic, collaborative approach to cleanup that helps site stakeholders work toward cleanup that is faster, better, and cheaper and sets the stage for appropriate redevelopment.

Figure 2-1. Assessing, Understanding, and Defining Issues Using The Triad Approach



The Triad approach represents an evolution and progression of technical thinking about contaminated sites. The Triad serves as a platform to integrate the experiences, lessons learned, and advances in science and technical tools and know-how gained over the past 25+ years of hazardous site investigation, cleanup, and reuse. Triad supports second-generation practices that maximize the use of innovative field tools. By using data in real time, these innovative tools and techniques more effectively address the uncertainty related to the variability of contamination across the site. The Triad approach, which is different from current practices, truly support all three benchmarks of “better, faster, and cheaper” projects. Further information about the Triad is available at *www.triadcentral.org*.

Among other criteria, a successful Triad project addresses:

- The length of the cleanup process
- The cost of assessment and cleanup
- Regulatory requirements
- Data collection components needed to successfully address site uncertainties

Building a Conceptual Site Model

A primary Triad product is an accurate CSM. A CSM has two important characteristics. It aids in delineating contaminant populations requiring different remediation techniques, and it improves the confidence and resource-effectiveness of project decision-making by actively identifying and acknowledging decision and data uncertainties early in the process. Through use of a CSM, the Triad approach helps to develop open channels of communication that will increase trust among stakeholders, as well as identifying and acknowledging the differing viewpoints of each stakeholder.

Conceptual Site Model

A CSM estimates:

- Where uncertainties and data gaps exist
- Where contamination is located
- What types of contaminants are present
- How much contamination is present
- How contaminant concentrations vary over the site and how much spatial patterning is present
- What is the predicted fate and migration of the contaminants
- Who might be exposed to contaminants
- What might be done to mitigate exposures
- What issues stand between the stakeholders and successful restoration of the site

A primary characteristic of the CSM is its evolutionary nature. As new data are collected, the CSM evolves incorporate new findings. Because the CSM is the foundation of the decision-making process, and each update of the CSM is communicated to all team members, the stakeholders can be confident that decisions are communicated to the entire team.

The CSM provides an up front analysis of potential reuses of the site. A site may not be suitable for certain reuses (i.e., park or school) due to the nature of contaminants onsite or remaining physical hazards, such as highwalls. For example, the Red Onion site in Virginia had to be compacted carefully to provide sufficient structural support for the prison construction (redevelopment) on the site. However, by identifying possible uses and restrictions for the site early in the process and restructuring project goals accordingly, cost avoidance may be realized. Further, by defining possible reuse scenarios early, data collection can focus on data gaps associated with those reuse scenarios instead of collecting information that can mislead or confuse site decision-makers.

Products from Systematic Project Planning

- Consensus on the desired outcome (i.e., end goal) for the site/project
- A preliminary CSM from existing information
- A list of the various regulatory, scientific and engineering decisions that must be made in order to achieve the desired outcome
- A list of the unknowns that stand in the way of making those decisions
- Strategies to eliminate or “manage around” those unknowns
- Explicit control over the greatest sources of uncertainty in environmental data (i.e., sampling related variables such as sample volume and orientation, particle size, sampling density, subsampling)
- “Stakeholder capital” (i.e., an atmosphere of trust, open communication, and cooperation between parties working toward a protective, yet cost-effective resolution of the “problem”)

Systematic Project Planning

The most important element of the Triad approach, ***systematic project planning*** (sometimes called “strategic planning”), supports the ultimate goal of confident decision-making. Systematic project planning provides the roadmap and benchmarks for the stakeholder team to assess progress. By carefully defining benchmarks early in the process, all stakeholders are given ownership of that process. Frequently reviewing the common measures of success help the project to stay on course.

Dynamic Work Strategies

The second element, ***dynamic work strategies***, is the element that allows projects to be completed “faster” and “cheaper” than traditional, static work strategies. Unlike static work plans, which require periods of inactivity while data are analyzed (both in the lab and relative to the site), work plans written in a dynamic or flexible mode guide the course of the project to adapt in real-time (i.e., while the work crew is still in the field). Flexible work plans allow the preliminary CSM to be tested and evolved to maturity (i.e., sufficiently complete to support the desired level of decision confidence by the entire stakeholder team). While the primary benefit of flexible work plans is that they support better resolution of uncertainties for the entire stakeholder team, and therefore build stakeholder confidence in the decision-making process, because the decisions are made in real time, significant cost and time savings are also realized (i.e., by reducing expensive remobilizations of sampling crews, a total project savings is realized).

Dynamic Work Strategies

- Provides flexibility to incorporate new data
- Reduces remobilization efforts
- Can include use of Decision Support Tools (DST) that can help in developing sampling or remedial strategies

Real-time Measurement Technologies

The third element of the Triad, ***real-time measurement technologies***, makes dynamic work strategies possible by gathering, interpreting, and sharing data rapidly enough to support real-time decisions. The range of technologies supporting real-time measurements includes field analytical instrumentation, in-situ sensing systems, geophysics, rapid turn-around from traditional laboratories, and computer systems that assist project planning, and store, display, map, manipulate, and share data. Although field analytical methods are usually less expensive to operate than fixed laboratory analyses, under the Triad approach, analytic budgets can be the same or higher than conventional sampling schemes because sample density is increased to manage sampling uncertainties. However, by increasing sampling density, Triad investigations can significantly reduce uncertainty associated with site conditions. More important than per-sample cost is the real-time aspect of these innovative data tools that dramatically lower the life cycle costs of Triad projects built on dynamic work strategies.

Real-time Measurement Technologies

- Use of technologies that result in improved quality control and quality assurance
- Significantly reduce costs associated with laboratory requirements that may not aid in reaching consensus decisions
- Significantly increases sample density
- Refer to *fate.cluin.org* for additional information about these technologies

2.2 SAFETY, ENGINEERING, AND ENVIRONMENTAL PROBLEMS RELATED TO COAL-MINED LANDS AND LAND REUSE

Coal-mined lands have a wide variety of safety, engineering, and environmental problems that can affect activities related to site redevelopment (EPA, 2000a).

Safety Problems. Safety problems at abandoned coal mines can pose immediate risk to people onsite:

Highwalls, which can exceed 100 feet in height, are the unexcavated faces of overburden and coal in a surface mine. Left in place without regrading, abandoned highwalls pose a falling hazard to users (e.g., dirt bikers, hikers, mountain bikers) of the site.

Old buildings, draglines, shovels, trucks, and other equipment in dilapidated condition can remain scattered around abandoned mine sites. Children or adults climbing on equipment or entering abandoned equipment and buildings can be subject to serious dangers, such as cuts and falls.

Old air shafts or vertical entries of underground mines may also result in falls, especially when located in woods, partially covered, and not readily visible. These shafts and open workings can be hundreds of feet deep. If not sealed, drift entrances into underground mines can also pose serious risks as old timbers and roofrock of these drifts can be very unstable and subject to collapse. Hunters and hikers sometimes seek refuge from bad weather in these entrances, and children may enter simply to hide or play.

Engineering Problems. Engineering problems at abandoned coal mines can affect existing structures and the approach to construction of new buildings, roads, and other infrastructure for redevelopment.

Subsidence of the ground surface occurs when it slowly sinks or collapses into underground mine openings below. Underground mines may have vertical shafts, slopes, drift openings, and mine workings (including haulageways water and drainage tunnels), and other passageways excavated from the subsurface that may cause subsidence. Buildings and other structures constructed on land undergoing active subsidence can crack, shift, tilt, and split. Damage to buildings can be so severe that they must be abandoned and demolished.

Piles of mine spoil (the fragments of rock and soil removed during mining) and coal refuse (the waste coal and crushed rock that results from coal processing) are often left at or near where the coal was mined. These piles can be highly erodible and unstable and thus, could potentially slide. These materials are particularly unstable if they are situated on steep hillsides, have water impoundments on the upper surfaces, or were placed over natural springs. Impoundments of coal slurry (a mixture of finely crushed coal and rock and water) can also slide or leak water and slurry through its walls.

Mine spoils and coal refuse can be very difficult to build on. During the mining operation, overburden rock and soil are crushed and disposed in mined areas. The crushed materials are much looser than the original materials (i.e., have a lower bulk density). Over time, they gradually consolidate. If spoils or coal refuse are redisturbed during preparation for land reuse, and there are plans to construct buildings, roads, or other structures, then testing and engineering studies should be conducted, and steps should be incorporated into the reclamation plan to compact the spoils and improve the stability of the materials, so that differential subsidence is not a potential problem.

Environmental Problems. Environmental problems related to abandoned coal mine lands are environmental can cause health risks to humans as well as wildlife and vegetation.

Abandoned buildings and structures, such as coal preparation plants, mine hoists, mining equipment, old vehicles, haul trucks, and other hardware related to the mining process, may contain compounds, such as solvents, metals, PCBs (from transformers and capacitors), engine oils, transmission fluid, antifreeze, fuels, grease, and other lubricants, that might have been spilled or intentionally disposed at the site, thereby contaminating, soil, ground water, and/or surface waters.

Open dumping or "midnight dumping" is the illegal disposal of municipal and industrial wastes and is common at abandoned mine sites. People looking to avoid the costs or inconvenience of legal dumping may dispose of their wastes in an abandoned pit or mine shaft causing additional contamination concerns.

Mine spoils and coal refuse can be poor growth media for plants because they can have a low water-retention capacity, low pH (i.e., acidic), high salinity, and high levels of toxic metals, including cadmium, zinc, and manganese. High levels of other contaminants common at coal mine sites, such as iron, aluminum, and sulfate, may cause additional cosmetic or aesthetic effects in water by altering its taste, color, or odor. Large numbers of surface mine sites and coal refuse disposal areas are barren and have lacked vegetation cover for more than a century. They resist practically any form of invasive plant species. To return these mined lands to agricultural fields, forests, or native vegetation, it is often necessary to add significant amounts of agricultural limestone, lime, or alkaline soil amendments to neutralize acidity; fertilizers to restore basic nutrients; and organic matter to help replenish soil and increase its water-holding capacity.

Erosion of mine spoils and coal refuse caused by stormwater runoff can be a problem, especially in the eastern and central United States where severe rainstorms can occur. Erosion occurs because the piles of mine spoils and coal refuse are often loose, unconsolidated, steep-sloped, and unvegetated. Transported sediments enter surrounding drainage channels, creeks, streams, and reservoirs, and clogged stream channels can subsequently cause flooding. Heavy sediment loads can coat streambeds and kill most benthic invertebtrates, which has a profound impact on fish and other aquatic animals.

AMD is the most severe and well-recognized environmental problem related to coal mining and can impact surface waters, including lakes, ponds, creeks, and even entire watersheds. AMD is water typically with a pH less than 4 that drains from mine workings and from mine spoils, and coal refuse (called acid rock drainage). The low pH is due to the formation of acid resulting from the oxidation of sulfide minerals (e.g., pyrite) in the host rock as it is exposed to air and water during mining. The acidic water solubilizes moderate to high concentrations of metals from the rock and sulfate.

When a watershed has been heavily mined, AMD can constitute the majority of water in the receiving surface waters. These water bodies can have pH values between 2.0 and 5.0 and contain hundreds of milligrams per liter (mg/L) of acidity and dissolved iron. Water bodies impacted this severely are usually devoid of fish and other aquatic oganisms. Only a very limited number of animal and plant species can survive under these conditions. Hundreds of projects have been performed in an attempt to evaluate and reclaim some of these watersheds and return them to healthy aquatic habitats. Remediating AMD in a watershed can be extremely difficult. Many times there is no at-source AMD abatement technique that is feasible or cost-effective. In these cases, treatment of the AMD is sometimes the only alternative for improving water quality and aquatic habitats in the receiving water bodies.

2.3 EXAMPLES OF POTENTIAL SITE REUSE

There are large areas of land in the eastern and central United States that were mined prior to 1977, and some of this land is located in populated areas or near major avenues of transportation. Hundreds of abandoned surface mine sites or coal refuse disposal areas in such areas have been graded, compacted, and reused for commercial and residential purposes. Examples of reuse include shopping centers, houses, and entire subdivisions. The Pittsburgh International Airport is an example of a large commercial project sited in large part on former surface-mined land. Generally, the mine sites most frequently reused are the ones that are in good locations, generally flat, and non-acidic. For buildings and roads, the crucial issues for reuse involve the overall stability and compaction of the underlying materials. If the mine spoils have the potential to slide, undergo differential settlement, or fail for other geotechnical reasons, these sites are typically avoided. Sites that are overly acidic are also generally avoided. However, even these types of sites have been reclaimed and reused if the site conditions allowed and the need for the land was great enough.

In some cases, mine sites may have very positive characteristics that have been used to full advantage. For example, in the central United States (including Illinois, Indiana, Missouri, western Kentucky, and Ohio) where the land is generally flat, abandoned surface mine sites tend to have lakes interspersed between rows or sections of mine spoil ridges. If the water quality of a lake is acceptable, then it is not uncommon for houses or entire subdivisions to be built on the mine spoils around the lake (Illinois Department of Mines and Minerals, 1985). The aesthetic value and the opportunity for fishing and boating makes these properties valuable and attractive for redevelopment. The cost of grading, compacting, and adding topsoil to the mine sites is offset by the value of the land after it is redeveloped.

Reusing mine sites for recreational purposes is also quite common. Many small county and municipal parks, ballfields, commercial golf courses, and picnic areas have been constructed on mined land. As shown in Table 2-1, a number of state parks and public recreation areas have been developed on abandoned mine lands. These parks make use of the hilly terrain and the large number of lakes, which are not common in much of the central U.S. states. At Goose Lake Prairie State Park in Illinois, mine spoil ridges were graded, limed, and seeded with native tallgrass species (Master and Taylor, 1979). The ridges were then incorporated as part of a hiking trail and used as an overlook for the surrounding prairie and wetlands. At Lake Hope State Park in Ohio and Moraine State Park in Pennsylvania, a large number of underground mine entrances and abandoned oil wells were sealed prior to developing the parks. Sealing the underground entrances prevented the discharge of AMD, thus upgrading and preserving the quality of water in the lakes. The AMD&Art Project, winner of one of EPA's 2005 Phoenix Awards (for excellence in brownfields redevelopment) uses passive treatment systems, including wetlands, to treat AMD at a site in Vintondale, Pennsylvania. Former "dead land" now is home to a rail trail and recreational park area (*www.amdandart.org*). At Finger Lakes State Park in Missouri, little or no effort was required to grade or cover the acidic spoil ridges or to treat the acidic water in the lakes because the primary uses of the park are off-road motorcycle and all-terrain vehicle trails (Figure 2-2) and a motorcross track. The intended use of the land did not warrant the high cost of reclaiming *all* of the sections of the mined land that contained acid spoils and acidic lakes, and there were no other contaminants or safety hazards present to pose a threat to users of the park. However, planning and foresight found a beneficial use for the land, which is now heavily used by people from around the country. (For more information on the park, see *http://www.mostateparks.com/fingerlakes.htm.*)

Figure 2-2. Dirt Biker, Finger Lakes State Park, Missouri

As mentioned previously, older surface-mined lands often contain numerous ponds and lakes. Besides fish, these water bodies can also serve as excellent aquatic habitats for beaver, muskrats, and waterfowl. Many of the coal-mining states lie along migratory paths of geese and ducks. Extensive research and field trials have been conducted to improve wetlands and lakes on mined lands for use by waterfowl, mammals, and other fauna (Samual, et al., 1978; Leedy and Franklin, 1981; Herricks, et al., 1982; Lawrence, et al., 1985; McConnell and Samual, 1985; Klimstra and Nawrot, 1985; Mitsch, et al., 1985; Brooks et al., 1985). At mine sites in Illinois, Indiana, and western Kentucky, artificial islands have been created and goose-nesting boxes have been built. Placing the nesting boxes on islands separated from the main shoreline greatly reduces the predation of eggs and young. Ducks and geese have made great use of these nesting opportunities.

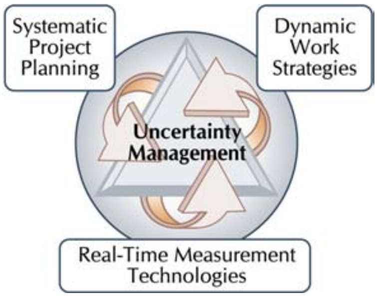
Table 2-1. Examples of Parks and Recreational Areas Created on Coal Mined Land

State	Park Name	Primary Uses	Site Restoration Activities, Notes	Information Source (s)
IL	Kickapoo State Recreational Area	Boating, swimming, fishing, camping, picnicking, hunting, horseback riding, mountain biking, scuba diving, baseball	Strip-mined between 1850 and 1938; first park in nation built on mine spoils in 1939; 2,842 acres of land and 22 mine lakes 0.2 to 57 acres in size; minimal mine spoil grading and revegetation	*http://www.epa.gov/superfund/programs/recycle/pdfs/rec_mining.pdf; http://dnr.state.il.us/lands/landmgt/PARKS/R3/Kickapoo.htm*
	Goose Lake Prairie State Park	Native prairie, wildlife, hiking	Minimal mine spoil grading; revegetation with tall prairie grasses,; five ponds/wetlands remain; park overlook on mine spoil ridge	*http://dnr.state.il.us/lands/Landmgt/PARKS/I&M/EAST/GOOSE/HOME.HTM*
	Pyramid State Recreational Area	Boating, swimming, fishing, camping, picnicking, hunting, horseback riding, mountain biking, hiking	Minimal mine spoil grading; revegetation; more than 500 acres of ponds and lakes ranging from 0.1 to 276 acres; largest recreational area in State	*http://dnr.state.il.us/lands/Landmgt/parks/r5/pyramid.htm; http://www.lib.niu.edu/ipo/io010214.html*
IN	Greene-Sullivan State Forest	Boating, swimming, fishing, camping, picnicking, hiking	6,764 acres of land, 122 mine lakes and ponds, two-day canoe trail	*http://www.in.gov/dnr/forestry/index.html; http://www.in.gov/dnr/forestry/stateforests/grnsull.htm&2*
	Shakamak State Park	Boating, swimming, fishing, camping, picnicking, hiking, biking	Reclaimed in 1930s	*http://www.in.gov/dnr/parklake/properties/park_shakamak.html*
	Minnehaha Fish and Wildlife Area	Boating, swimming, fishing, picnicking, hiking	11,400 acres of land; largest fish and wildlife area in state	*http://www.in.gov/dnr/fishwild/publications/minn.htm#history*
MO	Finger Lakes State Park	70 miles of motorcycle and ATV trails, canoeing, fishing, swimming, scuba diving, camping, hiking	Minimal mine spoil grading,;revegetation	*http://www.mostateparks.com/fingerlakes/geninfo.htm*
OH	Lake Hope State Park	Boating, swimming, fishing, camping, picnicking	Deep mines sealed	*http://www.dnr.state.oh.us/parks/parks/lakehope.htm*
	American Electric Power Recreation Area	Boating, swimming, fishing, camping, picnicking, hunting	Minimal mine spoil grading, planting of 50 million trees; construction of 380 campsites	*http://www.aep.com/environmental/stewardship/recland/ourstory.htm*
	B & N Coal Inc. Lands	Fishing, camping, picnicking	Minimal mine spoil grading	*http://www.dnr.state.oh.us/wildlife/pdf/pub293.pdf*
PA	Moraine State Park	Boating, swimming, fishing, picnicking	Deep mines sealed; surface mines backfilled and graded; 422 gas and oil wells plugged; fertilizer and lime added to spoil; thousands of trees planted	*http://www.dcnr.state.pa.us/stateparks/parks/moraine.aspx; http://www.dep.state.pa.us/dep/PA_Env-Her/moraine_state_park.htm*

2.4 IDENTIFYING AND CHARACTERIZING ISSUES RELATED TO SITE REUSE

The environmental and geotechnical problems found at mine sites can be varied and significant. Recognizing and fully characterizing these problems can be challenging, but necessary. Before investing large amounts of time and money in mine site characterization or cleanup, proper planning should be performed, input and consensus by stakeholders should be encouraged, and the potential environmental liabilities and safety issues of a site should be fully investigated. If the projected land use is industrial or residential and a large amount of construction is to take place, then more time and money should be spent on planning, market evaluation, and collection of existing site historical information and environmental data. These types of activities are consistent with use of the Triad approach, as discussed in the box below.

Use of the Triad Approach in Coal Mine Site Characterization



For coal mine sites, use of the Triad approach includes development of an accurate CSM. The CSM has two important characteristics. It aids in delineating contaminant populations requiring different remediation techniques, and it improves the confidence and resource-effectiveness of project decision-making by actively identifying and acknowledging decision and data uncertainties early and throughout the remedial process. These two products provide the decision-making team with realistic remediation objectives and develop open channels of communication that will increase trust among all stakeholders, as well as identifying and acknowledging the differing viewpoints of each stakeholder.

For building a Triad CSM, existing site information can be used to help perform preliminary assessments of the site's condition and the potential liabilities and limitations that might exist at the site. For example, mine maps should be obtained for any underground workings that might exist at the site. These maps can delineate the extent and interconnections of underground works, the dip of the mine floor, the presence of geologic faults or fracture zones, the thickness of overburden rock, areas where pillars may have been removed (these areas may be subject to more intense subsidence problems), and the locations of any mine entries or shafts (including air shafts and water drainage tunnels). Maps of surface mine sites often show the locations of sediment retention basins and locations where coal wastes may have been buried within the mine spoils (a common practice). Overall, these maps can be used to quickly identify potential hazards or environmental problems at a site; however, users should be cautioned that the maps may be incomplete or contain other inaccuracies. If records and files are available from the coal company and/or OSM (e.g., mine permit applications, permit amendments, notices of violation, inspector reports), these files may also provide useful information.

After the existing data and information have been collected and assessed, a plan or roadmap should be formulated regarding the potential land uses being considered for the mined land, the amount and types of additional data that may be needed, and the permits and approvals that may be required for developing the mine site(s).

Work can be initiated to collect the additional site data and characterize a site to the extent deemed appropriate for the intended post-reclamation land use. Some data are relatively easy to collect. For example, simple pH meters, specific conductivity meters, and field test kits can be used to quickly and cheaply evaluate water quality problems at a mine site or in a watershed. Measuring the pH of mine spoils and coal refuse in the field is possible, but can be somewhat more time consuming and tedious. Laboratory analyses of mine spoils and coal refuse for essential nutrients (e.g., nitrogen, phosphorus, potassium), water holding capacity, and toxic metals may be necessary if the land is to be used for agriculture, pastures, managed forests (i.e., tree farms), or residential properties that have a lawn and landscaping.

Determining the metals concentrations in the various wastes is an important characterization activity for making reuse decisions at coal mine sites. Total metals concentrations in soil, spoils, and coal refuse can be determined quickly using field portable x-ray fluorescence (XRF) spectroscopy. XRF analysis has been demonstrated to be an effective tool at sites with multiple metal contaminants, such as hard rock mine sites. Generally, elements of atomic number 16 (sulfur) through 92 (uranium) can be detected and quantified with an XRF. Anode stripping voltammetry is an innovative field portable instrument for measuring trace metals in water and extracts from soil, paint, dust, and particles.

If buildings or other large structures are to be built on graded mine spoils or coal refuse, professional geotechnical engineers need to be involved with the assessment of the site. They can make evaluations and recommendations regarding the stability of the geological materials and the potential for underground mine subsidence, differential compaction of mine spoils, and slumping, sliding, or liquifaction of the mine spoils or coal refuse. In addition, civil engineers may be needed to evaluate coal refuse impoundments and the structural integrity of the dams or berms retaining the coal wastes. Engineering studies and designs are also needed if underground mine entrances or shafts are to be sealed.

Demonstration of Method Applicability

When using field-portable site characterization technologies such as XRF, it is generally advisable to perform a demonstration of method applicability (DMA) study at the site where the technology is to be used. A DMA is an initial “pilot test” of the field-based analytical method using a few actual site samples and comparative laboratory analyses. The DMA concept is founded in EPA SW-846 guidance and performance-based measurement standards, and DMAs require clearly defined objectives and decision criteria. DMAs involve collection of samples from a site-specific matrix (such as soil, water, air, or tissue) followed by analysis of the samples using field-based and comparative fixed-laboratory analyses. They can provide useful information about whether the technology provides data of sufficient quality and quantity to make required decisions, and what the decision logic will be for using the technology in real time to make confident site decisions.

2.5 TECHNOLOGIES FOR SITE CLEANUP AND REUSE

Many approaches and technologies have been tested over the past 70 years to seal underground mines, to reclaim surface mines and coal-cleaning wastes, and to prevent and treat AMD. This section discusses control and treatment of mine wastes, including contaminated surface soils and AMD. It also provides a brief overview of various engineering techniques associated with mine site reclamation. Additional information about control and treatment technologies is available at *www.brownfieldstsc.org/miningsites/*.

2.5.1 Safety Hazards

Elimination of potential safety hazards at abandoned hard rock mine sites is the first priority and is relatively straightforward. The type of action to be taken is generally governed by the level of public access anticipated after the site has been reclaimed. For example, at a remote mine site that is being reclaimed for use as a wildlife habitat or rangelands, it may only be necessary to fence potentially hazardous areas and post warning signs. At the other extreme, such as at an urban mine site that is proposed for residential or commercial redevelopment, it may be necessary to not only backfill and seal mine openings and tunnels but to also remove or relocate all mine wastes in order to provide a stable ground surface for construction. In some cases, such reuse may even require extensive underground backfilling and grouting to minimize potential ground subsidence.

2.5.2 Control and Treatment—Contaminated Surface Soil or Mine Wastes

To minimize erosion problems and exposure of buried pyritic materials (the source of acidity) to water and oxygen, it may be necessary to sustain a vegetative cover on the final mine surface. Vegetation also serves to improve the aesthetics of a reclaimed site. Decades of research have been conducted on the characteristics and deficiencies of mine spoils and coal refuse as growing media and on the plant and tree species most tolerant to the sometimes extreme growing conditions. Additives, such as lime, fertliizer, and organic matter, are usually needed to improve the potential for revegetation. Because of the large areas of land that are usually involved at a reclamation site, the costs for lime, limestone, fertilizer, and other soil additives can be great.

Research, pilot testing, and full-scale reclamation operations have advanced the use of "waste" or recyclable materials to help neutralize acidity, increase the levels of nutrients available to the plants, increase organic carbon, and increase water-holding capacity in the reclaimed soil materials. Some successes have been achieved using:

- Wastes from coal-burning power plants (fly ash, bottom ash, scrubber sludge, and fluidized bed combustion wastes)
- Digested municipal sewage sludge (biosolids)
- Softening sludge from water treatment plants
- Dredged sediment from streams and rivers

These wastes can usually be obtained for free from the waste producers, or sometimes the waste producers will actually pay to have their wastes removed. Large areas of surface mine spoils and coal wastes have been reclaimed with sewage sludge in Illinois (Peterson et al., 1979; Pietz et al., 1992) and Pennsylvania. Dredge sediment from rivers was used at experimental plots at an abandoned mine site in Illinois in the 1980s and has recently been applied to a mine site in Pennsylvania (Pennsylvania Department of Environmental Protection [PaDEP], 2004a). Softening sludge from water treatment plants and wastes from coal-burning power plants can be very alkaline and therefore have a large potential for neutralizing acidic mine spoils and coal refuse (Adams et al., 1971, 1972; Aljoe and Renninger, 1999; PaDEP, 2004a). These materials have also been tested successfully at numerous mine sites. In addition to their unusually alkaline characteristics, digested sewage sludge and dredge sediment can also contain high levels of organic carbon and nutrients, both of which improve the quality of the reconstructed soil zone. However, some of these wastes or byproducts may have elevated levels of metals or other contaminants; thus, the materials should be tested for these before use. The webpages of EPA's Resource Conservation Challenge (EPA, 2005c, *http://www.epa.gov/epaoswer/osw/conserve/priorities/bene-use.htm*) and EPA's policies and goals on the use of coal ash to treat mine wastes (EPA, 2004a and 2004c) provide further information.

2.5.3 Control and Treatment—Mine Drainage

AMD discharges emanating from mine sites may not be an impediment to reclaiming and reusing the land for residential, commercial, farming, or other uses; however, acidic discharges have a negative impact on receiving creeks and streams. One AMD discharge may have a small impact on a stream, but when discharges are numerous or when there is one or more very large point-source discharges in a watershed that are very acidic, then more severe impacts will be observed in the receiving water body. The first objective in a reclamation project usually is to bury or cover pyritic materials, hydraulically isolate them, or neutralize them in place (i.e., mix lime or alkaline waste materials directly into the acidic spoils and coal refuse) so that they will not continue to be a source of acidity. When this is not possible or when "at-source" controls are not completely effective, passive treatment of AMD is generally used for controlling AMD at a mine site.

The objective of passive AMD treatment is to use chemical and biological reactions that aid AMD treatment in a controlled environment at the mine site before the water enters the receiving stream (PaDEP, 2004b and 2005a; Milavec, 2005a). Other potential cost-saving aspects of these technologies are that they do not require electricity, full-time operators, or extensive maintenance or repairs. For more than 25 years, new and better methods of passive AMD treatment have evolved. These techniques include the following:

- Constructed wetlands (aerobic and anaerobic)
- Limestone rip-rap lined channels and flow-through dams

- Anoxic limestone drains
- Limestone diversion wells

Figure 2-3. Constructed Wetland for AMD Treatment, Dents Run Watershed, Pennsylvania

Constructed wetlands may include one or more ponds or compartments where AMD flows through preferably at a slow rate. The iron is oxidized and precipitated within the wetland. Acidity is neutrlized by the vegetation photosynthesis and other biological activity which produces alkalinity. Numerous demonstration projects and studies have been performed which have evaluated the performance, costs, and longevity of passive wetland treatment systems. Figure 2-3 shows an example of a constructed wetland for AMD treatment. Several comprehensive documents provide details regarding the construction and performance of wetlands for the treatment of waste waters in general (EPA, 2000b; ITRC, 2003).

Channels and flow-through dams constructed of limestone rip-rap have been designed and implemented to treat AMD as it flows over and through the rip-rap (See Figure 2-4). However, limestone channels and dams may not provide long-term effectiveness if the rip-rap becomes coated with iron oxyhydroxide floc over time and is no longer reactive.

An anoxic limestone drain works similarly to a limestone channel. However, the drain is filled with flowing AMD and the AMD is not exposed to oxygen during passage through the drain. Hence, there is less potential for the limestone to become coated with iron oxyhydroxide precipitate. A limestone diversion well is also similar. This is a variation of an anoxic drain. In this design, AMD is diverted into the bottom of a vertical column (or well) of limestone under anaoxic conditions. The agitation of the water flowing up the column helps keep fresh surfaces on the limestone and makes it easier to load new limestone as it is used up.

Passive AMD treatment techniques are relatively simple and are designed to require little or no maintenance over time. These technologies typically can only treat small to moderate size discharges that have small to intermediate levels of iron and acidity. Otherwise, they tend to fail after a year of more of existence. In cases of larger mine discharges (e.g., greater than 100 gallons per minute) and/or total acidity exceeding 100 mg/L, effective passive treatment systems have been engineered; however sometimes a more complex treatment system is needed. These more aggressive treatment plants can be expensive compared to passive

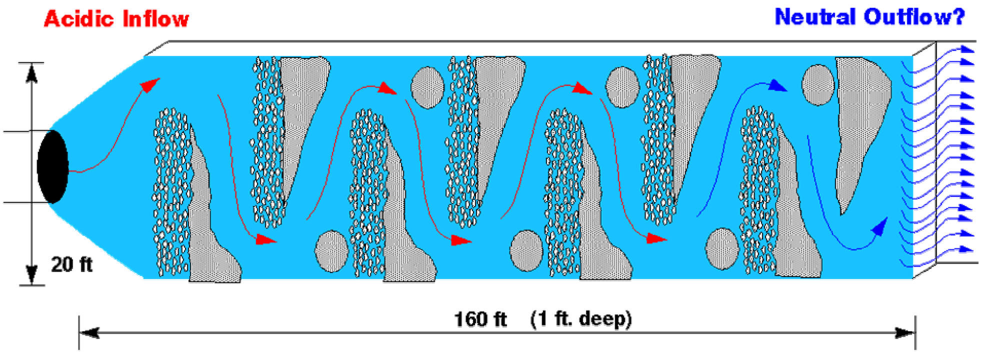


Figure 2-4. Example of Limestone Rip-Rap Channel

treatment systems, costing $1 million or more to build and $500,000 or more annually to operate.

In addition to treating AMD, it is important that the redevelopment of mine sites consider the impacts that the proposed development may have on the generation of new AMD. Construction of buildings, parking lots, tennis courts, etc. increases the amount of storm-water runoff from the property. If the storm-water runoff is not managed properly, it can drain through untreated mine spoils creating more AMD that transports contaminants offsite. Source controls, such as surface water diversions, can reduce the quantity of storm water running onto or off of a site. Regrading and revegetation of abandoned mine sites can reduce the quantity of storm-water runoff needing treatment by increasing infiltration into the soil surface and increasing plant transpiration. Construction of sedimentation basins and other such sediment capturing features should also be considered to reduce potential transport of contaminants offsite.

2.5.4 Control and Treatment–Engineering Considerations

Sealing techniqes for underground mine entrances have evolved since the 1930s, when the Civilian Conservation Corps sealed hundreds of abandoned mine entrances. Some of the simpler seals were intended to prevent human entry into a mine (to protect life) and to prevent air passage into or out of a mine. The intent was to keep oxygen out of a mine, halt the oxidation of pyrite, and gradually eliminate the source of AMD. The seals did not prevent the flow of water out of a mine and were not designed to withstand elevated water pressures (i.e., they were not bulkhead seals). Over several decades of research, the early types of seals proved to be ineffective for reducing acid loads in mine discharges. A strong bulkhead seal is necessary to seal a mine if stopping a discharge is desirable and if elevated water pressure in the flooded mine is anticipated (Scott and Hays, 1975). Such an approach is often complicated by the fact that once a mine is flooded and the water pressure increases, the mine water often finds other avenues to reach the ground surface, such as through fractures in rock; through abandoned, leaky oil, gas, water, or exploration wells; or through unknown air shafts or an adjacent underground mine. Sealing and flooding abandoned underground mines should be approached carefully and with appropriate levels of engineering studies and design.

Backfilling, grading, and contouring mine spoils and coal refuse can be costly, simply due to the large quantities of materials that commonly must be relocated, compacted, and smoothed. Pyritic mine spoil and coal refuse should be compacted and buried beneath non-acidic spoils. Efforts should be made to minimize the contact of acidic materials with air, surface water, and ground water. If the acidic materials can be surrounded and encapsulated with a thick layer of clayey, low permeability soil, the oxidation and leaching of these materials in the future can be minimized (OSM, 2002, *http://www.osmre.gov/amdpvm.htm*). Caution should be taken when grading or working on the surface of slurry materials. Slurry pond materials are typically saturated and do not drain easily. The bearing capacity of these materials is very low. Numerous instances have occurred in which trucks, dozers, or other vehicles have sunk quickly into slurry wastes because of engine vibrations even though the surface of the material was very dry and appeared to be stable.

One way of minimizing the erosion of mine spoils and coal refuse materials, and to minimize the formation of AMD is to keep water away from a mine site or have it pass through the mined area with minimal contact with the pyritic materials. This can be accomplished a number of ways through surface-water diversions, ground-water diversion, and channels liners (Scott and Hays, 1975; Miorin et al., 1979).

Industrial Sources of Contamination. For many sites, contamination sources include traditional types of industrial processes, such as machine maintenance and repair, vehicle repair, rail loading/unloading, electrical supply, fuel storage, and processing operations. These sources can lead to contamination of soil and ground water with solvents, petroleum, lubricants, PCBs, heavy metals, and other industrial compounds. For information about technologies and approaches for addressing these types of contaminated areas, see EPA's *Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Cleanup, Fourth Edition* (http://www.brownfieldstsc.org), which outlines the steps in the investigation and cleanup of a site slated for redevelopment and introduces brownfields stakeholders to the range of innovative technology options and resources available to them; the Federal Remediation Technologies Roundtable Cost and Performance Case Studies web page (http://www.frtr.gov/costperf.htm), which provide details about site-specific experiences and lessons learned in selecting and implementing treatment and site characterization technologies to clean up soil and ground water; and EPA REACHIT (http://www.epareachit.org/), an online database of information about providers of innovative remediation and characterization technologies.

2.6 STRATEGIES FOR SITE CLEANUP AND REDEVELOPMENT

The first steps toward site cleanup should be to determine the desired land use for the mined area and the impediments to site retoration and redevelopment (these are some of the key elements to strategic planning and a CSM). Contacting federal, state, and local government agencies to develop a list of stakehoders (interested parties) and potential sources of information and funding is also an early step. Stakeholders should include the members of the local community to gain their ideas and support early on in the planning process. Otherwise, public opposition to cleanup and redevelopment plans may arise as a result of their unfamiliarity with and distrust in the process.

The potential sources of information on mine sites, mining-related environmental problems, and cleanup programs in progress is quite large. Important sources of information on the history and environmental problems related to individual mine sites can often be obtained from OSM offices or state mine regulatory agencies and AML programs. Information on AMD point sources and impacted water bodies in a watershed can often be obtained from the EPA, U.S. Geological Survey, and state environmental and mine regulatory agencies. Thousands of scientific papers, reports, books, and government documents that deal with mining-related problems and remedial options are available.

Where the location of a site is advantageous and potential benefits of reclaiming and reusing the land exceed the costs of cleanup and redevelopment, state and local governments, industry, land developers, environmental groups, or private citizens may fund improvements or complete reclamation. However, in many cases additional sources of funding may be needed. One of the primary sources of funding for reclaiming abandoned coal-mined lands is OSM’s AML fund. Funds for reclamation of abandoned lands comes from a tonnage-based fee levied on active coal mine operations. The AML fund also obtains money from other fees, contributions, late payment interest, penalties, administrative charges, and interest earned on investment of principal.

Discharges from abandoned mines can severely impact streams, creeks, lakes, and reservoirs. Because impacts to a watershed are cumulative and because several mine sites (both surface and underground) can be the sources of the discharges, AMD problems and related impacts need to be evaluated and addressed on a watershed scale. In other words, it would not make sense to restore one mine site and eliminate problems caused by its discharge if there are many more sites contributing to the watershed problems. Therefore, efforts have been made and are continuing to be made to evaluate mine drainage problems on a watershed basis. In the 1960s and 1970s, Pennsylvania was evaluating AMD from abandoned mines on a watershed basis through its “Operation Scarlift” program. Currently, AML funding to remediate AMD problems in Pennsylvania is guided by “Pennsylvania’s Comprehensive Plan for Abandoned Mine Reclamation” and “A Model Plan for Watershed Restoration” (PaDEP, 1998, 1999), which establish a framework for organizing reclamation activities where they will provide the most positive benefits, coordinating with those involved with reclamation activities, and prioritizing expenditures and decision-making criteria.

State-supported programs may be available to provide additional sources of funding. As part of Pennsylvania's Growing Greener Program, the Environmental Stewardship and Watershed Protection Act authorizes PaDEP to allocate nearly $547 million in grants for AMD abatement, mine cleanup efforts, abandoned oil and gas well plugging, and local watershed-based conservation projects (PaDEP, 2005b, *http://www.dep.state.pa.us/growgreen/*). These projects can include watershed assessments and development of watershed restoration or protection plans, implementation of watershed restoration or protection projects, construction of mine drainage remediation systems, reclamation of previously mined lands, and demonstration/education projects and outreach activities.

Over the years, private citizens, volunteers, and cooperating businesses and industry have formed their own watershed groups aimed at the cleanup, restoration, and protection of streams impacted by coal-mining activities. These grassroot organizations have a strong, local, vested interest in seeing that streams are cleaned up and protected in the future. These groups have had real positive effects on the attitudes of the citizenry of an area and have led to success stories in cleaning and improving the watersheds of Appalachia and elsewhere. For example, "Hope and Hard Work, Making a Difference in the Eastern Coal Region" (Comp and Wood, 2001) describes numerous examples of these grassroots organizations and their accomplishments. Beginning in 2001, some AML funds have been made available to help develop and foster not-for-profit organizations, especially small watershed groups, that undertake local AMD projects. The maximum award for each cooperative agreement is normally $100,000 in order to assist as many groups as possible to undertake actual construction projects. A description of the Appalachian Clean Streams Initiative program, managed by OSM, is presented on the website *http://www.osmre.gov/acsihome.htm*. At this website, examples of numerous watershed organizations can be found and the varied goals and accomplishments for each of these groups. Similar types of information can be obtained from the document by Comp and Wood mentioned above.

The Section 206 Program of the U.S. Army Corps of Enfineers (USACE) allows the USACE to complete and implement a comprehensive watershed rehabilitation plan in cooperation with a local sponsor. Expenditures under this program up to $5 million are allowed, as long as the local sponsor provides up to 35% of the total project cost (Cavazza et al., 2003).

EPA is another source of funds through both its Brownfields Program and the Clean Water Act Section 319 Program. The Brownfields Program awards grants to eligible recipients for mine site assessment and cleanup. The Small Business Liability Relief and Brownfields Revitalization Act of 2002 authorizes up to $250 million in funds for brownfields grants annually. Both assessment grants and cleanup grants are available in amounts of $200,000. Revolving loan fund grants can range up to $1 million. EPA awards these grants to eligible recipients on a competitive basis once a year. From its inception in 1995 through 2005, the program awarded 709 assessment grants totaling over $190 million, 189 revolving loan fund grants worth more than $165 million, and $26.8 million for 150 cleanup grants. For more information on the grants program, visit *http://www.epa.gov/brownfields/pilot.htm*.

Section 319 of the Clean Water Act establishes the Nonpoint Source Management Program. Under Section 319, states, territories, and Indian tribes receive grant money to implement programs that are designed to reduce nonpoint source pollution, such as that from mining activities. From 2002-2004, $11 million of Section 319 monies were spent on 52 AMD sites within EPA's Region 3 alone (Delaware, District of Columbia, Maryland, Pennsylvania, West Virginia, and Virginia). For more information on Section 319 grants, visit http*://www.epa.gov/owow/nps/cwact.html* (EPA, 2005d).

2.7 CASE STUDIES

The following case studies provide examples of team-building, grassroots involvement, proper planning, and innovative techniques that have been used in redevelopment of coal mine sites.

2.7.1 Reclamation of Dents Run Watershed, PA

Neutralization of mine spoils and passive AMD treatment are ongoing within the Dents Run Watershed to reclaim more than 160 acres of surface-mined land for use as rangeland for elk herds. Working with the Bennetts Branch Watershed Association (BBWA), Pennsylvania Game Commission, USACE, Pennsylvania Bureau of Forestry, Western Pennsylvania Conservancy, and P&N Coal Company, the Pennsylvania Bureau of Abandoned Mine Reclamation developed a comprehensive watershed restoration plan for the 25-square-mile Dents Run Watershed. Located in Elk County in north-central Pennsylvania, the upper reaches of the Dents Run support a healthy native trout population, and the surrounding area is in the center of the state's growing elk range. AMD has severely degraded the lower 4.5 miles of stream, however, with the Porcupine Run sub-basin contributing over 90% of the pollution load.

Six areas occupying more than 160 acres that contain the most significant discharges were targeted for remediation. Site work began in October 2002 and is expected to be completed in 2008. The reclamation approach includes adding and mixing limestone with the acid spoils, which will be used to backfill surface mine pits. In addition, other acidic spoils will be isolated and 12 passive treatment systems for AMD constructed (see Figure 2-3), including anoxic limestone drains, vertical flow limestone reactors, manganese oxidation beds, aerobic wetlands, and settling ponds. Surface drainage controls are being implemented to minimize infiltration into the acid spoil burial areas.

The estimated total cost of the restoration project is $12 million, which will be provided by the Bureau of Abandoned Mine Reclamation, the USACE, BBWA, and P&N Coal Company. The coal company's contribution includes mining the limestone (for acid spoil neutralization) and reclaiming one of the six areas (Cavazza, et al., 2003; PaDEP, 2004b). The post-reclamation land use plan was developed in coordination with the Pennsylvania Game Commission, one of the primary landowners. Since the Dents Run Watershed is within a prime location for the state's elk herd, rangeland was selected by the stakeholders as the post-reclamation land use. An elk rangeland planting mix was recommended by the game commission and will be used to provide permanent soil cover after reclamation (Milavec, 2005b).

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2.7.2 Bark Camp Reclamation Project, Bark Camp Run, PA

A public-private endeavor through the Bark Camp Reclamation Project is facilitating the reclamation of an abandoned surface mine to its original contour using dredged sediments mixed with waste ash. The Bark Camp Reclamation Project is dedicated to conducting research and technology demonstrations on AMD and AML reclamation issues at abandoned coal mine sites within the Bark Camp Run watershed, which lies within the Moshannon State Forest in Pennsylvania. From the 1950s to 1988, two underground mines, a surface mine, and a coal preparation plant operated in the watershed, after which the operator went bankrupt and orphaned the site.

The surface reclamation demonstration is a cooperative agreement between PaDEP, the permitting and regulatory oversight agency; the New York/New Jersey Clean Ocean and Shore Trust, which provided dredge material for the effort; and Clean Earth Dredging Technologies, a Pennsylvania environmental contracting and recycling firm. The demonstration seeks to backfill two large strip mine pits and eliminate the dangerous highwalls exposed in the pits. Sediment dredged from harbors in New Jersey and New York is partially dewatered, mixed with 15% municipal incinerator ash, and shipped to central Pennsylvania via gondola railcars. After arriving at the site, more ash and waste lime is added to the mixture to form a cementitious blend. The blend is spread across the mine pits in one- to two-foot lifts and is roller-compacted to achieve a minimum compressive strength of 35 pounds per square inch within 28 days. The presence of the weak concrete will prevent air and water from contacting mine spoils, thus preventing AMD.

A total of 435,000 cubic yards of dredge material was placed in the mine pits between spring 1998 and 2002, and the land surface was returned to approximate original contour (PaDEP, 2004a). The final surface was covered with approximately 18-20 inches of artificial soil (crushed shale, paper fiber cellulose, organic material from a vegetable tannery, coal ash, and lime), which was intended to serve as a rooting medium for grasses and legumes. The mines were successfully backfilled, the highwalls were eliminated, and the acid discharges from the mine to the stream were eliminated. Monitoring of surface water and ground water showed no adverse impacts, except a short-term increase in chloride in the stream. It was determined that the municipal incinerator ash used contained elevated levels of chlorides; thus, the use of coal ash is recommended for future efforts (Varner, 2005).

The project is about 90% complete. The remaining 10% will be completed using sediment dredged from the Delaware River.

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Mine Site Cleanup for Brownfields Redevelopment:

Part 3–Hard Rock Mines

3.1 INTRODUCTION

Roughly 40% of the abandoned mine sites located in the United States are non-coal or hard rock mine sites. Hard rock mine sites are often characterized by acidic waters and acid mine drainage (AMD) as well as soil with acidic pH, acute metals toxicity, nutrient deficiencies, and a lack of vegetation. Hard rock mine sites typically have a variety of potentially contaminated materials, including waste rock and ore, mill tailings, smelter slag, and other wastes that may require investigation and remediation. Sometimes, the site contamination is fairly localized and well understood, but more commonly it is spread across many acres and throughout surface and subsurface environments. Many such sites have large, unvegetated areas associated with disposal of mill tailings and waste rock.

The types of hard rock (metal) mining can be grouped into the following four categories (EPA, 2000a):

Underground Mining. Underground mining has been the major method for production of certain metals but in recent years has been less common in the United States. The amount of underground mining fluctuates based on metal prices, the depth below the surface of the mineral deposits, the costs of tunneling compared to those of open pit mining, and other economic factors. Underground mining typically has less impact on the surface environment than do surface mining methods. This is the case because underground mining produces less surface disturbance (that is, there is a smaller facility “footprint”) and because smaller quantities of non-ore materials must be removed and disposed of as waste rock. Some large, underground hard rock mines may have AMD containing solubilized metals that can impact ground water and surface water quality. The quantity and nature of mine drainage are highly dependent on a site’s hydrogeology and geochemistry and can vary widely (EPA, 2000a).

Surface Mining in Open Pits. Surface mining in open pits has become the primary type of mining operation for most of the major metal ores in the United States. This type of mining was not common in the past, when mining operations focused on vein deposits. Open pit mining is typically used when the characteristics of the ore deposit (its grade, size, and location) make removing overburden (the host rock overlying the ore) cost-effective. At present, this is the most economical way of mining highly disseminated (lower-grade) ores. Open pit mining involves excavating an area of overburden and removing the ore exposed in the resulting pit. Depending on the thickness of the orebody, it may be removed as a single vertical interval or in successive intervals or “benches” (EPA, 2000a).

Dredging. Dredging is another method of surface mining that has been used to mine placer deposits, which are concentrations of heavy metallic minerals that occur in alluvial deposits associated with current or ancient watercourses. In some mining districts, widespread stream disturbance caused by placer mining or dredging may be present alongside other disturbances caused by underground mining and mineral processing. Commercial dredging has not been widely practiced in the United States in recent years, although placer mining is still an important industry in Alaska. Some abandoned large-scale dredging sites remain in the western United

States, and in some cases the dredges are still present in the dredge ponds created as part of the mining operations (EPA, 2000a).

In-Situ Solution Mining. In-situ solution mining is a method of extracting minerals from an orebody that is left in place rather than blasted and excavated. In general, a series of wells are drilled into the orebody, and a solvent is circulated through the formation by injection into certain wells and withdrawal from others. Although in-situ solution mining is not commonly used, it has been applied to uranium and copper deposits in suitable hydrogeologic settings. Although there may be little disturbance to the surface or subsurface in an in-situ solution mining operation, the potential effects on ground water may be significant. The ground-water geochemistry must be drastically altered for minerals to leach, and the ground-water flow may be altered by the pumping operations. Furthermore, minerals other than the target minerals may be dissolved and transported, which may be detrimental to the local ground water. The surface facilities for in-situ mining are mainly the surface impoundments or tanks needed to manage barren solutions (the solutions prior to injection) and pregnant solutions (the leachate withdrawn that contains the mineral value) (EPA, 2000a).

Part 3 of this primer provides detailed technical information about characterization, remediation, and redevelopment of hard rock mine sites. It covers:

- Specific characteristics and problems associated with hard rock mine sites
- Potential reuse scenarios for hard rock mine sites
- Approaches for assessment and cleanup of these sites, including use of the Triad approach
- Specific technologies for hard rock mine site remediation
- Additional information about hard rock mine site redevelopment, including case studies and resources

The remainder of Part 3 presents information on reclaiming and redeveloping abandoned and inactive hard rock mine sites for a variety of purposes, including recreational, wildlife habitat, reforestation, pastureland, commercial, industrial, and residential uses. One obstacle to the redevelopment of abandoned mine lands (AML) is often the lack of money and tools available to characterize and remediate the site. As discussed in Part 1, the EPA has several initiatives underway to address these challenges and to promote the redevelopment of AML. The use of the Triad approach is one way to streamline site cleanup. Triad, explained in more detail in Figure 2-1, is a dynamic, collaborative approach to cleanup that helps site stakeholders work toward cleanup that is faster, better, and cheaper and sets the stage for appropriate redevelopment.

3.2 SAFETY, ENGINEERING, AND ENVIRONMENTAL PROBLEMS RELATED TO HARD ROCK-MINED LANDS AND LAND REUSE

Hard rock-mined lands may have a wide variety of safety, engineering, and environmental problems that can affect activities related to redevelopment (EPA, 2000a).

Safety Problems. Safety problems at abandoned hard rock mines can pose immediate risk to people onsite:

Highwalls, which can exceed 100 feet in height, are the unexcavated faces of overburden and coal in a surface mine. Left in place without regrading, abandoned highwalls pose a falling hazard to users (e.g., dirt bikers, hikers, mountain bikers) of the site.

Old buildings, draglines, shovels, trucks, and other equipment in dilapidated condition can remain scattered around abandoned mine sites. Children or adults climbing on equipment or entering abandoned equipment and buildings can be subject to serious dangers, such as cuts and falls.

Old air shafts or vertical entries of underground mines may also result in falls, especially when located in woods, partially covered, and not readily visible. These shafts and open workings can be hundreds of feet deep. If not sealed, drift entrances into underground mines can also pose serious risks as old timbers and roofrock of these drifts can be very unstable and subject to collapse. Hunters and hikers sometimes seek refuge from bad weather in these entrances, and children may enter simply to hide or play.

Engineering Problems. Engineering problems at abandoned hard rock mines can affect existing structures and the approach to construction of new buildings, roads, and other infrastructure for redevelopment:

Subsidence of the ground surface occurs when it slowly sinks or collapses into underground mine openings below. Underground mines may have vertical shafts, slopes, drift openings, and mine workings (including haulageways water and drainage tunnels), and other passageways excavated from the subsurface that may cause subsidence. Buildings and other structures constructed on land undergoing active subsidence can crack, shift, tilt, and split. Damage to buildings can be so severe that they must be abandoned and demolished.

Piles of waste rock, tailings, and ore are often left at or near where the coal was mined. The geotechnical and engineering properties of the wastes can pose problems for land development. The waste piles can be highly erodible and unstable and thus, potentially could slide. They are particularly unstable if they are situated on steep hillsides, have water impoundments on the upper surfaces, or were placed over natural springs. Tailings impoundments were often constructed using wood cribbing or rock buttresses and were not designed or engineered to withstand major flooding or precipitation events.

Waste piles can be very difficult to build on. During mining, the waste rock and overburden were usually blasted, excavated, and dumped in unconsolidated piles nearby. Although the piles may gradually consolidate with time, they may need to be regraded and compacted in lifts or layers to prepare them for construction of buildings, roads, or other structures. Geotechnical testing and engineering studies should be conducted, and steps should be incorporated into reclamation plans to ensure the stability of waste rock and overburden materials.

Environmental Problems. A variety of environmental impacts may be associated with an abandoned hard rock mine site:

AMD may occur both from underground workings and from aboveground wastes such as waste rock and mill tailings. As indicated in the Abandoned Mine Site Characterization and Cleanup Handbook (EPA, 2000a), the severity and impacts of AMD are mainly a function of rock mineralogy and the availability of water and oxygen. Acid is generated at mine sites when metal sulfide minerals are oxidized and sufficient water is present to mobilize the sulfur ions. Acid generation can occur rapidly or can take years or decades to appear and reach its full potential. Even long-abandoned hard rock mine sites may have active AMD production and worsening environmental impacts.

Metal sulfide minerals are common constituents in the geologic formations associated with hard rock mining. The metals that are typically found in AMD are aluminum, copper, iron, lead, manganese, silver, and zinc. Elevated concentrations of these metals in ground water or surface water can preclude its use as drinking water or aquatic habitat.

Metal contamination of ground water, surface water, and sediments can result from the presence of abandoned hard rock mining operations can. Most mining occurred below the water table in either underground workings or open pits. Ground-water quality at the mining sites may be affected by metal transport resulting from surface water infiltration into overlying wastes or by direct hydraulic connections (open shafts) to ground water. Disturbances of ground-water hydrology by mine dewatering and pumpback systems also can cause impacts on local ground water. Surface water and sediments may be impacted when metal-contaminated ground water discharges to surface water downgradient of a mine site.

The dissolved contaminants in ground water and surface water at hard rock mine sites are primarily metals but may include sulfates, nitrates, and radionuclides. The dissolved metals typically include arsenic, cadmium, copper, iron, lead, manganese, silver, and zinc. Nitrates can be present at elevated concentrations because of the use of ammonium nitrate fuel oil blasting material. Low pH levels and high metal concentrations can have both acute and chronic effects on aquatic life. The metal contamination associated with AMD is a well-known problem, but metals can be mobilized and cause water pollution at near-neutral pH levels.

Sediment contamination can result when dissolved pollutants in surface water and storm water discharges from a site partition to stream sediments. In addition, fine-grained waste materials can be eroded from a mine site and transported by runoff, which deposits the sediments in nearby surface waters. Sediment contamination may affect human health through people's consumption of fish and other biota that bioaccumulate toxic pollutants from the sediments. In addition, elevated levels of toxic pollutants in sediments can have a direct acute impact on macroinvertebrates and other benthic organisms. Lower levels of sediment contamination may provide a long-term source of pollutants through their re-dissolution in the water column, which could lead to chronic contamination of water and aquatic organisms. No national sediment standards or criteria have been established for toxic pollutants associated with hard rock mining operations. An ecological risk assessment may be an appropriate tool for evaluating sediment-related impacts and potential reuse alternatives at a site.

Cyanide has a long history of use in hard rock mining. For decades, it has been used for gold recovery and to depress pyrite in base metal (copper, lead, and zinc) milling processes. In the 1950s, cyanide began to be used in large-scale leaching of gold. Continued improvements in cyanide heap-leach methodology have allowed increasingly lower-grade gold ores to be mined economically. The large-scale use of cyanide in the heap leaching of gold ores has significantly increased the potential for adverse environmental impact due to leakage or spills from such facilities.

Acute toxicity from cyanide can occur through inhalation or ingestion. Such exposure interferes with an organism's oxygen metabolism and can be lethal. Incidents have been reported in which waterfowl have died when using tailings ponds or other cyanide-containing solution ponds. In addition, a number of major cyanide spills have occurred, including one in South Carolina in 1990 when a dam failure resulted in the release of more than 10 million gallons of cyanide solution that caused fish kills for nearly 50 miles downstream. Regulatory authorities have been under increasing pressure to develop and enforce more stringent regulations and guidelines for the design, operation, closure, and reclamation of sites where cyanide is used.

Gaseous and particulate matter (PM) emissions to air occur during mining and mineral processing of hard rock ores. Gaseous emissions are primarily generated during roasting or smelting processes, thus, are not a concern at abandoned mine sites. The primary PM emissions are associated with flue dust from smelter or refinery stacks and fugitive dust from crushers, tailings ponds, and roads. If a smelter or refinery operated at a site, flue dust may still be found onsite, and uncontrolled releases may have contaminated downwind areas. Fugitive dust can be an issue at all mine sites because it is generated from waste rock dumps, spoil piles, tailings, soil stockpiles, roads, and other disturbed areas as well as during reclamation activities.

Spillage or disposal of nonhazardous or hazardous materials that are common to industrial sites (e.g., petroleum leaks from underground storage tanks or disposal of solvents used for machinery) may result in site contamination.

3.3 EXAMPLES OF POTENTIAL SITE REUSE

Many hard rock mine sites are relatively large and are located in non-urban areas. Contamination at hard rock mine sites is commonly spread across many acres and throughout surface and subsurface environments. Potential reuse scenarios for these types of sites in non-urban areas include use as recreational areas, wildlife habitats, and historic and scenic preservation areas. Hard rock mine sites located in urban areas as well as urban areas that have been affected by mine sites offer many of the same reuse scenarios as other types of brownfields, such as use as commercial, industrial, or residential sites (EPA, 2004d).

The increasing demand for land for residential, industrial, commercial, and recreational development is increasing both the pressure and the opportunities to use AML that was once ignored or avoided. In addition, the public has a general desire to protect and improve the streams, lakes, reservoirs, and aquatic resources of the country wherever possible. Consequently, efforts have been made at all levels of government (federal, state, and local) and by private fishing, boating, and ecology groups and organizations to clean up mine sites that are contributing contaminated sediments or AMD to streams, lakes, and reservoirs.

Communities are developing innovative recreational uses for AML. Recreational areas provide many benefits in that they help to attract tourists and investors, revitalize communities, and promote healthier communities. Recreational opportunities can be defined in two major categories: active and passive recreation. Active recreation is structured; can involve an individual or team; and requires a special facility, course, field, or equipment. Examples of active recreation include baseball, soccer, golf, and downhill skiing (EPA, 2005e).

Several factors can affect the ability of a former hard rock mine site to be reused for active recreation including the desired use of the site. In addition, the willingness of the property owner to sell the property or allow access to it can be crucial. Support from the property owner and cooperation between EPA and the property owner can often facilitate funding and redevelopment opportunities.

Passive recreation does not require a special facility and generally places minimal stress on a site’s resources. Examples of passive recreation include hunting, camping, hiking, bird-watching, cross-country skiing, bicycling, and fishing.

Almost any former hard rock mine site offers opportunities for passive recreational use. However, sites with a variety of ecosystems and recreational opportunities are often more appealing to a larger and more diverse population. In addition, the accessibility of a site can be a key factor in its popularity as a recreational area (EPA, 2005e).

There are many examples of abandoned hard rock mine sites that have been remediated and reused for either active or passive recreational purposes. For example, the Anaconda Smelter in Anaconda, Montana, once operated as a copper smelting facility. The smelter closed, leaving the town of Anaconda in a severe economic depression from the loss of jobs and revenue. In addition, contamination from the smelter operations scarred the landscape of the area. EPA, the community, and the current owners of the site successfully collaborated to remediate the site and reuse it as an award-winning golf course designed by Jack Nicklaus. The golf course not only has significantly improved the landscape of the site, but it has provided local jobs and is supporting the efforts of the community to establish itself as a recreational resort (EPA, 2004a).

Silver Bow Creek in Butte, Montana, was also a copper smelting site. This site was added to EPA's National Priorities List (NPL) in 1993 as a result of severe contamination of area ponds and soils. Through a partnership between EPA and the Atlantic Richfield Company, the site has been remediated, and portions of the site have been redeveloped as a sports complex. Recreational opportunities provided by the sports complex include youth baseball, a driving range, and volleyball courts. In addition, many of the site's ponds and wetlands have been restored for use by local and visiting fishermen. Additional plans are underway for continued restoration of the site to provide walking trails and a playground (EPA, 2004c).

The Bunker Hill Mining and Metallurgical Complex, a former lead smelter site in Silver Valley, Idaho, is another NPL site that was redeveloped for commercial use. The closure of the Bunker Hill Mine and several other area mines resulted in severe economic impacts on Silver Valley. EPA, the Panhandle Health District, and the State of Idaho collaborated to restore the ecology and soil of the area by remediating lawns and parks containing mine tailings, and planting trees. Redevelopment of more than 800 acres of the site included construction of a Motel 8; a McDonald's restaurant; and the Silver Mountain Resort, a popular ski resort. The new businesses have created approximately 225 new jobs. Institutional controls were also developed to ensure the protection of area residents from the contaminated soil remaining onsite (EPA, 2004d).

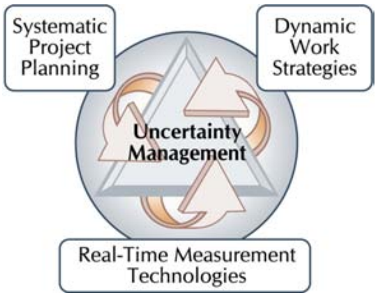
The former Murray Smelter site in Murray City, Utah, provides an example of a successful effort between the Superfund and Brownfields programs to reuse a hard rock mine site for commercial and industrial purposes. The 141-acre site is surrounded by residential areas, schools, and commercial buildings. The site was redeveloped to contain a Utah Transit Authority light rail station with a parking lot, a connector road, and a major retail warehouse club. Construction is also underway for a hospital on portions of the site. Site redevelopment is being supported in part by a Brownfields program grant. In addition, the site remedy could be integrated with identified reuse opportunities (EPA, 2004d).

AML often serves as excellent locations for wind farms as it is often located in mountainous areas that receive consistent wind flows. In addition, AML is often near existing infrastructure, including roads and utilities (EPA, 2005e). The large size of much AML means that many large wind turbines can be installed in one location. Wind farms are beneficial to an area because they can provide a renewable energy source, enhance economic growth, generate tax revenue, and return AML to productive use.

3.4 IDENTIFYING AND CHARACTERIZING ISSUES RELATED TO SITE REUSE

The environmental and geotechnical problems found at mine sites can be varied and significant. Identifying and fully characterizing these problems can be challenging, but such efforts are necessary. Before large amounts of time and money are invested in mine site characterization or cleanup, proper planning should be performed, input and consensus should be obtained from stakeholders, and potential environmental liabilities and safety issues should be fully investigated. If the projected land reuse for a mine site is industrial or residential, and if a large amount of construction is to take place, more time and money should be spent on planning, market evaluation, and collection of site historical information and environmental data. These types of activities are consistent with use of the Triad approach as discussed in the box below (Crumbling, 2004, EPA, 2003)

Use of the Triad Approach in Hard Rock Mine Site Characterization



The Triad approach represents an evolution of technical thinking about contaminated sites. Triad supports second-generation practices that maximize use of innovative field tools. Through generation and use of data in real time, these innovative tools and associated techniques more effectively address the uncertainties related to variability of contamination across a site. Although it is somewhat different from traditional practices, the Triad approach truly supports the goal of conducting “better, faster, and cheaper” projects. Further information about the Triad approach is available at *www.triadcentral.org*.

For abandoned hard rock mine sites, use of the Triad approach includes development of an accurate CSM. The CSM has two important characteristics. It aids in delineating contaminant populations requiring different remediation techniques, and it improves the confidence and effectiveness of project decision-making by identifying decision and data uncertainties early as well as throughout the entire cleanup process. Thus, the CSM provides the decision-making team with realistic remediation objectives, supports development of open channels of communication that increase trust among all stakeholders, and allows for identification and acknowledgment of differing stakeholder viewpoints.

For building a Triad CSM, existing information should be used to help perform preliminary assessments of a hard rock mine site’s condition and the potential liabilities and limitations that might be associated with the site. For example, mine maps should be obtained for any underground workings that might exist at the site. These maps can delineate the extent and interconnections of underground workings, the dip of the mine floor, the presence of geologic faults or fracture zones, the thickness of overburden rock, areas where pillars may have been removed (such areas may be subject to more intense subsidence problems), and the locations of any mine entries or shafts (including air shafts and water drainage tunnels). Maps of surface mine sites often show sediment retention basins and locations where wastes may have been buried within mine spoils (a common practice). Overall, these maps can be used to quickly identify potential hazards or environmental problems at a site; however, users should be cautioned that the maps may be incomplete or contain other inaccuracies. If records are available from the mining company or OSM (for example, mine permit applications, permit amendments, notices of violation, or inspector's reports), they may also provide useful information.

After existing site information has been collected and assessed, a plan or roadmap should be formulated that addresses the potential land uses being considered for the site, the amounts and types of additional data that might be needed, and the permits and approvals that might be required for redeveloping the site.

Work can then be initiated to collect additional site data and characterize a site to the extent appropriate for the intended post-reclamation land use. Some data are relatively easy to collect. For example, simple pH meters, specific conductivity meters, and field test kits can be used to quickly and inexpensively evaluate water quality problems at a mine site or in a watershed. Measuring the pH of mine spoils and refuse in the field is possible but would be somewhat more time-consuming. Analysis of mine spoil and refuse for essential nutrients (such as nitrogen, phosphorus, and potassium), water holding capacity, and toxic metals is necessary if the site is to be used for agriculture, pastures, managed forests (tree farms), or residential properties with lawns and landscaping.

Demonstration of Method Applicability

When using field-portable site characterization technologies such as XRF, it is generally advisable to perform a demonstration of method applicability (DMA) study at the site where the technology is to be used. A DMA is an initial "pilot test" of the field-based analytical method using a few actual site samples and comparative laboratory analyses. The DMA concept is founded in EPA SW-846 guidance and performance-based measurement standards, and DMAs require clearly defined objectives and decision criteria. DMAs involve collection of samples from a site-specific matrix (such as soil, water, air, or tissue) followed by analysis of the samples using field-based and comparative fixed-laboratory analyses. They can provide useful information about whether the technology provides data of sufficient quality and quantity to make required decisions, and what the decision logic will be for using the technology in real time to make confident site decisions.

Determining the metals concentrations in the various wastes at a hard rock mine site is typically the most important characterization activity for making reuse decisions. Total metals concentrations in soil, tailings, and other solid matrices can be determined quickly using field portable x-ray fluorescence (XRF) spectroscopy. XRF analysis has been demonstrated to be a very effective characterization tool at sites with multiple metal contaminants, such as hard rock mine sites. Generally, elements of atomic number 16 (sulfur) through 92 (uranium) can be detected and quantified with an XRF. At hard rock mine sites where mercury may be a contaminant and health and safety measures are critical, field portable mercury vapor analyzers can be used to detect mercury vapors in air, water, soil, and geological samples. Anode stripping voltammetry is an innovative field portable instrument for measuring trace metals in water and extracts from soil, paint, dust, and particles.

If buildings or other large structures are to be built on graded mine spoils or refuse at a site, geotechnical engineers need to be involved in the site assessment. Such personnel can make evaluations and recommendations regarding the stability of the geologic materials and the potential for underground mine subsidence; differential compaction of the mine spoils; and slumping, sliding, or liquefaction of the mine spoils or refuse. In addition, civil engineers may be needed to evaluate refuse impoundments and the structural integrity of the dams or berms retaining the wastes. Engineering studies and designs are also needed if deep mine entrances or shafts are to be sealed.

3.5 Technologies for Site Cleanup and Revelopment

The degree of cleanup required at an abandoned hard rock mine site depends on the type of reuse anticipated. Site reuse that includes access to the site by the public requires elimination or mitigation of potential safety hazards such as open adits or shafts, highwalls, and unstable slopes. Many types of reuse require removal or isolation of contaminated materials such as waste rock, tailings, slag, or other mineral processing wastes. Contaminated mine drainage (both acidic and nonacidic) may also require treatment or control measures to make a site suitable for reuse. The remainder of this section discusses various technologies that address safety hazards, as well as control and treatment of environmental media.

3.5.1 Safety Hazards

Elimination of potential safety hazards at abandoned hard rock mine sites is the first priority and is relatively straightforward. The type of action to be taken is generally governed by the level of public access anticipated after the site has been reclaimed. For example, at a remote mine site that is being reclaimed for use as a wildlife habitat or rangelands, it may only be necessary to fence potentially hazardous areas and post warning signs. At the other extreme, such as at an urban mine site that is proposed for residential or commercial redevelopment, it may be necessary to not only backfill and seal mine openings and tunnels but to also remove or relocate all mine wastes in order to provide a stable ground surface for construction. In some cases, such reuse may even require extensive underground backfilling and grouting to minimize potential ground subsidence.

3.5.2 Control and Treatment – Contaminated Surface Soil or Mine Wastes

The cleanup of contaminated surface soil or mine wastes typically involves removal and relocation of the contaminated materials or covering or capping of the materials with clean soil. These cleanup approaches are generally expensive, and as the cost of fuel continues to increase, they will become even more so. Costs can be a significant issue because many abandoned mine sites are quite large. Cleanup options that appear to have relatively low costs (for example, $50 or less per cubic yard of contaminated material) may end up costing millions of dollars because of the large quantities of material to be cleaned up.

To minimize erosion and exposure of mine waste and improve the aesthetics of a reclamation site, it may be necessary to establish a self-perpetuating vegetative cover on the final reclaimed surface. Decades of research has been conducted on the physical and chemical characteristics and nutrient deficiencies of mine wastes and contaminated soil to determine the best methods for transforming these materials into plant growing media. Research has also identified certain plants that can tolerate and survive on acidic and metal-contaminated soils that are toxic to most other plants. Soil amendments, such as lime, fertilizer, and organic materials are often needed to improve the harsh soil conditions and thus the potential for successful revegetation. Because large areas of land usually must be reclaimed at a mine site, the costs for soil amendments can be high. Considerations associated with use of soil amendments are discussed below.

3.5.2.1 Using Process Residuals

Use of process residuals as soil amendments (see Figure 3-1) may help address the problems of metal toxicity, infertility, and acidity that are common in soils at abandoned hard rock mine sites. Examples of useful process residuals are dairy, swine, and chicken wastes; waste water and drinking water treatment residuals; phosphorous fertilizer manufacturing by-products; pulp and paper production wastes; sugar beet processing wastes; and residuals from coal or wood-related processes. These materials are available in many parts of the country and may be free except for transport and application costs.

Figure 3-1. Example of Biosolids Compost

Residuals and other soil amendments can help rebuild soils by enhancing the soil structure, soil aggregation, nutrient cycling, and soil microbial populations. When potentially toxic levels of metals are present in soils at a site, it is important to understand that metal toxicity and bioavailability are directly related to the soil pH, metal speciation, and other site-specific plant and soil factors. For example, mine tailings at the California Gulch site in Leadville, Colorado, that contained 3,000 milligrams per kilogram (mg/kg) of zinc were toxic to plants, whereas yard soils at a site in Joplin, Missouri, containing similar zinc levels supported healthy vegetation.

3.5.2.2 Correcting pH

At many hard rock mine sites, the waste rock and ore may contain large amounts of iron pyrite (FeS_2). Over time, as the pyrite is exposed to air and water, the sulfur in the pyrite turns into sulfuric acid. The waste rock and ore may have some neutralization capacity but typically not enough to neutralize all the sulfuric acid. Additional liming (neutralization) materials can be applied to help neutralize the acidity. Liming materials may include agricultual limestome, cement kiln dust, coal fly ash, wood ash, or sugar beet process wastes. For limestone and commercial lime, the particle size is an important factor because small particles will go into solution and react with acid much more quickly than larger particles.

3.5.2.3 Addressing Metal Toxicities

The metal contaminants of greatest concern at abandoned hard rock mine sites are arsenic, cadmium, lead, and zinc (EPA, 2000a). If it was used onsite in amalgamation milling, mercury also can be a major contaminant. Free mercury is a risk to both human health and the environment and is very difficult to locate in the subsurface because it is dense and can migrate downward to some depth through unconsolidated materials. Only general information, recommendations, and precautions regarding metal toxicities at hard rock mine sites are presented in this section.

Arsenic behaves differently in the environment than cadmium, lead, and zinc. Arsenic's bioavailability and toxicity are determined by many factors, including the physical and chemical forms of the arsenic, the route of exposure, the dosage, and the organism affected. Terrestrial plants accumulate arsenic by root uptake from soil and by adsorption of airborne arsenic deposited on leaves. In general, inorganic arsenic compounds are more toxic than organic arsenic compounds, and trivalent species (As^{3+}) are more toxic than pentavalent species (As^{5+}).

Cadmium, lead, and zinc in soil can be rendered less mobile and thus less bioavailable by adding soil amendments. Three soil amendments that help immobilize these metals in soils are phosphorous fertilizer materials (such as diammonium phosphate, phosphoric acid, and triple super phosphate), organic amendments (such as biosolids, compost, manure, and chicken litter), and Portland cement. Many soil amendment types and application rates can be used to help immobilize metals in soils.

Before soil amendments are used, treatability studies should be conducted. These studies are crucial to optimizing the design mix or "recipe." The design mix can be optimized by conducting pilot studies to determine the blending, mixing, and incorporation methods needed to achieve the best end results in the field.

3.5.2.4 Addressing Ecological Concerns

At sites where ecological risks are the primary concerns, in-situ remediation techniques, such as theuse of soil amendments may have advantages over other remedial options. In-situ remediation methods can improve soil fertility, water-holding capacity, microbial populations, and tilth. In addition, the cost of in-situ remediation is often an order of magnitude lower than that of other options. Properly amended soils will support long-term, self-perpetuating plant communities.

Sites in close proximity to residential areas where the risk to human health is also a concern can be remediated using a combination of alternatives, such as excavation of surface contamination, in-situ soil treatment with phosphorous fertilizer, and use of soil covers with organic amendments.

3.5.2.5 Establishing Performance Measures

It is important to establish performance measures early in the remediation process with the input and support of local stakeholders and appropriate regulators. It may be difficult to identify relevant and appropriate measures for judging the performance of in-situ remediation methods in which wastes are left onsite, albeit with reduced contaminant mobility or bioavailability. Existing toxicity and bioaccumulation tests, such as the earthworm toxicity and rye grass germination tests, may have limited applications. Other traditional sampling and leach test procedures (such as the toxicity characteristic leaching procedure and the synthetic precipitation leaching procedure) may not accurately represent human or ecological exposure routes at a site. Specialized measures, such as the relative bioavailability tests for the human health physiologically based extraction test, are good for lead contamination and adequate for arsenic contamination but address only the ingestion route of exposure.

3.5.3 Control and Treatment–Mine Drainage and Storm-Water Runoff

Drainage from adits and shafts occurs at many abandoned hard rock mine sites. Although most hard rock mine drainage is acidic, there are cases in which such drainage is not. Depending on the proposed reuse of a site and the nature and quantity of the mine drainage, it may be necessary to provide either control or treatment of the drainage as part of site reclamation.

Reducing or eliminating mine drainage through use of source controls such as surface water diversion or collection, ground-water diversion, and channel liners is generally the preferred option. Unfortunately, past experience has shown that such containment actions as shaft sealing, tunnel backfilling or grouting, and curtain grouting may be ineffective in reducing or eliminating mine drainage in the long term. Even when source controls do not completely eliminate mine drainage, they may be successful in reducing the volume of drainage that needs treatment.

Conventional treatment methods for mine drainage include chemical precipitation, clarification, and filtration. Although these methods are effective, they are usuallly very expensive and labor-intensive. Where mine drainage flows are greater than 100 gallons per minute and/or total acidity levels exceed 100 milligrams per liter, conventional water treatment methods may be needed to meet water quality standards. Conventional water treatment plants can cost $1 million or more to build and $500,000 or more per year to operate.

Passive treatment systems for AMD are relatively simple to construct and may require minimal operation and maintenance. However, passive treatment systems can generally treat only small to moderate flows with low to moderate levels of iron, dissolved metals, and acidity. The main objective for a passive treatment system is to facilitate chemical and biological reactions that will precipitate and remove contaminants from the AMD before it enters a receiving stream. Passive treatment systems for AMD have evolved over the last 25 years and include the following types:

- Constructed wetlands (aerobic and anaerobic)
- Aeration channels and settling ponds
- Limestone riprap-lined channels and flow-through dams
- Anoxic limestone drains or diversion wells
- Anaerobic sulfate-reducing bioreactors
- Successive alkalinity-producing systems
- Synthetic rock leach beds
- Phytoremediation

This primer is not the appropriate place to describe these passive technologies in detail, but it should be noted that a constructed wetland may include one or more ponds or compartments sized to allow mine drainage to flow through at a low rate. Aluminum, iron, and other metals are oxidized and precipitated within the wetland. Acidity is neutralized by vegetation photosynthesis and other biological activities that produce alkalinity. Numerous demonstration projects and studies have been performed to evaluate the performance, costs, and longevity of passive treatment systems for AMD. Comprehensive documents are available that provide details regarding the performance of wetlands constructed for treatment of waste waters in general (EPA, 2000b; ITRC, 2003).

Storm-water runoff from abandoned hard rock mine sites also has the potential to leach and transport contaminants offsite. Source controls, such as surface water diversions, can reduce the quantity of storm water running onto and off a site. Regrading and revegetation of abandoned mine sites can reduce the quantity of storm-water runoff to be treated by increasing infiltration into the soil surface and increasing plant transpiration. Construction of sedimentation basins and other such sediment capturing features should also be considered to reduce potential transport of contaminants off the site.

3.5.4 Control and Treatment–Mine Pit Lakes

Some abandoned hard rock mine sites may have unreclaimed, open pits that have filled with water from surface water runoff and from ground water. Hydrogeologic research efforts and computer modeling applications have focused on mine pit lake water quality. Physical and biogeochemical characteristics of the mine pit lakes must be evaluated to reclaim existing acidic mine pits and help predict the water quality of future pit lake systems. Pit lake water quality variables include bathymetry, distributions of temperature and salinity, compositions of surface inflow and ground water, lake turn over, precipitation, evaporation, dissolved oxygen, and concentrations of major ions such as manganese and iron. Computer models use these variables to predict the water-rock reactions within the pit lake and the effects of these reactions on pit lake water quality over short and long time periods.

Most hard rock pit lakes will have poor to very poor water quality. In some cases, these pit lakes may be able to be reclaimed for recreational use, or for use as reactors to treat AMD, however reclamation of pit lakes is generally viewed as an exception. One example of where this type of research is ongoing is for the Sleeper Pit Lake in Nevada, where a pit lake was neutralized and various nutrients added, and now sustains various fish populations. Further information is available at *http://www.kinross.com/op/mine-kubaka/kubaka-report-ed1-appendix.html*.

Industrial Sources of Contamination. For many sites, contamination sources include traditional types of industrial processes, such as machine maintenance and repair, vehicle repair, rail loading/unloading, electrical supply, fuel storage, and processing operations. These sources can lead to contamination of soil and ground water with solvents, petroleum, lubricants, PCBs, heavy metals, and other industrial compounds. For information about technologies and approaches for addressing these types of contaminated areas, see *EPA's Road Map to*

Understanding Innovative Technology Options for Brownfields Investigation and Cleanup, Fourth Edition (http://www.brownfieldstsc.org), which outlines the steps in the investigation and cleanup of a site slated for redevelopment and introduces brownfields stakeholders to the range of innovative technology options and resources available to them; the Federal Remediation Technologies Roundtable Cost and Performance Case Studies web page (http://www.frtr.gov/costperf.htm), which provide details about site-specific experiences and lessons learned in selecting and implementing treatment and site characterization technologies to clean up soil and ground water; and EPA REACHIT (http://www.epareachit.org/), an online database of information about providers for innovative remediation and characterization technologies.

3.6 STRATEGIES FOR SITE CLEANUP AND REDEVELOPMENT

The degree and type of cleanup required at an abandoned hard rock mine site depend to a large degree on how the site will be reused. Therefore, the first thing to determine as part of a mine site reclamation project is the desired future land use. In addition to traditional site reuse scenarios, such as development for residential or commerical purposes or reclamation as parkland or wildlife habitat, a wide variety of innovative reuse scenarios have been proposed and implemented over the last several years. Examples of such scenarios include reuse of sites as wind farms, wetland mitigation banking, water quality trading credits, and carbon sequestration areas. EPA has published previous reports on innovative site reuses and is currently developing additional reports. Such reports can be found on EPA's AML website at *http://www.epa/gov/superfund/ programs/aml/revital/index.htm*.

Once a proposed reuse scenario is selected for a site, impediments to site reclamation, including identification of impacted populations and associated risk divers, can be identified. It is important to remember that certain populations, especially children, may be especially vulnerable to common hard rock mine contaminants, such as arsenic, cadimum, and lead. At this point, it is necessary to contact the appropriate government agencies (federal, state, and local) in order to identify interested parties (stakeholders) and potential sources of information and funding. As discussed earlier, these necessary steps are elements of the Triad approach.

Drainage from abandoned hard rock mine sites can severely impact streams, lakes, and reservoirs. These watershed impacts are cumulative and need to be evaluated and addressed on a watershed basis. Over the years, private citizens, volunteers, and cooperating businesses and industries have formed their own watershed groups to pursue the cleanup, restoration, and protection of local water bodies impacted by hard rock mining activities. These grassroots organizations have strong, vested interests in the cleanup and future uses of these waters. Such groups have had positive effects on the attitudes of local residents and have produced success stories in cleaning up and otherwise improving mine-impacted watersheds. Grassroots organizations may be extremely useful in promoting and supporting AML reclamation as part of their watershed protection and improvement programs.

The potential sources of information on abandoned mine sites, mine-related environmental problems, and AML cleanup programs are numerous. Important sources of information on the histories and environmental problems of individual mine sites can often be obtained from OSM, state regulatory offices or environmental protection agencies, and state AML programs. Other abandoned mine information can be obtained from EPA; the U.S. Geological Survey; government documents; and scientific papers, reports, and books.

A primary source of funding for reclamation of abandoned hard rock mine sites in the western United States is OSM's AML fund. This fund obtains monies from a tonnage-based fee levied on active coal mine operations, and these monies are distributed to states for use in reclaiming abandoned coal mine sites and other abandoned mine sites.

3.7 CASE STUDIES

The following case studies provide examples of team building, grassroots involvement, proper planning, and innovative techniques that have contributed to reclamation and redevelopment of hard rock mine sites.

3.7.1 Use of Biosolids at Mine Sites in Joplin, Missouri

The Jasper County Mine Site in Missouri contains over 8 million cubic yards of mine tailings spread over 7,000 acres. Mine tailings were processed and left in piles or impoundments on the ground surface, and as a result, large areas of the site are barren. In pilot studies conducted by the Missouri Department of Natural Resources and the University of Washington, biosolids from local waste-water treatment plants were applied to the mine tailings at a rate of 50 to 100 dry tons per acre. Agricultural lime was added at a rate of 10 to 25 dry tons per acre. The mine tailings are composed primarily of silt- to gravel-sized carbonate and silicate rock, and are very nutrient poor. The addition of biosolids provides much-needed organic matter to the mine wastes to promote plant growth. The treated area now supports a self-sustaining plant cover (Doolan, 2005). Studies have shown that earthworms can now survive in the area's soil. Plant tissue analysis revealed low metal concentrations, indicating that plants are not taking up metals to a point that creates a threat to wildlife. Statistics indicate that this area has become a habitat for local wildlife.

The record of decision signed for cleanup of mine wastes at the site in 2004 includes provisions for the use of biosolids to amend metals-contaminated soils and remnant waste piles. EPA anticipates this addition of biosolids will reduce the bioavailability of lead and zinc in the mined areas to the point where the land can be returned to productive wildlife habitat.

In studies to determine the in-situ treatment of lead in residential yard soils, test plots were established to assess the effect of phosphate addition on reducing the bioavailability of the lead. Residential yards, particularly in the city of Joplin, were contaminated with high concentrations of lead, zinc, and cadmium as a result of air depositions from smelting of locally mined ore and runoff from mine tailings piles. As part of the pilot study, a range of amendments were tested to assess their ability to reduce the threat posed by lead in the soils. The amendments included phosphorus as phosphoric acid, trisodium phosphate, and phosphate rock. A high-iron biosolid compost was also tested. The phosphoric acid amendment (which was added to soils at 1% phosphorus) resulted in approximately a 50% reduction in blood lead levels in immature swine. Rats fed the same material exhibited a 30% reduction in blood lead levels. The same reduction in blood-lead levels in rats was observed when biosolid compost was added to the soil at 10% by volume.

These studies showed that the toxicity of metals can be reduced through the addition of phosphate, or phosphate rich materials. Phosphoric acid alone can reduce the bioavailibilty of metals to both people and animals, as well as, plants. The addition of biosolids, rich in phosphate, reduces the metals toxicity, and also provide the organic requirements for plant growth in revegetating mine wastes.

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3.7.2 Use of In-situ Biosolids and Lime Addition at the California Gulch Superfund Site, Operable Unit 11, Leadville, Colorado

The California Gulch Superfund Site, located in Leadville, Colorado, includes 16.5 square miles of land contaminated by heavy metals from historic mining operations. Mining operations, dating back to 1859, included mining for lead carbonate, zinc, copper, silver, and iron-manganese ore; smelting operations; and cyanide, molybdenum, and zinc-concentrating mills. These operations resulted in large volumes of mine waste and AMD from mine workings. California Gulch was placed on the National Priorities List in 1983. The primary contaminants of concern at this site are cadmium, copper, lead, manganese, and zinc.

A field demonstration of using amendments was conducted at Operable Unit 11, the Arkansas Floodplain, where tailings have been deposited into and along the banks of the Upper Arkansas River. Because of the acidic nature of the tailings, the deposits were devoid of vegetation, resulting in streambank instability and an increased risk to wildlife from exposure to metals. In 1998, EPA Region 8 and EPA's Environmental Response Team Center evaluated the use of amendments to reduce the bioavailability of metals to the biota at Operable Unit 11.

An amendment mixture of municipal biosolids and agricultural limestone was applied to portions of the tailings deposits. Samples were collected from four areas, ranging in size from 72,000 to 123,400 square meters, that received the amendment mixture. Samples were collected in 1998 and for two years following amendment addition. The samples were analyzed for a variety of parameters, including various forms of nitrogen and carbon, metals (e.g., cadmium, lead, and zinc), earthworm survival and biomass, plant growth, and small mammals.

The use of biosolids and lime amendments reduced metal availability and increased soil fertility sufficiently to restore function to the ecosystem. Following treatment, the tailings had ecosystem functions that were generally comparable with those from the contaminated vegetated area, with greater microbial activity than in upstream control samples. (Brown et al., 2005; EPA, 2005b). Figure 3-2 shows the site following treatment.

Figure 3-2. California Gulch Site Superfund Site Following Treatment

While this project was geared toward cleanup, the Leadville site also has recieved Superfund grants targeted for redevelopment. These redevelopment activities include a bike path, interpretative signage of the historic cultural resources, development of a lake and open space along the Arkansas River for public recreation, preservation of buildings at a historic ranch, redevelopment plans for a slag waste site, and putting together a storm water management plan for a abandon railyard. (Holmes, 2005)

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3.7.3 Reclamation of Wickes Smelter Site in Jefferson County, Montana

The Montana Department of Environmental Quality was responsible for reclaiming the Wickes Smelter site, a historical mine and smelter site located around the unincorporated community of Wickes in Jefferson County, Montana. Mining and ore processing activities were conducted at the site from the late 1860s to 1893; the ore processing activities included roasting and mercury amalgamation for gold, silver, and lead ores. A portion of the site has been reclaimed and redeveloped into community open space that is used as a ball field and for other recreational purposes. In addition, the area's residential yards were remediated to achieve risk-based cleanup levels (Figure 3-3).

The reclamation work included cost-effective investigation and characterization of the mine and smelter wastes, soils, sediments, and intermittent surface water. Surface and subsurface areas were investigated using backhoes, drill rigs, and hydraulic push-probes. Solid matrix samples were analyzed using a field-portable X-ray fluorescence spectrometer. Engineers, environmental scientists, and toxicologists completed an integrated investigation and engineering evaluation, which included a streamlined risk assessment, evaluation of applicable or relevant and appropriate requirements, and evaluation of potential reclamation alternatives along with the costs and schedules for implementing them. Other characterization efforts included surface sampling of residential yards, subsurface sampling of mercury-containing wastes, evaluation of potential waste repository sites, hydrologic modeling in support of repository cap design, evaluation of mercury-containing waste treatment and disposal options, and structural and restoration evaluations of the site's 67-foot-tall smokestack. Assessment of remedial options for approximately 400 tons of mercury-contaminated soils at the site included analysis of land disposal restrictions, and application of corrective action management units.

Surface soils in the smelter area contained arsenic concentrations ranging from 45 to 10,592 mg/kg and lead concentrations ranging from 70 to 32,226 mg/kg. Subsurface materials in the smelter area contained arsenic concentrations ranging from 146 to 64,267 mg/kg and lead concentrations ranging from 1,096 to 28,689 mg/kg. The recreational risk-based cleanup levels for arsenic and lead were 323 and 2,200 mg/kg, respectively. The residential yard soils and mine waste rock did not contain arsenic and lead concentrations as high as those in the smelter waste materials. The residential risk-based cleanup levels for arsenic and lead were 23 and 400 mg/kg, respectively.

The site reclamation project cost approximately $1.9 million and was completed in June 2005. Figure 3-3 shows a portion of the residential area that was reclaimed. Directly behind and uphill of the residential area is the reclaimed waste rock dump that was removed during the project. The project included the following major activities (Surbrugg, 2005):

- Excavating and transporting 101,747 cubic yards of mine waste for disposal in a 5-acre waste repository in the northwest portion of the site
- Excavating soils from nine residential yards, replacing cover soils, sodding eight yards, and seeding one yard
- Constructing a separate mercury-containing waste disposal cell within the repository and excavating, transporting, and disposing of 2,264 cubic yards of mercury-containing waste
- Seeding, fertilizing, and mulching over 41 acres of excavation and construction areas and installing 8,252 square yards of erosion control mat

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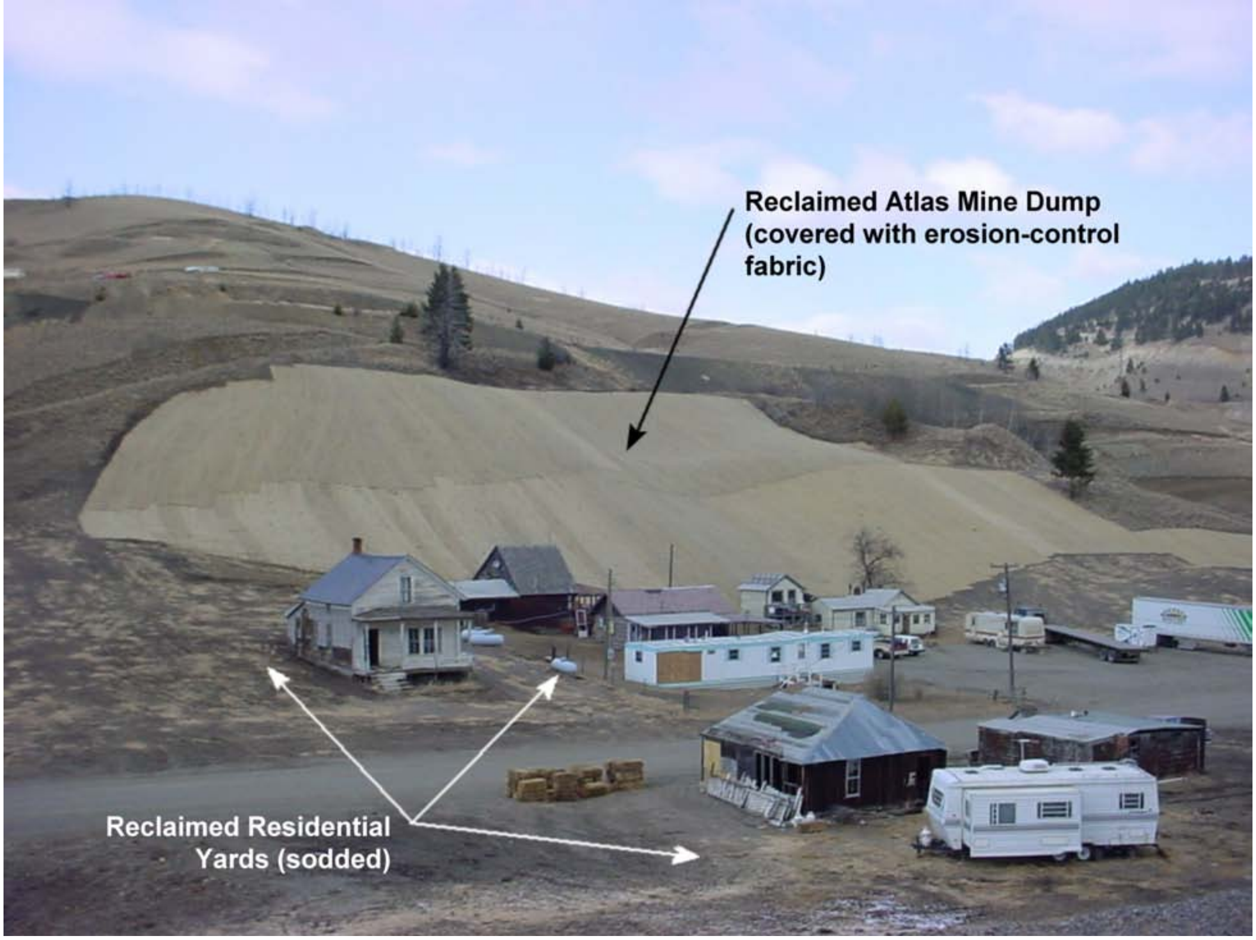

Figure 3-3. Reclaimed Residential Area at Wickes Smelter Site

APPENDIX A

EPA Regional Brownfields Coordinators

An online list of regional contacts is available at *www.epa.gov/swerosps/bf/regcntct.htm*

REGION 1
Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont

http://www.epa.gov/region01/Brownfields/

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Fax: 617-918-1291

REGION 2
New Jersey, New York, Puerto Rico, Virgin Islands

http://www.epa.gov/r02earth/superfnd/brownfld/bfmainpg.htm

U.S. EPA Region 2 Brownfields Office
290 Broadway
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New York, NY 10007-1866
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Fax: 212-637-4360

REGION 3
Delaware, Washington, D.C., Maryland, Pennsylvania, Virginia, West Virginia

http://www.epa.gov/reg3hwmd/brownfld/hmpage1.htm

U.S. EPA Region 3 Brownfields Office
1650 Arch Street
Philadelphia, PA 19103
Phone: 215-814-3129 or 1-800-814-5000
Fax: 215-814-3254

REGION 4
Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee

http://www.epa.gov/region4/index.html

U.S. EPA Region 4 Brownfields Office
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REGION 5
Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin

http://www.epa.gov/R5Brownfields/

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REGION 6

Arkansas, Louisiana, New Mexico, Oklahoma, Texas

http://www.epa.gov/earth1r6/6sf/bfpages/sfbfhome.htm

U.S. EPA Region 6 Brownfields Office
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REGION 7

Iowa, Kansas, Missouri, Nebraska

http://www.epa.gov/region07/Brownfieldss/index.html

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REGION 8

Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming

http://www.epa.gov/region08/land_waste/bfhome/bfhome.html

U.S. EPA Region 8 Brownfields Office
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REGION 9

Arizona, California, Hawaii, Nevada, American Samoa, Guam

http://www.epa.gov/region09/waste/brown/index.html

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REGION 10

Alaska, Idaho, Oregon, Washington

http://www.epa.gov/Region 10/

U.S. EPA Region 10 Brownfields Office
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APPENDIX B

State/Tribal Abandoned Mine Land Programs

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APPENDIX C

References

Adams, L.M., J.P. Capp, and D.W. Gillmore. 1972. Coal Mine Spoil and Refuse Bank Reclamation with Powerplant Fly Ash. In Proceedings 3rd Mineral Waste Utilization Symposium, pp. 105-111.

Adams, L.M., J.P. Capp, and E. Eisentrout. 1971. Reclamation of Acidic Coal Mine Spoils with Fly Ash. U.S. DOI, Bureau of Mines, Rept. of Investigations 7504, 28 pp.

Aljoe, W.W. and S. Renniger. 1999. U.S. Department of Energy Projects Involving the Use of Coal Combustion By-Products in Mining Applications. In Mining and Reclamation for the Next Millenium, Proceedings, 16th Annual National Meeting of the American Society of Surface Mine Reclamation, August 13-19, 1999, Volume 1, pp. 25-37.

Brooks, R.P., D.E. Samual, and J.B. Hill (eds.). 1985. Wetlands and Water Management on Mined Lands. Proceedings of Conference, Pennsylvania State University, October 23-24, 1985.

Brooks, R.P., J.B. Hill, F.J. Brenner, and S. Capets. 1985. Wildlife Use of Wetlands on Coal Surface Mines in Western Pennsylvania. In Wetlands and Water Management on Mined Lands, Proceedings of a Conference held October 23-24, 1985, The Pennsylvania State University, State College, Pennsylvania, pp. 337-352.

Brown, S., M. Sprenger, A. Maxemchuk and H. Compton. 2005. “Ecosystem function in alluvial tailings after biosolids and lime addition.” Journal of Environmental Quality. January/February, Vol.34/1.

Cavazza, E.E., R.L. Beam, and T.C. Malesky. 2003. The Dents Run Acid Mine Drainage and Ecosystem Restoration Project. In Proceedings, 2003 Annual Conference of the National Association of Abandoned Mine Land Programs, Louisville, KY., 16 p.

Comp. T. A. and M.R. Wood. 2001. Hope and Hard Work – Making a Difference in the Eastern Coal Region. DOI Office of Surface Mining and EPA Region 3. June. Available at: *www.brownfieldstsc.org/miningsites.cfm*.

Crumbling, D.M. 2004. Summary of the Triad Approach. White Paper for U.S. Environmental Protection Agency (EPA) Office of Superfund Remediation and Technology Innovation. Mail Code 5102G. March 25.

Doolan, M. 2005. Personal communication (e-mail) between Mark Doolan (EPA, Region 7) and Mike Adams (EPA) on September 9, 2005.

Earthworks. 2005. Cleaning Up Abandoned Mines. *http://www.earthworksaction.org/ewa/aml.cfm*. Downloaded March 1, 2005.

EPA (U.S. Environmental Protection Agency). 2005a. *Mine-Scarred Lands Revitalization – Models through Partnerships.* Office of Solid Waste and Emergency Response. EPA 560-R-05-003. *www.epa.gov/brownfields*. August 2005.

EPA (U.S. Environmental Protection Agency). 2005b. Cost and Performance Summary Report. In Situ Biosolids and Lime Addition at the California Gulch Superfund Site, OU 11, Leadville, Colorado. *http://www.frtr.gov/costperf.htm*. February 2005. Available at: *www.brownfieldstsc.org/miningsites.cfm*.

EPA. 2005c. Resource Conservation Challenge webpage, August 4, 2005. *http://www.epa.gov/epaoswer/osw/conserve/priorities/bene-use.htm*.

EPA 2005d. Clean Water Act Section 319 webpage, April 5, 2005. *http://www.epa.gov/owow/nps/cwact.html*.

EPA. 2005e. “Meeting Community Needs, Protecting Human Health and the Environmental, Active and Passive Recreational Opportunities at Abandoned Mine Lands.” Online Address: *http://www.epa.gov/superfund/programs/recycle/pdfs/rec_mining.pdf*.

EPA. 2004a. Brownfields Mine-Scarred Lands Initiative – Federal Agencies Collaborate with Communities. Office of Solid Waste and Emergency Response. EPA 560-F-04-252. *www.epa.gov/brownfields*. September. Available at: *www.brownfieldstsc.org/miningsites.cfm*.

EPA. 2004b. Proposal Guidelines for Brownfields Assessment, Revolving Loan Fund, and Cleanup Grants. Office of Solid Waste and Emergency Response. EPA 560-F-04-253. September 2004. *www.epa.gov/brownfields*.

EPA. 2004c. Cleaning Up the Nation’s Waste Sites: Markets and Technology Trends, 2004 Edition. EPA, Office of Solid Waste and Emergency Response, Report EPA 542-R-04-015, September 2004. *http://clu-in.org/marketstudy*.

EPA. 2004d. Reference Notebook. Abandoned Mine Lands Team. September 2004.

EPA. 2004e. About the Eagle Mine Site. U.S. EPA Region 8 webpage. December 2004. *http://www.epa.gov/region8/superfund/sites/co/eaglmine.html*.

EPA. 2003. Using the Triad Approach To Streamline Brownfields Site Assessment and Cleanup. Brownfields Technology Primer Series. EPA 542-B-03-002. June.

EPA. 2000a. Abandoned Mine Site Characterization and Cleanup Handbook. EPA Regions 8 and 9. EPA 910-B-00-001. August 2000. Available at: *www.brownfieldstsc.org/miningsites.cfm*.

EPA. 2000b. “Manual, Constructed Wetlands Treatment of Municipal Wastewaters.” EPA/625/R-99/010.

Herricks, E.E., A.J. Krzysik, R.E. Szafoni, and D.J. Tazik. 1982. Best Current Practices for Fish and Wildlife on Surface-Mined Lands in the Eastern Interior Coal Region. U.S. Fish and Wildlife Service, FWS/OBS-80/86, May 1982.

Holmes, M., EPA Region 8. 2005. Comments Provided on Draft Case Study. August 2005.

Illinois Department of Mines and Minerals, Land Reclamation Division. 1985. Citizen’s Guide to Coal Mining and Reclamation in Illinois.

ITRC (Interstate Technology Regulatory Council). 2003. Technical and Regulatory Guidance Document for Constructed Treatment Wetlands. December 2003.
Klimstra, W.D. and J.R. Nawrot. 1985. Wetlands as a Byproduct of Surface Mining: Midwest Perspective. In Wetlands and Water Management on Mined Lands, Proceedings of a Conference held October 23-24, 1985, The Pennsylvania State University, State College, PA, pp. 107-119.

Klimstra, W.D., and J.R. Nawrot. 1985. Wetlands as a Byproduct of Surface Mining: Midwest Perspective. In Wetlands and Water Management on Mined Lands, Proceedings of a Conference held October 23-24, 1985, The Pennsylvania State University, State College, Pennsylvania, pp. 107-119.

Lawrence, J.S., W.D. Klimstra, W.G. O’Leary, and G.A. Perkins. 1985. Contribution of Surface-Mined Wetlands to Selected Avifauna. In Wetlands and Water Management on Mined Lands, Proceedings of a Conference held October 23-24, 1985, The Pennsylvania State University, State College, PA, pp. 317-325.

Leedy, D.L. and T.M. Franklin. 1981. Coal Surface Mining Reclamation and Fish and Wildlife Relationships in the Eastern United States. U.S. Fish and Wildlife Service, FWS/OBS-80/24 and FWS/OBS-80/25.

Master, W.A. and J.D. Taylor. 1979. Grundy County Reclamation Demonstration Project, Phase II, Progress Report for 1977-1978. Argonne National Laboratory, Report ANL/LRP-TM-16.

McConnell, D.L. and D.E. Samual. 1985. Small Mammal and Avian Populations Utilizing Cattail Marshes on Reclaimed Surface Mines in West Virginia. In Wetlands and Water Management on Mined Lands, Proceedings of a Conference held October 23-24, 1985, The Pennsylvania State University, State College, PA, pp. 329-336.

Milavec, P.J. 2005a. Abandoned Mine Drainage Abatement Projects: Successes, Problems, and Lessons Learned. Pennsylvania Department of Environmental Protection, Bureau of Abandondoned Mine Reclamation. *http://www.dep.state.pa.us/dep/deputate/minres/bamr/amd/amd_abatement_projects.htm*.

Milavec, P.J. 2005b. Personal communication (e-mail) between Pamela Milavec (PaDEP) and Carolyn Perroni (Environmental Management Support, Inc.) on September 23, 2005.
Miorin, A.F., R.S. Klingensmith, R.E. Heizer, and J.R. Saliunas. 1979. Tioga River Mine Drainage Abatement Project. EPA-600/7-79-035, February 1979.

Mitsch, W.J., M.A. Cardamone, J.R. Taylor, and P.L. Hill. 1985. Wetlands and Water Quality Management in the Eastern Interior Coal Basin. In Wetlands and Water Management on Mined Lands, Proceedings of a Conference held October 23-24, 1985, The Pennsylvania State University, State College, PA, pp. 121-137.

OSM (U.S. Office of Surface Mining). 2003. People Potentially at Risk From Priority 1 & 2 AML Hazards. White Paper. Revised May 28, 2003.

OSM (U.S. Office of Surface Mining). 2002. Acid Mine Drainage prevention and mitigation techniques webpage. March 5, 2002 *http://www.osmre.gov/amdpvm.htm*.

PaDEP (Pennsylvania Department of Environmental Protection). 2005a. The Science of Acid Mine Drainage and Passive Treatment *http://www.dep.state.pa.us/dep/deputate/minres/bamr/amd/science_of_AMD.htm*.

PaDEP. 2005b. Welcome to the Growing Greener Program! Webpage. *http://www.dep.state.pa.us/growgreen/.*

PaDEP. 2004a. The Use of Dredged Materials in Abandoned Mine Reclamation; Final Report on the Bark Camp Demonstration Project.

PaDEP. 2004b. Mine Drainage Abatement Plan for the Bennett Branch of Sinnemahoning Creek, Interim Project Report, Clearfield, Elk and Cameron Counties, PA, September 21, 2004.

PaDEP. 1999. A Model Plan for Watershed Restoration. Developed with other state and federal agencies, January 1999. *http://www.dep.state.pa.us/dep/deputate/minres/bamr/documents/modelplan.html*.

PaDEP. 1998. Pennsylvania's Comprehensive Plan for Abandoned Mine Reclamation. Issued June 1997, Revised June 1998 *http://www.dep.state.pa.us/dep/deputate/minres/bamr/complan1.htm.*

Peterson, J.R., R.I. Pietz, and C. Lue-Hing. 1979. Water, Soil, and Crop Quality of Illinois Coal Mine Spoils Amended with Sewage Sludge. In Utilization of Municipal Effluent and Sludge on Forest and Disturbed Land (W.E. Sopper and S.N. Kerr, eds.), Penn State University Press, University Park, PA., pp. 359-368.

Pietz, R.I., T.C. Granato, J.C.R. Carlson, J. Gschwind, D.R. Zenz, and C. Lue-Hing. 1992. Reclamation of the St. David Illinois Coal Refuse Pile With Sewage Sludge and Other Amendments. In New Trends – Utilization of Recycled Materials and Waste Products in Mine Reclamation. Conference Proceedings, 14th Annual Abandoned Mined Land Conference, August 23-27, Chicago, IL, pp. 304-355.

Samual, D.E., J.R. Stauffer, C.H. Hocutt, and W.T. Mason (eds.). 1978. Surface Mining and Fish/Wildlife Needs in the Eastern United States. Proceedings of a Symposium, Morgantown, WV, U.S. Fish and Wildlife Service, Biological Services Program FWS/OBS-78/81, December 1978.

Scott, R.L. and R.M. Hays. 1975. Inactive and Abandoned Underground Mines - Water Pollution Prevention and Control. EPA-440/9-75-007.

Surbrugg, E. 2005. Personal Communication from Ed Surbrugg, Tetra Tech EMI. July 11, 2005.

Triad Resource Center Website. 2004. *http://www.triadcentral.org/index.cfm*. Accessed November 2004.

USGS (U.S. Geological Survey). 2000. The Human Factor in Mining Reclamation. U.S. Geological Survey Circular 1191. Available at: *www.brownfieldstsc.org/miningsites.cfm*.

USACE (U.S. Army Corps of Engineers). 1969. The Incidence and Formation of Mine Drainage Pollution. Appendix C of Acid Mine Drainage in Appalachia. Appalachian Regional Commission. June 1969.

Varner, John. 2005. Personal communication (phone call) between John Varner, PaDEP, and Mike Adams (EPA) on September 27, 2005.

Younger, P.L., S.A. Banwart, and R.S. Hedin. 2002. Mine Water: Hydrology, Pollution, Remediation. Kluwer Academic Publishers.

Zipper, C.E. and S. Winter. 1997. Powell River Project: Stabilizing Reclaimed Mines to Support Buildings and Development. Virginia Cooperative Extension Publication 460-130.

Additional Resources

ARC (Appalachian Regional Commission). 1969. Acid Mine Drainage in Appalachia. Report to the President of the United States and Congress, June 30, 1969.

Brown, S. and C. Henry. Not dated. Using Biosolids for Reclamation/Remediation of Disturbed Soils. White Paper. University of Washington.

Burger, J.A., and C. Zipper. 1998. How to Restore Forests on Surface-Mined Land. Virginia Cooperative Extension Service Publication No. 460-123, September 1998. *http://www.ext.vt.edu/pubs/mines/460-123/460-123.html*.
Burger, J.A., D.L. Kelting, and C. Zipper. 1998. Maximizing the Value of Forests on Reclaimed Mined Land. Virginia Cooperative Extension Service Publication No. 460-138, September 1998 [*http://www.ext.vt.edu/pubs/mines/460-138/460-138.html*].

Costello, C. NNEMS Fellow. 2003. Acid Mine Drainage: Innovative Treatment Technologies. Prepared for EPA Office of Solid Waste and Emergency Response. October. Available at: *www.brownfieldstsc.org/miningsites.cfm*.

EPA. 2005. A Breath of Fresh Air for America's Abandoned Mine Lands: Alternative Energy Provides a Second Wind. Available at:*http://permanent.access.gpo.gov/websites/epagov/www.epa.gov/superfund/programs/aml/revital*.

EPA. 2005. Meeting Community Needs, Protecting Human Health and the Environmental: Active and Passive Recreational Opportunities at Abandoned Mine Lands. Available at:*http://permanent.access.gpo.gov/websites/epagov/www.epa.gov/superfund/programs/aml/revital*.

EPA. 2004. Land Conservation and Former Mine Lands: Preserving Natural Land Resources, Planning for the Future. Fact sheet. July 2004. Available at:*http://permanent.access.gpo.gov/websites/epagov/www.epa.gov/superfund/programs/aml/revital.*

EPA. 1999. Characterization of Mine Leachates and the Development of a Ground-Water Monitoring Strategy for Mine Sites. EPA 600-R-99-007. February 1999. Available at: *www.brownfieldstsc.org/miningsites.cfm*.

EPA. 1997. A Citizen's Handbook to Address Contaminated Coal Mine Drainage. EPA Region 3. EPA 903-K-97-003. September. Available at: *www.brownfieldstsc.org/miningsites.cfm*.

EPA. 1995. EPA Office of Compliance Sector Notebook Project - Profile of the Metal Mining Industry. Office of Enforcement and Compliance Assurance. EPA/310-R-95-008. September. Available at: *www.brownfieldstsc.org/miningsites.cfm*.

Jones, D.W., M.J. McElligott, and R.H. Mannz. 1985. Biological, Chemical and Morphological Characterization of 33 Surface Mine Lakes in Illinois and Missouri. Peabody Coal Company.
Nelson, R.W., J.F. Osborn, and W.J. Logan. 1982. Planning and Management of Mine-Cut Lakes at Surface Coal Mines. U.S. Office of Surface Mining, Report OSM/TR-82/1.

Toffey, W.E. Not Dated. Philadelphia Water Department. Twenty-Five Years of Mine Reclamation with Biosolids in Pennsylvania.

Torbert, J.L., J.A. Burger, and J.E. Johnson. 1996. Commercial Forestry as a Post-Mining Land Use. Virginia Cooperative Extension Service. Publication No. 460-136. June. Available at: *http://www.ext.vt.edu/pubs/mines/460-136/460-136.html*.

Torbert, J.L., J.A. Burger, T.J. Nichols, and J.E. Johnson. 1997. Growing Christmas Trees on Reclaimed Surface-Mined Land. Virginia Cooperative Extension Service. Publication No. 460-116. March. Online Address: *http://www.ext.vt.edu/pubs/mines/460-116/460-116.html*.

NOTE: Additional reference materials related to redevelopment of mine sites are available at *www.brownfieldstsc.org/miningsites.cfm*.

APPENDIX D

Acronyms

AMD	acid mine drainage
AML	abandoned mine lands
BTSC	Brownfields and Land Revitalization Technology Support Center
BBWA	Bennetts Branch Watershed Association
CSM	conceptual site model
EPA	U.S. Environmental Protection Agency
ITRC	Interstate Technology Regulatory Council
MSL	mine-scarred land
NPL	National Priorities List
OSM	U.S. Office of Surface Mining
PaDEP	Pennsylvania Department of Environmental Protection
PCBs	polychlorinated biphenyls
PM	particulate matter
SMCRA	Surface Mining Control and Reclamation Act

Glossary

PLEASE NOTE: Use of these terms does not constitute a regulatory determination under either RCRA or CERCLA. This glossary may only be used to assist the user and should not be used for regulatory purposes.

Acid Mine Drainage (AMD): Water with a pH generally less than 4 that drains from mine workings and mine wastes. The low pH is due to the formation of acids resulting from the oxidation of sulfide minerals (e.g., pyrite) in the host rock when exposed to air and water. Due to its acidity, AMD tends to contain elevated levels of metals leached from the ore and host rock.

Acid Rock Drainage (ARD): see acid mine drainage.

Adit: A nearly horizontal passage from the surface by which a mine is entered and drained.

Alkaline: Of or relating to the capacity of water to accept protons (acidity). Substances with a pH greater than 7 are said to be alkaline.

Alluvial mining: The use of dredges or hydraulic water to extract ore from placer deposits.

Anoxic limestone drain: A type of passive treatment system consisting of a trench of buried limestone into which acid water is diverted. Dissolution of limestone increases pH and alkalinity.

Beneficiation: Physical treatment of crude ore to improve its quality for some specific purpose. Also called mineral processing. RCRA defines beneficiation as: restricted to the following activities: Crushing; grinding; washing; dissolution; crystallization; filtration; sorting; sizing; drying; sintering; pelletizing; briquetting; calcining to remove water and/or carbon dioxide; roasting, autoclaving, and/or chlorination in preparation for leaching; gravity concentration; magnetic separation; electrostatic separation; flotation; ion exchange; solvent extraction; electrowinning; precipitation; amalgamation; and heap, dump, vat, tank, and in-situ leaching. See 40 CFR 261.4 (b)7 for more information.

Bioavailability: The degree of ability of the contaminant to be absorbed by an organism and interact with its metabolism.

Cut and Fill Stoping: If it is undesirable to leave broken ore in the stope during mining operations (as in shrinkage stoping), the lower portion of the stope can be filled with waste rock and/or mill tailings. In this case, ore is removed as soon as it has been broken from overhead, and the stope filled with waste to within a few feet of the mining surface. This method eliminates or reduces the waste disposal problem associated with mining as well as preventing collapse of the ground at the surface.

Brownfields: Abandoned, idled, or under used industrial and commercial facilities/sites where expansion or redevelopment is complicated by real or perceived environmental contamination. They can be in urban, suburban, or rural areas.

Coal Refuse: The waste coal and crushed rock that results from coal processing.

Drift: A horizontal mining passage underground. A drift usually follows the ore vein, as distinguished from a crosscut, which intersects it.

Dump Leach: A process for dissolving and recovering minerals from subore-grade materials from a mine waste dump. The dump is irrigated with water, sometimes acidified, which percolates into and through the dump, and runoff from the bottom of the dump is collected and mineral in solution is recovered by a chemical reaction.

Extraction: The process of removing ore from the ground.

Gangue: The fraction of ore rejected as tailing in a separating process. It is usually the valueless portion, but may have some secondary commercial use.

Heap Leach: A process in which crushed ore is laid on a slightly sloping, impervious pad and uniformly leached by the percolation of the leach liquor trickling through the beds by gravity to ponds. The metals are recovered by conventional methods from the solution.

Highwall: The unexcavated faces of overburden and coal in a surface mine.

Lime: Calcium oxide, CaO

Limestone: A sedimentary rock formed by chemical precipitation from sea water or fresh water that is composed primarily of the mineral calcite (calcium carbonate).

Mine: An opening or excavation in the earth for the purpose of extracting minerals.

Mine-Scarred Lands: Lands, associated waters, and surrounding watersheds where extraction, beneficiation, or processing of ores and minerals (including coal) has occurred.

Mineral: A naturally occurring, solid, inorganic element or compound, with a definite composition or range of compositions, usually possessing a regular internal crystalline structure.

Ore: A natural deposit in which a valuable metallic element occurs in high enough concentration to make mining economically feasible.

Orebody: A continuous, well-defined mass of material of sufficient ore content to make extraction economically feasible.

Overburden: Material of any nature, consolidated or unconsolidated, that overlies a deposit of ore that is to be mined.

Oxyhydroxides: Chemical compounds that contain one or more cations bonded to both oxygen and hydroxide (OH) anions.

Passive treatment systems: Systems that do not require periodic or continual maintenance or upkeep to maintain system effectiveness. Examples include aerobic or anaerobic wetlands, anoxic limestone drains, open limestone channels, alkalinity producing systems, and limestone ponds.

pH: The negative logarithm of the hydrogen ion concentration, in which pH = -log [H+]. Neutral solutions have pH values of 7, acidic solutions have pH values less than 7, and alkaline solutions have pH values greater than 7.

Placer: A sedimentary deposit of unconsolidated material (usually gravel in river beds or sand dunes) containing high concentrations of a valuable mineral or native metal, usually segregated because of its greater density.

Pyrite: A brass-colored mineral, FeS_2, occurring widely and used as an iron ore and in producing sulfur dioxide for sulfuric acid; sparks readily if struck by steel; occurs in sedimentary rocks including coal seams.

Roasting: The oxidation of ore or concentrate (usually of sulfide concentrates) at an elevated temperature to obtain metal oxides. The material is not melted. Roasting is usually used to change metallic compounds into forms more easily treated by subsequent processing.

Shaft: An excavation of limited area compared with its depth, made for finding or mining ore or coal, raising ore, rock or water, hoisting and lowering men and materials, or ventilating underground workings.

Slag: A mixture of oxides (sometimes halides) of metals or nonmetals formed in the liquid state at high temperatures. A flux is usually added to encourage slag production, where the slag represents the undesirable (waste) constituents from smelting and refining an ore or concentrate.

Smelting: Obtaining a metal from an ore or concentrate by melting the material at high temperatures. Fluxes are added that, in the presence of high temperatures, reduce the metal oxide to metal resulting in a molten layer containing the heavy metal values and form a slag layer containing impurities. Smelting is usually performed in blast furnaces.

Spoil: Debris or waste rock from a mine. Also called waste rock, overburden, or gob (coal mining).

Subsidence: A slow sinking or collapsing of the ground surface into underground mine openings below.

Tailings: Rock discarded from the mining process.

Watershed: The land area that drains into a stream; the watershed for a major river may encompass a number of smaller watersheds that ultimately combine at a common point.

Wetlands: A lowland area such as a marsh or swamp that is saturated with moisture. They can be natural features of an environment or engineered impoundments.