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ABANDONED MINE SITE CHARACTERIZATION and CLEANUP HANDBOOK

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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Reply To
Attn Of: ECL-117

Handbook Users:

The Abandoned Mine Site Characterization and Cleanup Handbook (Handbook) is the result of the collective efforts and contributions of a number of individuals. During the earliest days of Handbook development, Mike Bishop of EPA Region 8 lead the effort to develop a Superfund Mine Waste Reference Document for EPA project managers working on mine site cleanup. That effort evolved into the Handbook in recognition of the many regulatory and non-regulatory mechanisms that are used today to manage the characterization and cleanup of mines sites.

Users are encouraged to consider the information presented in the Handbook against the backdrop of site specific environmental and regulatory factors. The Handbook has been developed as a source of information and ideas for project managers involved in the characterization and cleanup of inactive mine sites. It is not guidance or policy.

The list that follows acknowledges the efforts of writers, reviewers, editors, and other contributors that made development of the Handbook possible. It is always a bit risky to develop a list of contributors because it is inevitable that someone gets left out; to those we have neglected to acknowledge here we apologize.

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Disclaimer

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Introduction

NOTICE

This document provides a reference resource to EPA and other staff addressing characterization and cleanup of abandoned mine sites. The document does not, however, substitute for EPA statutes, regulations and guidance, nor is it a regulation itself. Thus it cannot impose legally-binding requirements on EPA, States, or the regulated community, and may not apply to a particular situation based on the circumstances. EPA may change this reference document in the future, as appropriate.

1.1 Introduction

The Abandoned Mine Site Characterization and Cleanup Handbook (Handbook) has been developed by the Environmental Protection Agency as a resource for project managers working on addressing the environmental concerns posed by inactive mines and mineral processing sites. **The information contained in the Handbook is not policy or guidance, rather it a compendium of information gained during many years of experience on mine site cleanup projects.** This information was developed primarily for EPA staff, but may also prove useful to others working on mine site characterization and cleanup projects, including: states, other federal agencies, tribes, local government, public interest groups, and private industry. Handbook users are encouraged to refer to appropriate agency guidance and/or policy during development of site specific mine site investigation and cleanup projects.

Earlier drafts of this document focused on the tools available for mine site cleanup under the authorities of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). However, with the recent release of EPA's National Hardrock Mining Framework, the agency has stated its preference that a broad range of regulatory and non-regulatory tools be considered in implementing inactive mine site cleanup projects. Consistent with the recognition of the need for a more flexible approach, the title Superfund Mine Waste Reference Document, has been replaced.

This handbook focuses on environmental hazards at abandoned mining sites. At many sites, however, physical hazards (e.g., open shafts or adits, unstable buildings, unstable slopes, etc.) present a safety hazard to the investigators and/or general public. These safety hazards also deserve careful consideration in developing site management strategies but are not considered in this document.

EPA's National Hardrock Mining Framework emphasizes the need for developing partnerships in addressing the environmental concerns posed by inactive mines. This manual reflects the same philosophy. Effective partnerships will assist in dealing with the difficult issues often posed by mine sites, including: extensive areas of contamination, complex land ownership patterns, liability issues, overlapping jurisdictions, and long term management considerations. Often in evaluating cleanup options at mine sites, a watershed approach to assessing environmental impacts will be required to understand the scope of potential problems and design appropriate solutions. Partnerships can facilitate the design of cleanup strategies that address multiple interests within a watershed. Collaborative efforts to set priorities for mine site cleanup, coupled with utilization of the appropriate mix of regulatory and non-regulatory tools for getting the work done, should result in successful projects.

Because this handbook was originally written for use by CERCLA program staff there are frequent references to guidance or other references developed under the auspices of Superfund. This does not suggest that CERCLA authorities are to be applied at each abandoned mine site. Rather, these references are provided to the reader as resources to be considered in developing site characterization and cleanup strategies under whatever regulatory or non-regulatory approach that is appropriate at a particular site. Experience has demonstrated that the conceptual framework utilized in the CERCLA process is effective in investigating environmental concerns and identifying appropriate cleanup actions; however users of this Handbook are encouraged to consider the information provided here in the context of site specific considerations.

1.2 Contents of Handbook

The Abandoned Mine Site Impact Characterization and Cleanup Handbook is divided into several chapters, each dealing with an issue that is important in either site investigation, cleanup, or long-term management.

Chapter 1: Introduction, this chapter, introduces the Handbook to readers.

Chapter 2: Overview of Mining and Mineral Processing Operations introduces users to the types of operations, related wastes, and waste management practices typical of mine sites and mineral processing facilities. Knowledge of the historical operations that took place on the site will aid the project manager during site scoping, site characterization, and the cleanup alternative selection process.

Chapter 3: Environmental Impacts from Mining introduces site managers to the types of impacts abandoned mining operations can have on the environment. Knowledge of these impacts will be important during site scoping, characterization, and cleanup alternative selection. This background information provides valuable insight into the contaminants that may be present, potential threats to human health and the environment, and feasibility of response actions.

Chapter 4: Setting Goals and Measuring Success outlines considerations in setting goals for mine site cleanup and in assessing the success of mine site cleanup initiatives. The chapter covers the coordination among federal and state agencies in determining the goals that need to be met and resolving conflicts between different goals in different agencies. The chapter further discusses how a site manager can “measure” the success of meeting the goals that were set for the site.

Chapter 5: Community Involvement at Mining Waste Sites provides information regarding community involvement planning for site investigation and cleanup work at mining waste sites. Community involvement planning should parallel all aspects of the site cleanup process from the onset of scoping to conclusion of site work. While the relevant public participation requirements of the statutes under which the cleanup is taking place must be met, these activities represent only a starting point for community involvement at many sites. Additional guidance on Superfund community involvement requirements and other community involvement activities can be found in *Superfund Community Involvement Handbook & Toolkit.*

Chapter 6: Scoping Studies of Mining and Mineral Processing Impact Areas provides an overview of the scoping process at abandoned mining and mineral processing sites. The first section of the chapter presents background information on the scoping process in general. The individual tasks associated with the scoping process can be found in Chapter 2 of the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA.* The remainder of the chapter addresses the problems and issues the site manager should consider when scoping an abandoned mining or mineral processing site.

Chapter 7: Sampling and Analysis of Impacted Areas outlines concepts and issues related to designing and implementing a sampling and analysis program for characterizing mining and mineral processing site waste management areas. The chapter presents general information about the sampling and analysis process. The individual tasks associated with sampling and analysis can be found in Chapters 3 and 4 of the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA.* Mining and mineral processing sites present many problems and issues that are not characteristic of other sites. The chapter presents unique characteristics of mining and mineral processing sites and briefly discuss how these characteristics can affect the sampling and analysis program. The remainder of the chapter addresses issues associated with sampling and analysis at abandoned mining and mineral processing sites.

Chapter 8: Scoping and Conducting Ecological and Human Health Risk Assessments at Superfund Mine Waste Sites discusses environmental and human health considerations in risk assessment development. While not all mine sites will require that a risk assessment be completed, the process to determine risk will be similar to the CERCLA process that is presented here. The chapter highlights some of the unique issues related to risk assessments at mine waste sites and provides some guidance to help address these issues. This chapter furnishes Remedial Project Managers (RPMs), Site Assessment Managers (SAMs), Removal Managers, and other federal and state authorities with a summary of key issues relevant to mine waste site risk assessments as well as a compilation of references to other helpful resources.

Chapter 9: Site Management Strategies discusses options that a site manager may consider for managing risk at abandoned mining and mineral processing sites. The site manager can be a state, federal, tribal or local authority, or private landowner and be managing the site under a number of regulatory or non-regulatory programs. The characterization of the site and the risk assessment are used to identify the risks at the site. While these risks can be both environmental or physical, this discussion will focus on the environmental risk. As with any remediation project, strategic planning is critical in abandoned mine characterization initiatives as well as clean-up activities.

Chapter 10: Remediation and Cleanup Options identifies remediation and cleanup options to be considered in designing and implementing inactive mine site cleanup projects. The chapter will assist the user with a basic understanding of the types and availability of cleanup technologies for typical mining and mineral processing sites.

This chapter consists of three general sections. The first discusses technologies with demonstrated effectiveness at mine sites. The second section focuses on emerging or innovative technologies. The third section addresses institutional controls. Finally the last section identifies sources of information regarding available technologies and means of accessing this information

Chapter 11: The Regulatory "Toolbox" discusses the tools available to project managers in developing strategies for an abandoned mine site cleanup. Regulation of mining activities occurs via a complex web of sometimes overlapping jurisdictions, laws, and regulations covering several environmental media. Land ownership and tenancy issues further complicate regulatory considerations. Each abandoned mine site faces a somewhat unique set of regulatory requirements, depending on statute or regulation; whether it is on State, Federal, Tribal, or private land; local regulations; and the specific environmental considerations unique to the site.

The chapter begins with a general discussion of the use of CERCLA for remediating mining and mineral processing sites, then discusses applicability; implementation; enforcement; other Superfund tools; limitations; ability to interact with other statutes, and interaction with federal facilities. Finally, this chapter will discuss tools other than CERCLA that may be used at mining sites, including non-regulatory programs and initiatives.

The appendices provide additional information and references of selected topics.

Users of the Handbook are reminded that mine site cleanup projects are conducted against a complex backdrop of federal, state, tribal, and local regulations and policies. These often change. Similarly, considerable effort is now being devoted to developing more cost effective cleanup technologies for inactive mine sites. Therefore, readers are advised to refer to sources listed in the references in conjunction with using this manual to be certain to have the most up to date information available in designing site characterization and cleanup projects. Other sources of information are Internet web pages, including those that can be reached through the EPA home page at http://www.epa.gov.

Chapter 2
Overview of Mining and Mineral Processing Operations

2. 1 *Introduction*

This chapter introduces users to the types of operations, waste streams, and waste management practices typical of historic mine sites and mineral processing facilities. Knowledge of the operating history of the site will be valuable during site scoping, site characterization, and the cleanup alternative selection process. In addition, this knowledge will assist in locating potential physical hazards, such as mine openings that may have become obscured. Knowledge of the wastes and waste management practices will provide additional insight into the potential threats to human health and the environment, as well as feasibility of response actions.

The production of minerals for economic use involves a series of physical and chemical processes. These may occur at any time from excavation of the ore that contains the metal in mineral form through production of the metal in marketable form. Users should be aware that mining terms have not been used consistently over the years. This can complicate the process of identifying site histories and operations. Some particularly noteworthy instances where this can occur are explained in the text.

The chapter is divided into sections addressing Mining (or “extraction”), Beneficiation (e. g. , milling and leaching), and Mineral Processing (e.g., smelting and refining). Each section in this chapter begins with a discussion of processes followed by a discussion of wastes generated. It is worthwhile to note that the three types of operations may or may not be co-located. For example, in many mining districts, the beneficiation plant is located at a central location to serve a number of individual mines with the concentrate being further transported to a remote smelter. In contrast, other sites, such as Bunker Hill in Northern Idaho, had the mine, concentrator, and smelter all located together. When mineral processing operations are co-located with extraction and beneficiation operations, comingling of relatively small quantities of mineral processing waste with beneficiation waste often has occurred. This is important due to the physical characteristics of the waste , as well as the applicable waste management regulations.

The definition of a mine site may be broad. EPA, in its Clean Water Act effluent limitation guidelines for discharges from mines, has defined a mine as an area of land upon or under which minerals or metal ores are extracted from natural deposits in the earth by any methods, including the total area upon which such activities occur or where such activities disturb the natural land surface. A mine, under this definition, also includes land affected by ancillary operations that disturb the natural land surface, and can include adjacent land whose use is more incidental to mining activities (e. g. , roads, workings, impoundments, dams, ventilation shafts, drainage tunnels, refuse banks, dumps, stockpiles, overburden piles, spoil banks, tailings, holes or depressions, structures, or facilities).

2. 2 *Mining*

The initial step of the mining and mineral processing operations is the actual removal of the mineral value in ore from the host rock or matrix. Minerals may be extracted from the earth using a variety of techniques (note that the term extraction also may be used within the industry to describe pyrometallurgical and metallurgical processes--that is outside this mining definition). Most extraction processes result in the removal of ore and associated rock or matrix in bulk form from the deposit, using blasting and various mechanical means to break the ore into pieces of manageable size or to separate the ore minerals from unwanted material.

In the interest of economic efficiency, the extraction process is designed to remove ore of a predetermined grade or higher, leaving behind as much of the lower grade ore and barren rock as possible. Because this ideal separation is not always possible in practice, some lower grade rock is mined while some higher grade ore is left behind. It is important to note that the term “ore” is an economic one. In general, ore is earthen material that contains minerals of sufficient value to be extracted economically. Because the value of a mineral can change rapidly and substantially, the distinction between “ore” and other mined materials (which generally contain mined values that cannot be economically extracted *at the time*) is also variable, both from mine to mine and, for any specific mine, over time.

2. 2. 1 Types of Mining Processes

Mining can be categorized as surface mining, underground mining, and *in situ* mining. Surface mining is used to excavate ores at or close to the earth's surface; included in surface mining are open pit mining, highwall or strip mining used to excavate coal or other deposits (abandoned coal mines are not addressed in this handbook), and dredging to excavate placer deposits. Underground and *in situ* mining both remove minerals from deeper deposits, the former by extracting under the surface and removing the ore and the latter by sinking injection, and extraction wells and leaching the ore in place.

Open Pit Mining. Surface mining with open pits has become the primary type of mining operation for most of the major metallic ores in the United States. It is the method of choice when the characteristics of the ore deposit (e. g. grade, size, location) make removing overburden (i. e. , host rock overlying the mineral laden ore) cost effective. At present, this is the most economical way of mining highly disseminated (i. e. , lower-grade) ores. Open pit mining involves excavation of an area of overburden and removal of 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. With the larger orebodies common to metals mining, the orebody typically is mined in benches either by drilling vertical holes from the top of the bench and blasting the ore onto the adjacent lower level or, in less resistant materials, by excavating with digging/scraping machinery without the use of explosives.

Explosives typically used in open pit mining are comprised of chemicals which, when combined, contain all the requirements for complete combustion without oxygen supply. Early explosives consisted chiefly of nitroglycerine, carbonaceous material and an oxidizing agent. These mixtures were packaged into cartridges for convenience in handling and loading into drill holes. In recent years, fertilizer-grade ammonium nitrate mixed with about six percent fuel oil was recognized as an explosive capable of being detonated with a high explosive primer. This application has spread to the point where virtually all open-pit mines use this mixture (called ANFO) for primary blasting.

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 sedimentary deposits associated with current or ancient watercourses. In some mining districts, widespread stream disturbance by placer mining or dredging may be present alongside the other disturbances from underground mining, beneficiation, and/or mineral processing. Commercial dredging has not been widely practiced in the United States in the 1990's, although placer mining is still an important industry in Alaska. Some abandoned large-scale dredge operations remain in the western United States, and in some cases the dredges are still present in the dredge ponds created as part of the operation.

Underground Mining. Underground mining has been the major method for the production of certain metals but in recent years has been increasingly less common in the United States. The mid-1990's have seen a mild resurgence of underground mining as the depths of several major open pit mines have reached their economic limit. Underground mining typically has significantly less impact on the surface environment than do surface methods. This is primarily the result of reduced surface disturbance (i.e., a smaller facility “footprint”) and the much lower quantities of non-ore materials that must be removed and disposed as waste. Large underground workings, when abandoned, have sometimes caused subsidence or caving at the surface, resulting in disturbance to structures, roads, and surface water drainages. In addition, drainage from underground mines may cause significant alteration to the quality of ground water and can affect surface water as well. Mine drainage water quality is highly dependent on the characteristics of host rock and can vary widely.

***In Situ* Solution Mining**. *In situ* mining is a method of extracting minerals from an orebody that is left in place rather than being broken up and removed. (*Ex situ* leaching operations, discussed as beneficiation in Section 2. 4, operate on the same principal but with excavated ore.) In general, a series of wells are drilled into the orebody and a solvent circulated through the formation by injection through certain wells and withdrawal through 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 is little disturbance of the surface and underground at an *in situ* operation, the effect of the operation on the groundwater quality can be significant as the chemistry of the ground water must be drastically altered by the introduced solvents and the pumping operation. Furthermore, other materials in addition to the target minerals may be dissolved with the potential for affecting the local ground water, and, depending on their mobility, surrounding areas.

Surface operations include management of barren solution (i.e., leachate prior to injection) and pregnant leachate (leachate withdrawn and containing the mineral value) in surface impoundments or, more recently, tanks.

2. 2. 2 Mining Wastes and Hazardous Materials

The largest quantity of wastes generated by extraction operations are mine water and waste rock. A third waste material, overburden, is generated at surface mines. Note that the use of the terms “mining waste" and "waste management unit" in this document do not imply that all the materials in question are solid wastes as defined by the Resource Conservation and Recovery Act (RCRA). Wastes from extraction and beneficiation continue to be excluded broadly from regulation as hazardous waste, although they are regarded as solid waste; overburden, as noted below, has an additional exclusion.

Overburden. Overburden is the surface material (i.e., topsoil and rock) removed during surface mining operations to expose the ore beneath. In recent years, mine management plans required by States and by Federal land management agencies require that topsoil be salvaged and stockpiled for use in reclamation during closure or decommissioning. Overburden is specifically exempted from being regulated as a RCRA hazardous waste when it is "returned to the mine site" (40 CFR 26l. 4(b)(3)).

Mine Water. Water entering a surface or underground mine is referred to as mine water. Sources of this water are groundwater seepage, surface water inflow, or direct precipitation. In the absence of a natural or manmade drainage, active mine operations below the water table must pump out mine water to access the orebody. Depending on the hydrogeology of the mine this can be accomplished as simply pumping the water from the mine to grouting the rock in the mine to prevent inflow to using a series of extraction wells around a mine to create a cone of depression in the ground water table, thereby reducing infiltration. At some mines enormous quantities may have to be pumped continuously from the mine during operations. Active mines may use mine water for dust control and as process water in the mill circuit; otherwise they typically discharge the flow to surface water under a National Pollutant Discharge Elimination System (NPDES) permit or similar state permit. Mine water discharge from operating mines is typically regulated and often does not have the residence time in the ore or mine needed to create highly acidic waters or waters highly-loaded with dissolved metals. However, the need to treat mine water prior to discharge is highly site specific.

When a mine closes, dewatering the mine generally ceases. Underground mines often fill; mine water may be released through openings such as adits, or through fractures and fissures that reach the surface. If present, man-made gravity drains will continue to flow. Surface mines that extend below the water table will return to that level when pumping ceases, either forming a lake in the pit or inundating and saturating fill material. Recovery of ground water to or near pre-mining levels following the cessation of pumping can take substantial amounts of time, however, and the effects resulting from ground water drawdown may continue to be felt for decades.

Water from abandoned mines may contain significant concentrations of heavy metals and total dissolved solids and may have elevated temperatures and altered pH, depending on the nature of the orebody and local geochemical conditions. These waters may become acidic over time when exposed to oxygen and, if present, pyrites or other sulfide minerals. The acidic water may also solubilize metals contained in the mine and mined materials, creating high concentrations of metals in solution. These acidic metal-laden waters may contaminate down-gradient ground-water and surface water resources. Neutral and alkaline mine waters may also contain metals in excess of water quality standards and be of significant concern to human health and the environment.

Waste Rock. Waste rock consists of non-mineralized and low-grade mineralized rock removed from, around, or within the orebody during extraction activities. The cutoff grade that differentiates low-grade waste rock from useable ore is an economic distinction and may vary over time (see above). Therefore, what may have been disposed as waste rock (or stored as “sub-ore”, “proto-ore” or “low grade ore”) in the past may be ore at another time.

Waste rock includes granular, broken rock and soils ranging in size from fine sand to large boulders, with the content of fine material largely dependent on the nature of the formation and the extraction methods employed during mining. Waste rock is typically disposed in large piles or dumps adjacent to and/or down-slope of the point of extraction; waste rock frequently can be seen in close proximity to old mine shafts and openings. These sites historically were in locations of natural drainage; surface water run-on and infiltration have caused natural leaching from the waste rock piles. Waste rock has often been used on the mine site for fill, tailings dams, or other construction purposes. Current operations frequently use engineering controls to prevent run-on (e. g. , diversion systems) or run-off (drainage systems installed during construction); retrofitting waste rock sites at abandoned mines with surface water controls is often necessary for controlling waste rock impacts at abandoned mines.

Waste rock geochemistry varies widely from mine to mine and may vary significantly at individual mines over time as differing lithologic strata are exposed and geochemical processes alter characteristics of the waste. Waste rock at metal mines will contain some concentration of the target mineral along with other metals. The mobility of any particular constituent of waste rock is highly dependent on site specific conditions, such as climate, hydrology, geochemistry of the disposal unit and its foundation, mineralogy, and particle size. Waste rock from metal mines often contains sulfitic materials as components of the host rock. The concentration of sulfide minerals and of neutralizing minerals is an important factor in the potential for waste rock to generate acid drainage.

If prone to acid generation, such uses can lead to concern about widespread contamination, acid generation, or other long-term problems. Site scoping activities often includes identifying and mapping locations where these uses occurred.

2. 3 Beneficiation: Milling

Following the initial mining step, ore is reduced in size by the crushing and/or grinding circuit, and the target mineral is concentrated by various methods. These widely varying concentration processes are collectively referred to as beneficiation. Ore dressing and milling typically refer to a specific subset of operations under beneficiation and are the focus of this section. Leaching, also considered by EPA (under the RCRA program) to be beneficiation, is discussed separately in Section 2. 4.

In general, the criteria established by EPA (under the RCRA program) describe beneficiation as activities that serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ores for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e. g. , crushing or grinding) or enlarging (e. g. , pelletizing or briquetting) particle size to facilitate processing. Generally, no chemical changes occur in the mineral value during beneficiation. (Beneficiation operations may be referred to as “processing” in the older literature and occasionally by industry today.)

2. 3. 1 Types of Beneficiation (Milling) Processes

Most ores contain the valuable metals disseminated in a matrix of less valuable rock called gangue. The purpose of ore beneficiation is the separation of valuable minerals from the gangue to yield a product that has a much higher content of the valued material. Beneficiation milling operations are functionally categorized as either comminution, in which the mined ore is crushed and ground to physically liberate the target mineral, or concentration. Concentration is the separation of the mineral values liberated by comminution from the rest of the ore. These separation steps, often conducted in series, utilize the physical differences between the valuable mineral and the host rock to achieve separation and produce a concentrate containing the valuable minerals and a tailing containing the waste material and reagents. Many physical properties, including the following, are used as the basis for separating valuable minerals from gangue: specific gravity, conductivity, magnetic permeability, affinity for certain chemicals, and solubility in a leachate (leaching is discussed in Section 2. 4). Types of processes that affect separation include gravity concentration, magnetic separation, electrostatic separation, and flotation.

Gravity Concentration. Gravity-concentration processes exploit differences in density to separate ore minerals from gangue. Selection of a particular gravity-based process for a given ore will be strongly influenced by the size to which the ore must be crushed or ground to separate values from gangue, as well as by the density difference and other factors. In general, the first two methods were historically used in the recovery of gold.

Coarse/Fine Concentration. Separation in this step involves particle density rather than size. Sluices are commonly used in this step, although jigs and screens may also be employed. The heavy minerals settle within the lining material of the sluice, while the lighter material is washed through. Most of the material that enters the sluice exits as slurry waste that is discharged to a tailings pond or undergoes further concentration. After coarse concentration, most waste material has been removed, leaving a concentrate. The concentrate may then be subjected to fine concentration methods, including jigs, spiral classifiers, shaking tables, and pinched sluices. The waste at this stage is a slurry. Amalgamation sometimes followed fine concentration.

Amalgamation. Native gold or free gold can be extracted by using liquid mercury to form an amalgam. The gold is then recovered by filtering the amalgam through a canvas cone to drain off the excess mercury. Although the amalgamation process has, in the past, been used extensively for the extraction of gold from pulverized ores and placer gravels, it has largely been superseded in recent years by cyanidation processes (i.e. leaching). The current practice of amalgamation in the United States is limited to small-scale barrel amalgamation of a relatively small quantity of high-grade, gravity-concentrated gold ore. The amalgam is then retorted to separate the gold and mercury. Historically, the methods used to obtain the amalgam allowed some of the mercury/amalgam to escape the process. Several Superfund sites (notably Carson River, see Highlight 2-1) have experienced severe mercury contamination from amalgamation.

Highlight 2-1
Carson River Mercury

The Carson River Mercury Site consists of a 50-mile stretch of the Carson River, downstream of Carson City, Nevada. The site has been contaminated by mercury used in the amalgamation of gold and silver. In the late 1800s, large amounts of mercury were used during the milling of the Comstock Lode near Virginia City. Gold mining and processing began in the late 1880's. An estimated 7,500 tons of mercury were lost during the processing. Mercury has contaminated the hundreds of tailings piles and the Carson River sediments.

Sink/Float Separation. Sink/float separation, also known as heavy media separation, uses buoyancy forces to separate the various minerals on the basis of density. The ore is fed to a tank containing a medium whose density is higher than that of the gangue and less than that of the valuable ore minerals. As a result, the gangue floats and overflows the separation chamber, and the denser values sink and are drawn off at the bottom. Media commonly used for sink/float separation in the ore milling industry are suspensions of very fine ferrosilicon or galena (PbS) particles. The float material (waste) may be used for other applications, such as aggregate, since it is already crushed.

Magnetic Separation. Magnetic separation is applied in the ore milling industry, especially the beneficiating ores of iron, columbium and tantalum, and tungsten, both for extraction of values from ore and for separation of different valuable minerals recovered from complex ores. Separation is based on differences in magnetic permeability (which, although small, is measurable for almost all materials) and is effective in handling materials not normally considered magnetic. The basic process involves transport of ore through a region of high magnetic-field gradient where the most magnetically permeable particles are attracted to a moving surface, behind which is the pole of a large electromagnet. These particles are carried out of the main stream of ore and released into a conveyance leading to further processing. Although dry separators are used for rough separations, drum separators are most often run wet on the slurry ground in the mill.

Electrostatic Separation. Electrostatic separation is used to separate minerals on the basis of their conductivity. This process is inherently dry and uses very high voltages. In a typical application, ore is charged at 20,000 to 40,000 volts, and the charged particles are dropped onto a conductive rotating drum. The conductive particles lose their attractive charge very rapidly and are thrown off and collected, while the non-conductive particles keep their charge and adhere by electrostatic attraction. They may then be removed from the drum separately.

Flotation. Flotation is a process by which the addition of chemicals to a crushed ore-water slurry causes particles of one mineral or group of minerals to adhere to air bubbles. When air is forced through the slurry, the rising bubbles carry with them the particles of the mineral(s) to be separated from the matrix. A foaming agent is added that prevents the bubbles from bursting when they reach the surface; a layer of mineral-laden foam is built up at the surface of the flotation cell and this is removed to recover the mineral.

Flotation concentration has become a mainstay of the metal ore milling industry because it is adaptable to very fine particle sizes. It also allows for high rates of recovery from slimes, which are generated in crushing and grinding and which are not generally amenable to physical processing. As a physical- chemical surface phenomenon, this process can often be made highly specific, thereby allowing production of high-grade concentrates from very low-grade ore (e. g. , more than 95 percent MoS_2 concentrate from 0. 3 percent ore). Its specificity also allows separation of different ore minerals (e. g. , CuS, PbS, and ZnS) where desired, as well as operation with minimum reagent consumption because reagent interaction typically occurs only with the particular materials to be floated or depressed.

Details of the flotation process (e. g. , exact type and dosage of reagents, fineness of grinds, number of regrinds, cleaner-flotation steps) differ at each operation where it is practiced and may often vary with time at a given mill. A complex system of reagents is generally used, including five basic types of compounds: pH conditioners (regulators, modifiers), collectors, frothers, activators, and depressants. At large-capacity mills, the total reagent usage can be high even though only small quantities are needed per ton of ore, since tens of thousands of tons of ore per day may be beneficiated. The reagents often remain in the waste water, allowing the usage to be lowered by recycling the water. The reagents in the waste water may however impact some of the other steps in the process, prohibiting the water from being recycled.

Sulfide minerals are all readily recovered by flotation using similar reagents in small doses, although reagent requirements and ease of flotation do vary throughout the class. Sulfide flotation is most often carried out at alkaline pH. Sulfide minerals of copper, lead, zinc, molybdenum, silver, nickel, and cobalt are commonly recovered by flotation. Non-sulfitic ores also may be recovered by flotation, including oxidized ores of iron, copper, manganese, the rare earths, tungsten, titanium, and columbium and tantalum. Generally, the flotation processes for oxides are more sensitive to feed-water conditions than sulfide floats; consequently, oxidized ores can run less frequently with recycled water. Flotation of these ores involves very different reagents from sulfide flotation. The reagents used include fatty acids (such as oleic acid or soap skimmings), fuel oil, and various amines as collectors, as well as compounds (such as copper sulfate, acid dichromate, and sulfur dioxide) as conditioners.

2. 3. 2 Beneficiation (Milling) Wastes and Hazardous Materials

The wastes generated by beneficiation milling operations are collectively known as tailings. Readers should also be aware that unused or discarded chemicals associated with these beneficiation operations at historic mining sites also may remain onsite and need to be managed during remediation. These could include: mercury at sites that have used amalgamation and chemicals used in flotation such as copper sulfate, various amines, and sodium cyanide.

Tailings. Tailings are the waste portions of mined material that are separated from the target mineral(s) during beneficiation. By far the larger proportion of ore mined in most industry sectors ultimately becomes tailings that must be disposed. In the gold industry, for example, only a few hundredths of an ounce of gold may be produced for every ton of dry tailings generated. Similarly, the copper industry typically mines relatively low-grade ores that contain less than a few percent of metal values; the residue becomes tailings. Thus, tailings disposal is a significant portion of the overall waste management practice at mining and milling operations.

The physical and chemical nature of tailings is a function of the ore being milled and the milling operations used to beneficiate the ore. The method of tailings disposal is largely controlled by the water content of the tailings. Generally, three types of tailings may be identified based on their water content: wet, thickened, and dry. The type of tailing is less important from a remediation perspective than from an active management perspective, although knowledge of the type of tailings may help site managers characterize the material and better understand the potential remediation alternatives.

Although the tailings have much lower concentrations of the target mineral(s) than in the mined ore, they may be a source of contamination at the site due to the presence of sulfides such as pyrite (acid generation), metals (available for mobilization in ground or surface waters), and reagents added during beneficiation. Tailings that are fine grained and managed under drier conditions are especially prone to producing dust. Sulfide tailings oxidized by weathering are potential generators of acidic runoff.

In the past, and at present in some other countries, tailings often were disposed where convenient. The tailings were discharged into rivers if flow was sufficient, held behind dams if necessary, or placed on land. In the U.S., tailings now are managed, wet or thickened, in tailings impoundments or dry in disposal piles. In addition to placement in management units, certain tailings may be slurried as backfill into underground mines.

Tailings Impoundments. Wet tailings are slurried to tailings and settling ponds, where excess liquid is evaporated or drained and the tailings allowed to dry. These impoundments may range in size from under an acre to up to a thousand acres. While the thickness (I. e. , depth or height) of these tailings impoundments may in some extreme cases be as much as 1,000 feet, the thickness most commonly ranges from ten to fifty feet.

Four main types of slurry impoundment layouts are employed: valley impoundments, ring dikes, in-pit impoundments, and specially dug pits (See Appendix A for Glossary terms). The stability of tailing dams at abandoned mines represents a remediation concern. Historic methods of tailings management included disposal into topographically low areas, often streams and wetlands. To the extent that these areas became diked incidentally by the nature of their deposition they are considered inactive impoundments for remediation planning.

Tailings Piles. Tailings may be dewatered or dried prior to disposal, thus reducing seepage volume and the area needed for an impoundment or pile. Dry tailings piles are considerably different from tailings piles created as a result of thickened tailings disposal. Dry tailings may be disposed in a variety of pile configurations, including a valley-fill (I. e. , discharged to in-fill a valley), side hill (disposed of on a side of a hill in a series of piles), and level pile deposition in lifts that are continually added.

Mine Backfilling. Slurried tailings may be disposed in underground mines as backfill to provide ground or wall support, thereby decreasing the above-ground surface disturbance and stabilizing mined-out areas. (Waste management economics may also drive deposition in underground mines.) For stability reasons, underground backfilling generally requires tailings that have a high permeability, low compressibility, and the ability to rapidly dewater (I. e. , a large sand fraction). As a result, often only the sand fraction of tailings is used as backfill. Tailings may be cycloned to separate out the coarse sand fraction for backfilling, leaving only the slimes to be disposed of in an impoundment. To increase structural competence, cement may be added to the sand fraction before backfilling. In the proper geologic setting, this practice may have significant value to remediation teams looking to fill underground mines and fissures to stop acidic mine water release while reducing tailings volume on the surface. In other cases efforts to backfill or seal the mine could increase the risk of generating AMD.

Subaqueous Disposal. Underwater disposal in a permanent body of water, such as a lake, ocean, or an engineered structure (e. g., a pit or impoundment), has been an historical management practice and is still practiced in some other countries (e. g., Canada). The potential advantage to underwater disposal is the inhibition of oxidation of sulfide minerals in tailings, thus preventing or slowing acid generation. Substantial uncertainty exists regarding other short- and long-term effects on the water body into which the tailings may be disposed. Regulations under the Clean Water Act (e. g. , the effluent limitation guidelines for mills that beneficiate base and precious metal ores) effectively prohibit subaqueous disposal of tailings in natural water bodies (i.e., any discharge to "waters of the U. S. ").

2. 4 Beneficiation: Leaching

Leaching is the process of extracting a soluble metallic compound from an ore by selectively dissolving it in a suitable solvent, such as water, sulfuric acid, or sodium cyanide solution. The target metal is then removed from the "pregnant" leach solution by one of several electrochemical or chemical means. (Note that digestion, where the ore concentrate is digested completely or significantly by a strong liquor, is not considered leaching under RCRA. The significance of this difference is that wastes from digestion are not excluded from management as hazardous waste, while wastes from leaching operations are excluded.)

Specific solvents attack only one (or, at most, a few) ore constituent(s), including the target metal or mineral. (Note that *in situ* mining is fundamentally the same leaching operation except the ore is not excavated.) Ore may be crushed or finely ground to expose the desired mineral prior to leaching. The tailings from a other beneficiation process, such as flotation, may be leached to remove additional metal. Ores that are too low in grade to justify the cost of milling may be recovered by dump or heap leaching.

2. 4. 1 Types of Processes Associated with Leaching

The leaching process consists of preleaching activities, the actual leaching operation, and the recovery of the mineral value from the pregnant leach liquor. Each of these efforts is distinct from the others and generates different types of waste streams.

Preleaching Activities. Depending on the grade of the ore and the type of leaching operation for which the ore is intended, some preprocessing may be required. Most heap and dump leach operations use ores that are not preprocessed other than by some comminution (e. g. crushing). (Note that, under RCRA, EPA has included in the definition of beneficiation the activities of roasting, autoclaving, agglomeration, and/or chlorinating in preparation for leaching; wastes from these activities currently are exempted from regulation as hazardous wastes.)

Roasting. The activity of roasting ores is discussed because particulate materials from roasting operations, known as fines, have been found to contribute to the environmental impacts at several mine sites being remediated under CERCLA. Certain ores are subjected to heating in roaster furnaces to alter the compound, to drive off impurities, and/or to reduce water content. For example, roasting is used to treating sulfide gold ore, to make it more amenable to leaching. The roasting, with sodium, of certain metals that form insoluble anionic species (e. g. , vanadium) convert the ore values to soluble sodium salts (e. g. , sodium vanadate), which, after cooling, may be leached with water.

Roasters do not use the intense heat of the smelters and refineries and the ores are not processed in a molten state with chemical changes occurring. Roasting may, however, drive off sulfur dioxide or other substances and emissions often have significant particulate content.

Autoclaving. Autoclaves use pressure and high temperature to prepare some ores for leaching activities. The autoclave is used to convert the ore to an oxide form which is more amenable to leaching. The ore is generally in a slurry form in the autoclave.

Leaching Operations. Leaching operations may be categorized both by the type of leachant used as well as the physical design of the operations.

Physical Design. Several types of leaching operations are used, typically dependant on the ore-grade, the leachant, and the target material.

Dump Leaching. Piles of low-grade ore are often placed directly on the ground, leachant added by a spray or drip system, and leachate containing the solubilized target metal collected from underneath the dump over a period of months or years. The dumps are dedicated, that is they are designed to leave the ore in place after leaching operations are complete. Dump leach operations designed to recover gold more often are being designed with a plastic liner prior to placing the ore in order to facilitate recovery of pregnant solution as well as to minimize release to the environment of the cyanide leachant.

Heap Leaching. In heap leach operations the ore is placed on lined pads in engineered lifts or piles. The pad may be constructed such that heavy machinery may be used to off load the leached ore for disposal prior to placing new ore on the pad but more commonly the heap remains in place when leaching ends. As with dump leaching the leachant may be applied by spray or portable drip units; recovery is from beneath the ore on the impermeable pad (typically designed with a slight grade and a collection system).

Tank Leaching. In vat or tank leaching the milled ore is placed in a container equipped for agitation, heating, aeration, pressurization, and/or other means of facilitating the leaching of the target mineral.

In all three cases a solution management system is required, either in surface impoundments or tanks. Some operations use ponds that were designed with a compacted earthen liner (e. g. , clay), but most copper and all gold operations use synthetic liners with leachate collection systems. Dumps often have a collection pond down-gradient from the dump; heap leach units are more likely to have a system for collecting solution directly off the pad. Tank and vat leaching operations may be completely closed systems with no ponds incorporated in the design.

Leachants. Leaching also may be characterized by the type of solution being used to leach the ore and recover the target metal.

Acid Leaching. Certain target metals are particularly receptive to leaching by acidic solutions. Copper, for example, is leached by a sulfuric acid solution.

Cyanide Leaching. Sodium cyanide has been used extensively to recover gold from low-grade ores. Continued improvements in cyanidation technology have allowed increasingly lower grade gold ores to be mined economically.

Dissolution. Water is used to separate certain water-soluble compounds, such as sodium, boron, potassium, and certain salts (some that may be formed by roasting). The compounds are dissolved, purified using basic water chemistry and filtration, then recrystallized.

Recovery Processes. The values contained in the pregnant leach solution are recovered by one or more of several methods, including the following:

Precipitation. In this process, the metals dissolved in the pregnant leachate are forced into an insoluble solid form and then filtered or settled out for recovery. Methods to cause precipitates to form may be chemically treating, evaporating, and/or changing the temperature and/or pH.

Electrowinning. The pregnant leachate may be placed in an electrolytic cell and an electric charge applied. The metal plates out of the solution on the cathode. Insoluble precipitates may settle out as a material referred to as slimes.

Carbon Adsorption. Activated carbon may be used to adsorb the metal values from the solution. The carbon is then leached to recover the adsorbed metals.

Cementation. In this method, the metal is "cemented" out of solution by replacement with less active metal. For example, when a copper leachate solution ($CuSO4$) is brought into contact with scrap iron plates, the copper replaces the iron on the scrap plates and the iron goes into solution ($FeSO4$). The copper is then removed by washing the scrap plates.

Solvent Extraction. A chemical-specific solvent may be used to selectively extract a mineral value dissolved in the pregnant leachate. This is often used in the case of copper ore leaching; a proprietary organic chemical dispersed in a kerosene dilutent is used. The copper may then be extracted from the organic base with a strong sulfuric acid which can be electrowinned.

2. 4. 2 Leaching Wastes and Hazardous Materials

Dump and Heap Leach Waste. Following leaching, the large piles of spent ore that remain are usually left in place. These leach piles vary widely in size, the largest may cover hundreds of acres, may rise to several hundred feet, and may contain tens of millions of tons of leached ore. Reusable heap leach pad operations typically have a nearby waste unit for disposal of spent ore. Alternatively, leached ore from pads may be moved to a dedicated dump for additional and long term dump leaching. Uncollected leachate from these piles is a potential source of contamination of ground water, surface water, and soil. In addition, other contaminants (notably, arsenic, mercury, and selenium, but also including many other heavy metals) that are present in the spent ore may appear in leachate over time. Acid drainage may be generated from the oxidation of sulfide ores and require control. For both dump and heap leaching, transport by wind-blown dust and/or storm-water erosion may result in physical contamination off site.

Spent Leachate. When the leach operation is decommissioned or the leachate become necessary for replacement, the spent leachate becomes a waste requiring appropriate management. Leachate in the piles may continue to be released after operations cease. For example, where gold extraction processes use cyanide to leach the metal from the host rock, the unpurged or untreated cyanide solution may be washed by rain and snowmelt into streams or ground water systems if recovery and recycling systems are not working properly.

Electrowinning Slimes and Crud. Slimes and crud result from impurities separated from the metal value in electrowinning. The slimes that settle out typically are recovered and treated to recover precious metals, such as gold and silver. Crud results from impurities that foam up in the electrolytic bath used in electrowinning; these typically are vacuumed from the cells and returned to the leach operations.

Spent Carbon. Spent carbon is the waste product remaining after the desired metals have been removed from activated carbon. The activated carbon may contain other metals and chemicals that were in the ore or used in process, including mercury or cyanide. The spent carbon is often “reactivated” in the mining process.

2. 5 Mineral Processing

Following beneficiation (i.e., leaching or milling) to concentrate the mineral value, the concentrate typically is processed to further extract and/or refine the metal, thus preparing it for its final use or for incorporation into physical or chemical manufacturing (as noted previously, mineral processing is often used within the industry to refer to any post-extraction activities, including beneficiation; EPA, at least under the RCRA program, excludes beneficiation from mineral processing). At some locations, post-mineral processing operations may occur, or have occurred, as well (note that under RCRA, EPA delineated a regulatory distinction between mineral processing and post-mineral processing, although the actual regulatory significance of this is now minimal). An example of post-mineral processing is the alloying process, in which various alloys are added to, for example, steel (i.e., a product of mineral processing) to make alloy steel (which is not a product of mineral processing). While this may not affect how a site manager approaches the remediation if the operations are co-located, it may affect the understanding of ARARS or what potential impacts from various operations may be expected.

2. 5. 1 Types of Mineral Processing Operations

There are a variety of mineral processing operations, including the following major categories: pyrometallurgical operations (e. g. , smelting, refining, roasting), hydrometallurgical operations (e. g. , digestion of phosphate in producing phosphoric acid), and electrometallurgical operations (e. g. , electrolytic refining).

Note that mineral processing may be further categorized as primary or secondary. Broadly defined, primary mineral processing is focused on processing concentrates from extraction and beneficiation of raw ores whereas secondary processing focuses on recycling metals or minerals. Primary mineral processing, such as smelting, may, and often does, incorporate into its charge mineral processing wastes (e. g. , flue dust), scrap, and/or other metals/mineral bearing materials (e. g. , sludge or residues). (Note that under RCRA, EPA requires that feedstocks be at least 50 percent extraction and beneficiation products to be considered primary; the significance focuses on certain wastes such as lead smelter slag that are exempt at primary lead smelters but regulated as potentially hazardous waste at secondary lead smelters).

Smelting. Smelting is the most common pyrometallurgical process and involves the application of heat to a charge of ore concentrate and flux in a furnace. Smelting produced separate molten streams of matte (i.e. , molten product), slag and dross, and dust, an important by-product. Historically, high-grade ore from the mine may have been smelted directly with no intermediate concentration.

Roasting. Roasting, a *relatively* low heat pyrometallurgical process, may be used to prepare ores, especially sulfide ores, for smelting (note that EPA, under the RCRA program, makes a distinction between roasting prior to leaching, which is beneficiation, and roasting prior to smelting, which is mineral processing). Roaster furnaces produce particulate matter referred to as roaster fines, as well as gaseous emissions such as sulfur dioxide. Where sulfur dioxide is generated, such as the copper smelting sector, the sulfur elements are now often captured in acid plants and saleable or useable sulfuric acid generated. In the past, sulfur dioxide emissions, as well as arsenic and other contaminants, were uncontrolled, and in some cases contaminated wide areas.

Retorting. In processing metals that are relatively volatile, retort furnaces are employed to heat the ore concentrate and vaporize the metal (e. g. , zinc, mercury, phosphorus). The vaporized metals are then condensed and recovered. The non-volatilized waste material remaining in the retort is typically referred to as slag (e. g. , zinc slag, ferrophosphorus).

Fire Refining. Fire refining is a pyrometallurgical process that typically involves heating smelted material (e. g. , blister copper) in a furnace. A flux may be added, and air then blown through the mixture to oxidize impurities. Most of the remaining sulfur and other impurities vaporize or convert to slag. Copper is fire refined with the molten copper being poured into molds to form anodes to be used in electrolytic refining if required. Refining in the lead sector, referred to as softening, generates slags with antimony, arsenic, tin, and copper oxides.

Drossing. In the lead sector, drossing follows the initial smelting. In this step, the molten lead is agitated in a drossing kettle and cooled to just above the freezing point, thereby causing metal oxides, including lead oxide and copper oxide, to solidify and float to the surface as dross. The dross, predominantly lead oxide, is treated for metals recovery. Other drossing-refining steps in the lead sector are decopperizing, where sulfur is added rather than oxygen to remove cuprous sulfide as dross, and desilverizing, where zinc is added to alloy insolubly with precious metals that float up as dross.

Electrolytic Refining. Electrolytic refining, a electrometallurgical process typically applied in the copper and zinc industry, uses an electric current in an electrolytic bath in which the metal feed is dissolved. In the copper sector, this may occur following fire-refining by using anodes of copper that dissolve with the copper reforming on the cathode. Zinc concentrates from leaching also may be refined electrometallurgically. The leachate is placed in the electrolytic cell, a current is applied, and the metal is removed on the cathode. Within the cells, impurities will either dissolve in the electrolyte but not plate on the cathode or precipitate as a material referred to in the industry as “slimes”. Cathodes are removed and melted in a furnace and the metal cast into saleable shapes.

Digestion. Digestion is a hydrometallurgical process in which the concentrate is reacted with a strong liquor (typically hot acid) and the metal value is dissolved. This pregnant liquor is then processed to purify and precipitate the metal or mineral compound. Impurities may be left behind as digester solids or precipitated out separately from the mineral value. Primary examples of digestion operations are phosphoric acid production (i.e., in which phosphate concentrate is digested with sulfuric acid to produce phosphoric acid and calcium sulfate otherwise known as phosphogypsum) or production of titanium tetrachloride.

2. 5. 2 Types of Mineral Processing Wastes and Hazardous Materials

Each of the different types of mineral processing operations generate its own specific waste streams. Note that certain are large volume wastes, and where considered to be of low hazard, continue to be excluded from regulation as hazardous under EPA’s RCRA program. Many of the mineral processing wastes that are identified below are or were recycled back to the mineral processing facilities, since they generally contain high levels of metals. Others were disposed or dispersed at the mine site and are the focus of remedial concern at many abandoned or inactive mine sites.

Slag and Dross. Slag and dross are partially fused wastes produced when impurities in metallic ores or concentrates separate from the molten metal during smelting and fire-refining processes. Slag contains the gangue minerals, such as waste minerals and non-valuable minerals, and the flux. In some sectors, the slag is processed to recover some portion that may be of value. In these cases, the portion not recovered is disposed, typically onsite, or sold for use as fill or base material where regulations allow. Historically, several sites where slag was used as road bed material have significantly impacted local environments.

Dross is the collection of impurities, typically metal oxides, that float on the molten metal in the furnace. Often, it consists of materials that can be recovered for their mineral value. Dross often was either recycled or sent on for further processing. Both dross and slag also have historically been disposed in waste piles. Current regulation, however, calls for prescribed landfill disposal if not recycled.

Spent Furnace (Refractory) Brick. This material, as its name implies, is from the furnace or refractory liner and is generated in a relatively small quantity. Smelters within some mineral processing sectors return this material to the blast furnace to recover any accumulated mineral value; otherwise, this material is placed in disposal units. At some historical sites these brick remain, creating needs for remediation.

Potliner. Potliner is a specialized form of electrolytic cell liner used in the aluminum production process. Potliners may contain toxic levels of arsenic and selenium, as well as detectable levels of cadmium, chromium, barium, lead, mercury, silver, sulfates, and cyanide. While portions of the potliners currently are now recovered and recycled, much of the material is managed as a listed hazardous waste.

Roaster Fines. Fine particulate materials may be generated by roaster furnace operation. Currently, these materials are typically recycled to the mineral processing operation as permitted under RCRA. Historically, however, roaster fines, at least at some sites, went uncollected and were dispersed downwind; in other cases they were collected and disposed in waste piles. At least one Superfund National Priority List (NPL) site has identified roaster fine impacts on the mine site.

Stack Emissions. Emissions from the smelter and refiner furnaces are, under current regulations, treated to remove regulated materials, including particulates, lead, and sulfur dioxide. In some historic operations, these stack emissions were released unaltered, resulting in the dispersal of contaminants to a wide area, especially in the predominant downwind area. Lead contamination by smelter emission has created significant contamination at several of the NPL mine sites. Today, the dusts in these emissions are collected to meet air emission standards, and the resulting air pollution control dusts are managed appropriately.

Pollution Control Sludges. With the advent of wastewater treatment and air pollution control, sludges have been generated at most mineral processing operations. In the cases of smelter operations, these sludges are typically recycled to the smelter to recover mineral value. Where this is not feasible, the sludge is disposed onsite.

Slimes from Electrolytic Refining. Slimes result from impurities that settle out of the electrolytic bath used in electrolytic refining or electrowinning. Typically, these are recovered and treated to recover precious metals, such as gold and silver.

Spent Electrolyte. Spent electrolyte (often called bleed electrolyte when it is removed in small portions rather than at one time) typically is contaminated by a variety of metals and other compounds. Today, these electrolytes are typically purified and recycled.

Process Wastewater. Various process wastewaters are and have been generated during various pyrometallurgical operations. Historically, these have been co-managed with tailings if the smelter or refinery was co-located. In other cases, discharge to surface waters or surface impoundments was the preferred approach. Today, these wastes are managed under the Clean Water Act (i.e., under the NPDES program), RCRA (e. g, surface impoundment regulation and land application), or the Safe Drinking Water Act (e. g. , discharge into injection wells).

2. 6 Additional Sources of Information

For additional comprehensive references to mineral processing and associated wastes, see the following EPA documents:

> USEPA, OSW. 12-95. Identification and Description of Mineral Processing Sectors and Waste Streams. WDC; and
>
> USEPA, OSWER. 7-90. Report to Congress on Special Wastes from Mineral Processing. EPA 530-S W-90-070C. WDC.
>
> USEPA, OSWER. 12-85. Report to Congress on Wastes from the Extraction and Beneficiation of Metallic Ores, Phosphate Rock, Asbestos, Overburden from Uranium Mining, and Oil Shale. EPA 530-SW-85-033.
>
> USEPA, OW. 11-82. Development Document for Effluent Limitations Guidelines and Standards for the Ore Mining and Dressing Point Source Category, EPA 440/1-82/061.

Chapter 3
Environmental Impacts from Mining

3.1 Introduction

This chapter introduces site managers to the types of impacts mining and mineral processing operations can have on the environment. Knowledge of these impacts will be important during site scoping, characterization, and alternative selection. This background information provides valuable insight into the contaminants that may be present, potential threats to human health and the environment, and feasibility of response actions. There are thousands of inactive and/or abandoned mine sites on federal, state, tribal and private land. While the majority of these sites are not believed to present significant environmental problems, there are, nonetheless, many sites that do create significant impacts. In addition to the impacts of individual mine sites, the cumulative impact of multiple sites within a historic mining district often has the potential to impair beneficial uses of local surface and groundwater.

Highlight 3-1
Major categories of mining impacts:

- Acid Drainage
- Metals contamination of ground/surface water and sediments
- Sedimentation
- Cyanide
- Air emissions and deposition
- Physical impacts

A variety of environmental impacts may occur at an abandoned mine site. Highlight 3.1 lists the major categories of abandoned mine site impacts. Leading the list is acid generation, which is one of the largest problems from hardrock metal mining. This chapter describes those that are specific to mine sites. Effects from process or waste management units common to non-mine sites (e.g., leaking underground storage tanks, solvent disposal from mechanical shops) or involving contaminants found at many sites (e.g., PBCs, solvents, petroleum, chemicals used in processing); are not addressed in this reference document.

The following sections describe each of these environmental impacts characteristic of mine sites requiring remediation.

3.2 Acid Drainage

The formation of acid drainage and the contaminants associated with it has been described as the largest environmental problem facing the U.S. mining industry (for additional information regarding acid drainage refer to Appendix B). Commonly referred to as acid rock drainage (ARD) or acid mine drainage (AMD), acid drainage may be generated from mine waste rock or tailings (i.e., ARD) or mine structures, such as pits and underground workings (i.e., AMD). Acid generation can occur rapidly, or it may take years or decades to appear and reach its full potential. For that reason, even a long-abandoned site can intensify in regard to its environmental impacts.

The severity of, and impacts from, AMD/ARD are primarily a function of the mineralogy of the rock material and the availability of water and oxygen. While acid may be neutralized by the receiving water, some dissolved metals may remain in solution. Dissolved metals in acid drainage may include lead, copper, silver, manganese, cadmium, iron, and zinc, among other metals. Elevated concentrations of these metals in surface water and ground water can preclude their use as drinking water or aquatic habitat.

Acid Drainage Generation. Acid is generated at mine sites when metal sulfide minerals are oxidized and sufficient water is present to mobilize the sulfur ion. Metal sulfide minerals are common constituents in the host rock associated with metal mining activity.

Prior to mining, oxidation of these minerals and the formation of sulfuric acid is a function of natural weathering processes. The oxidation of undisturbed orebodies followed by the release of acid and mobilization of metals is slow. Natural discharge from such deposits poses little threat to receiving aquatic ecosystems except in rare instances. Mining and beneficiation operations greatly increase the rate of these same chemical reactions by removing large volumes of sulfide rock material and exposing increased surface area to air and water. Materials/wastes that have the potential to generate ARD as a result of metal mining activity include mined material, such as spent ore from heap and dump leach operations, tailings, and waste rock units, as well as overburden material. AMD generation in the mines themselves occurs at the pit walls in the case of surface mining operations and in the underground workings associated with underground mines.

The potential for a mine or its associated waste to generate acid and release contaminants depends on many factors and is site-specific. These site-specific factors can be categorized as generation factors, control factors, and physical factors.

Generation Factors. Generation factors determine the ability of the material to produce acid. Water and oxygen are necessary to generate acid drainage; certain bacteria enhance acid generation. Water serves as a reactant, a medium for bacteria, and the transport medium for the oxidation products. A ready supply of atmospheric oxygen is required to drive the oxidation reaction. Oxygen is particularly important in maintaining the rapid oxidation catalyzed by bacteria at pH values below 3.5. Oxidation of sulfides is significantly reduced when the concentration of oxygen in the pore spaces of mining waste units is less than 1 or 2 percent. Different bacteria are better suited to different pH levels and physical factors (discussed below). The type of bacteria and population sizes change as growth conditions are optimized.

Chemical Control Factors. Chemical control factors determine the products of oxidation reaction. These factors include the ability of the generation rock or receiving water to either neutralize the acid (i.e., positive effect) or to change the effluent character by adding metals ions mobilized by residual acid (i.e., negative effect). Neutralization of acid by the alkalinity released when acid reacts with carbonate minerals is an important means of moderating acid production and can serve to delay the onset of acid production for long periods or even indefinitely. The most common neutralizing minerals are calcite and dolomite. Products from the oxidation reaction, such as hydrogen ions and metal ions, may also react with other non-neutralizing constituents. Possible reactions include ion exchange on clay particles, gypsum precipitation, and dissolution of other minerals. The dissolution of other minerals contributes to the contaminant load in the acid drainage. Examples of metals occurring in the dissolved form include aluminum, manganese, copper, lead, zinc, and others.

Physical Factors. Physical factors include the physical characteristics of the waste or structure, the way in which acid-generating and acid-neutralizing materials are placed, and the local hydrology. The physical nature of the material, such as particle size, permeability, and physical weathering characteristics, is important to the acid generation potential. Though difficult to weigh, each of these factors influences the potential for acid generation and is, therefore, an important consideration for long term waste management. Particle size is a fundamental concern because it affects the surface area exposed to weathering and oxidation. Surface area is inversely proportional to particle size. Very coarse grain material, as is found in waste rock dumps, exposes less surface area but may allow air and water to penetrate deeper into the unit, thereby exposing more material to oxidation and ultimately producing more acid. Air circulation in coarse material is aided by wind, changes in barometric pressure, and possibly convective gas flow caused by heat generated by the oxidation reaction. In contrast, fine-grain material (e.g., tailings) may retard air and very fine material may limit water flow; however, finer grains expose more surface area to oxidation. The relationships among particle size, surface area, and oxidation play a prominent role in acid prediction methods and in mining waste management units. As waste material weathers with time, particle size is reduced, exposing more surface area and changing physical characteristics of the waste unit. However, this will be a slower process

Highlight 3-2
Eagle Mine

Zinc and other base and precious metals were produced from ores excavated from the underground mine in central Colorado from 1878 to 1977. The resultant wastes consist of roaster piles, tailings ponds, waste rock piles and acid drainage from the mine. Percolation from the tailings ponds has contaminated ground water below and down gradient of the ponds. The ground water discharges to a nearby stream. Runoff from the roaster, waste piles and acid drainage from the mine also discharge directly to the stream. The main parameters of concern are pH, arsenic, cadmium, copper, lead, manganese, nickel, and zinc. In particular, concentrations of cadmium, copper, and zinc exceed water quality criteria in the stream. In addition, levels of dissolved solids are also above background concentrations. At least two private wells previously used for drinking water have been contaminated. The site is currently on the National Priorities List and various remedial actions have taken place.

A number of studies and publications address acid drainage. Historically, acid generation remediation efforts have centered around acid drainage from coal mines and their associated spoils. Increasingly, acid generation is being managed at hardrock mines. Active treatment (e.g., lime treatment and settling) has been successfully used and passive treatment (e.g., anoxic limestone drains) have been tried with some limited success and constant improvement.

3.3 Metal Contamination of Ground and Surface Water, and Associated Sediments

Mining operations can affect ground water quality in several ways. The most obvious occurs in mining below the water table, either in underground workings or open pits. This provides a direct conduit to aquifers. Ground water quality is also affected when waters (natural or process waters or wastewaters) infiltrate through surface materials (including overlying wastes or other material) into ground water. Contamination can also occur when there is an hydraulic connection between surface and ground water. Any of these can cause elevated pollutant levels in ground water. Further, disturbance in the ground water flow regime may affect the quantities of water available for other local uses. In addition, contaminated ground water may discharge to surface water down gradient of the mine, as contributions to base flow in a stream channel or springs.

Dissolved pollutants at a mine site are primarily metals but may include sulfates, nitrates, and radionuclides; these contaminants, once dissolved, can migrate from mining operations to local ground and surface water (contamination of surface water may also occur as contaminated soil or waste materials are eroded and washed into water bodies). These are discussed in section 3.4.). Dissolved metals may include lead, copper, silver, manganese, cadmium, iron, arsenic, and zinc. Elevated concentrations of these metals in surface water and ground water may preclude their use as drinking water. Low pH levels and high metal concentrations can have acute and chronic effects on aquatic life/biota. While AMD/ARD can enhance contaminant mobility by promoting leaching from exposed wastes and mine structures, releases can also occur under neutral pH conditions.

Dissolution of metals due to low pH is a well known characteristic of each acid drainage. Low pH is not necessary for metals to be mobilized and to contaminate waters; there is increasing concern about neutral and high pH mobilization.

Sources. Primary sources of dissolved pollutants from metal mining operations include underground and surface mine workings, overburden and waste rock piles, tailings piles and impoundments, direct discharges from conventional milling/beneficiation operations, leach piles and processing facilities, chemical storage areas (runoff and spills), and reclamation activities. Discharges of process water, mine water, storm and snowmelt runoff, and seepage are the primary transport mechanisms to surface water and ground water.

Highlight 3-3
California Gulch

The California Gulch Superfund site, located in the upper Arkansas River Valley in Lake County, Colorado, is an example of a site severely affected by metal contamination. The study area for the remedial action encompasses approximately 15 square miles and includes California Gulch, a tributary of the Arkansas River, and the City of Leadville. Mining for lead, zinc, and gold has occurred in the area since the late 1800's. The site was added to the National Priority List (NPL) in 1983. A remedial investigation (RI) conducted by EPA in 1984 indicated that the area is contaminated with metals, including cadmium, copper, lead, and zinc migrating from numerous abandoned and active mining operations. A primary source of the metals contamination in the Arkansas River is via the California Gulch. The Yak Tunnel, built to drain the local mine workings, drains into the California Gulch. Acid generated in the mine dissolves and mobilizes cadmium, copper, iron, lead, manganese, zinc, and other metals. The tunnel and its laterals and drifts collect this metal-laden acidic water and discharge it into California Gulch, the Arkansas River, and the associated shallow alluvial ground-water and sediment systems. From previous investigations and sampling data, it was concluded that, as of the early 1980's, the Yak Tunnel discharged a combined total of 210 tons per year of cadmium, lead, copper, manganese, iron, and zinc into California Gulch. Starting in 1990, one of the PRPs consented to build and operate a treatment plant for the Yak Tunnel discharge. The treatment plant operates continuously and has significantly improved water quality of the Arkansas River, into which it discharges.

Naturally occurring substances in the site area are the major source of these pollutants. Mined ore not only contains the metal being extracted but varying concentrations of a wide range of other metals (frequently, other metals may be present at much higher concentrations and can be significantly more mobile than the target mineral). Depending on the local geology, the ore (and the surrounding waste rock and overburden) can include trace levels of aluminum, arsenic, asbestos, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, selenium, and zinc.

Chemicals used in mining and beneficiation are also a potential source of water contamination. Common types of reagents include copper, zinc, chromium, cyanide, nitrate and phenolic compounds, and sulfuric acid at copper leaching operations. With the exception of leaching operations and possibly the extensive use of nitrate compounds in blasting and reclamation, the quantities of reagents used are relatively small compared to the volumes of water generated. As a result, the risks from releases of toxic pollutant from reagents not related to leaching are generally limited.

Sediment Contamination. Mining processes can result in the contamination of associated sediments in receiving streams when dissolved pollutants discharged to surface waters partition to sediments in the stream. In addition, fine grained waste materials eroded from mine sites can become sediments, as described in Section 3.4 below. Specifically, some toxic constituents (e.g., lead and mercury) associated with discharges from mining operations may be found at elevated levels in sediments, while not being detected in the water column or being detected at much lower concentrations. Sediment contamination may affect human health through the consumption of fish and other biota that bioaccumulate toxic pollutants. Elevated levels of toxic pollutants in sediments also can have direct acute and chronic impacts on macroinvertebrates and other benthic organisms. Finally, sediment contamination provides a long-term source of pollutants through potential re-dissolution in the water column. This can lead to chronic contamination of water and aquatic organisms. Currently, no national sediment standards/criteria have been established for toxic pollutants associated with mining operations. An ecological risk assessment may be an appropriate tool to evaluate sediment impacts.

3.4 Sedimentation of Surface Waters

Because of the large land area disturbed by mining operations and the large quantities of earthen materials exposed at sites, erosion is a primary concern at mine sites. Erosion may cause significant loading of sediments and any entrained chemical pollutants to nearby streams, especially during severe storm events and high snowmelt periods. Historic mining and mineral processing sites may have discharged wastes directly into surface waters. This has been particularly the case with tailings, that historically in many areas were deposited directly into surface waters or placed at the edge of surface waters where erosions would transport the tailings to the surface waters.

Erosion. Water erosion may be described as the process by which soil particles are detached, suspended, and transported from their original location. Sedimentation is the byproduct of erosion, whereby eroded particles are deposited at a different location from their origin.

The factors influencing erosion and sedimentation are interrelated and all relate to either the impact of precipitation or runoff velocity and volume. Sedimentation is considered the final stage in the erosion process; thus, the mechanisms affecting erosion also affect sedimentation. The main factors influencing erosion include rainfall/snowmelt runoff, soil infiltration rate, soil texture and structure, vegetative cover, slope length, and implementation of erosion control practices.

Sources of Loading. Major sources of erosion/sediment loadings at mining sites include open pit areas, heap and dump leach operations, waste rock and overburden piles, tailings piles, haul and access roads, ore stockpiles, exploration areas, and reclamation areas. The variability in natural site conditions (e.g., geology, vegetation, topography, climate, and proximity to and characteristics of surface waters) combined with significant differences in the quantities and characteristics of exposed materials at mines preclude any generalization of the quantities and characteristics of sediment loadings. New sources are frequently located in areas with other active operations, as well as historic abandoned mines. Other non-mining sources also may contribute to erosion impacts in the watershed. At smelter sites historic air emissions may have caused toxicity to local vegetation, increasing erosion potential in impacted areas.

Highlight 3-4
Mineral Creek and Pinto Creek

The impacts of mines on aquatic resources have been well documented. For example, a Mineral Creek fisheries and habitat survey conducted by the Arizona Game and Fish and the U.S. Fish & Wildlife Service showed that significant damage was caused by an active mining activity on the shores of Mineral Creek. In summary, the upstream control station showed an overhead cover (undercut bank, vegetation, logs, etc.) of 50% to 75%. The dominant substrate was small gravel, and in stream cover consisted of aquatic vegetation. Five species of fish were captured for a total of 309 individual fish. In contrast, the downstream station showed an overhead cover of less than 25%. The dominant substrate was small boulders, and in stream cover consisted of only interstitial spaces and very little aquatic vegetation. No species of fish were captured and very few aquatic insects were observed or captured. This Mineral Creek survey shows a significant degradation of habitat quality below the mine. Pinto Creek, which received a massive discharge of tailings and pregnant leach solution from an active copper mine, was also surveyed. The tailings had a smothering, scouring effect on the stream. Pinto Creek is gradually recovering from this devastating discharge through the import of native species from unaffected tributaries. However, the gene pool of the native fish is severely limited as only one age group of fish has repopulated Pinto Creek. A second unauthorized discharge of pollutants to the creek could eliminate that fish species.

Environmental Impacts. Particulate matter is detrimental to local fish populations. Decreased densities of macroinvertebrate and benthic invertebrate populations have been associated with increased suspended solids. Enhanced sedimentation within aquatic environments also has the effect of inhibiting spawning and the development of fish eggs and larvae, as well as smothering benthic fauna. In addition, high turbidity may impair the passage of light, which is necessary for photosynthetic activity of aquatic plants.

Contaminated Sediments. Exposed materials from mining operations, such as mine workings, wastes, and contaminated soils, may contribute sediments with chemical pollutants, including heavy metals. Contaminated sediments in surface water may pose risks to human health and the environment as a persistent source of chemicals to human and aquatic life and those non-aquatic life that consume aquatic life. Human exposure occurs through experiencing direct contact, eating fish/shellfish that have bioaccumulated toxic chemicals, or drinking water exposed to contaminated sediments. Continued bioaccumulation of toxic pollutants in aquatic species may limit their use for human consumption. Accumulation in aquatic organisms, particularly benthic species, can also cause acute and chronic toxicity to aquatic life. Finally, organic-laden solids have the effect of reducing dissolved oxygen concentration, thus creating toxic conditions.

Physical Impacts. Beyond the potential for pollutant impacts on human and aquatic life, physical impacts are associated with the sedimentation, including the filling of deep pools resulting in the loss of habitat for fish and an increase in temperature. The sedimentation can also result in the filling of downstream reservoirs reducing the capacity for both flood control and power generation. The sedimentation can also cause the channel to widen and become shallower, which may increase the frequency of overbank flow.

3.5 Cyanide

Highlight 3-5
The Summitville Mine

The Summitville Mine is an open-pit, heap-leach gold mine using cyanide beneficiation. The mine operated until 1992 when it was shut down by the company in part due to continued releases of cyanide to the environment. The largest release, caused by pump failures resulted in a cyanide laden contaminant plume that killed fish for a distance of 17 miles in the Alamosa River.

The use of cyanide has a long history in the mining industry. For decades, it has been used as a pyrite depressant in base metal flotation, a type of beneficiation process (see Section 2.3). It also has been used for more than a century in gold recovery (see Section 2.4). In the 1950's, technology advances that allowed large-scale beneficiation of gold ores using cyanide (first demonstrated in Cripple Creek, Colorado) set the stage for the enormous increase in cyanide usage when gold prices skyrocketed in the late 1970's and 1980's. Continued improvements in cyanidation technology have allowed increasingly lower grade gold ores to be mined economically using leach operations. The use of cyanide in the leaching of gold ores has an increased potential to impact the environment because of the greater quantity that is used in leaching.

Highlight 3-6
Romanian Cyanide Spill

On January 31, 2000, a tailings dam failed at the Aurul gold mine near the town of Bai Mare in Romania. The failure released approximately 3.5 million cubic feet of water contaminated with cyanide and heavy metals into the the Szamos and Tizsa Rivers in Romania, Hungary, and Yugoslavia, approximately 800kms of river, before flowing into the Danube, impacting approximately 1200 km of river. The total fish kill was estimated at over 1000 metric tons of fish.

The acute toxicity of cyanide (inhalation or ingestion of cyanide interferes with an organism's oxygen metabolism and is lethal) coupled with impacts from a number of major incidents have focused attention on the use of cyanide in the mining industry. Through the 1980's, as cyanidation operations and cyanide usage proliferated, incidents were reported in which waterfowl died when using tailings ponds or other cyanide-containing solution ponds. In addition, a number of major spills 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, causing fish kills for nearly 50 miles downstream of the operation. Regulatory authorities have responded by developing increasingly stringent regulations or non-mandatory guidelines which address the design of facilities that use cyanide (e.g., liners), operational concerns (e.g., monitoring, treatment), or closure/reclamation requirements.

Environmental Impacts. Cyanide can cause three major types of potential environmental impacts.

Free-standing Cyanide Solution. Cyanide-containing ponds and ditches can present an acute hazard to wildlife and birds. Tailings ponds may present similar hazards, although cyanide concentrations are typically much lower. Rarely in the case of abandoned mines should acute cyanide toxicity be of concern.

Release (i.e., spills) of Cyanide Solution. Spills can result in cyanide reaching surface water or ground water and causing short-term (e.g., fish kills) or long-term (e.g., contamination of drinking water) impacts. Again, because cyanide solution is not typically present at abandoned mine sites in quantities large enough to release as a spill, this type of impact is unlikely at abandoned mine sites.

Cyanide Leachate from Process or Waste units. Cyanide in active heaps and ponds and in mining wastes (e.g., heaps and dumps of spent ore, tailings impoundments) may be released and present hazards to surface water or ground water. In all but a few major cases, cyanide spills have been contained onsite, and soils have provided significant attenuation in most cases. Cyanide may also increase the potential for metals to go into solution and, therefore, be transported to other locations.

In general, cyanide is not considered a significant environmental impact concern over the long term for inactive or abandoned mines. If detoxification and reclamation are effectively performed, most residual cyanide in closed heaps and impoundments will be strongly complexed with iron. Although the stability of such complexes over long periods is not well understood, cyanide is generally considered to be much less of a long-term problem than acid generation, metals mobility, and other types of environmental impacts.

Types of Cyanide. Some basic knowledge of the different forms of cyanide is necessary to understand regulatory standards and remediation activities. Cyanide concentrations are generally measured as one of the following four forms:

Free Cyanide. Free cyanide refers to the cyanide that is present in solution as CN or HCN and includes cyanide-bonded sodium, potassium, calcium, or magnesium (free cyanide is very difficult to measure except at high concentrations and its results are often unreliable, difficult to duplicate, or inaccurate).

Weak Acid Dissociable (WAD) Cyanide. WAD cyanide is the fraction of cyanide that will volatilize to HCN in a weak acid solution at a pH of 4.5. WAD cyanide includes free cyanide, simple cyanide, and weak cyanide complexes of zinc, cadmium, silver, copper, and nickel.

Total Cyanide. Total cyanide refers to all of the cyanide present in any form, including iron, cobalt, and gold complexes.

Cyanide Amenable to Chlorination (CATC). CATC cyanide refers to the cyanide that is destroyed by chlorination. CATC is commonly used at water treatment plants.

Free cyanide is extremely toxic to most organisms, and this form has been most frequently regulated (i.e., EPA established a maximum contaminant level [MCL] under the Safe Drinking Water Act and recommended an ambient water quality criterion for protection of freshwater aquatic life under the Clean Water Act). Mining-related standards and guidelines developed more recently by states often specify WAD cyanide, largely because of the difficulty in measuring free cyanide at the low concentrations of regulatory concern. Longer term environmental concerns with cyanide, those not related to acute hazards from spills, revolve around the dissociation into toxic free cyanide of complexed cyanides in waste units and the environment. Unsaturated soils provide significant attenuation capacity for cyanide. Within a short time and distance, for example, free cyanide can volatilize to HCN if solutions are buffered by the soil to a pH roughly below 8. Adsorption, precipitation, oxidation to cyanate, and biodegradation can also attenuate free cyanide in soils under appropriate conditions. WAD cyanide behavior is similar to that of free, although WAD cyanide also can react with other metals in soils to form insoluble salts.

3.6 Air Emission and Downwind Deposition

Particulate material (PM) and gaseous emissions are emitted during mining, beneficiation, and mineral processing (refer to Chapter 2 for details about mining processes and associated waste). Gaseous emissions are generated by process operations, primarily those using heat to treat or convert ores or concentrates (e.g., roasting or smelting). Generally, particulate releases are flue dusts (e.g. from sinter, roaster, smelter, or refinery stacks) or fugitive dust (e.g. from crushers, tailings ponds, road use).

Highlight 3-7
The Bunker Hill Area

The Bunker Hill Mining and Metallurgical Complex Superfund site is an example of a mining site affected by airborne pollutants. The complex includes the Bunker Hill Mine (lead and zinc), a milling and concentration operation, a lead smelter, a silver refinery, an electrolytic zinc plant, a phosphoric acid and phosphate fertilizer plant, sulfuric acid plants, and a cadmium plant. EPA has since demolished and capped the smelter complex. The major environmental problems at the Site were caused by smelter operations and mining and milling. The smelter discharged heavy metal particulates and gases, particularly sulphur dioxide, to the atmosphere. Prior to the l970's, recovery of heavy metal particulates, such as zinc and lead, was not required from smelter stacks. Instead, tons of metal particulates were emitted directly from the stack into the atmosphere. The lead and zinc plant stacks historically used baghouses and electrostatic precipators to capture particulates for recovery of valuable metals. Because of a fire and subsequent problems with the baghouses, the plant continued to emit these particulates during the early-to-mid 1970's. Significant ecological damage has occurred in the areas surrounding the site. Soils near the smelting complex have been severely impacted by years of sulfur dioxide impact and metals deposition. The hillsides around the smelter complex were denuded of vegetation due, in part, to the smelter and mining activity. In response, 3,200 acres of hillside have been replanted since 1990.

The remediation of impacts caused by gaseous and particulate emissions from process units typically focuses on contaminated soils associated with downwind deposition. At abandoned mine sites, the processes that were the source of the emissions typically have either ceased operation or installed air pollution controls, therefore continued deposition is unlikely. Fugitive dust may still, however, be emitted from unstabilized waste management units and contaminated sites or from transportation and remediation activities.

Gaseous Emissions. Pyrometallurgical processes often generate gaseous emissions that are controlled to some extent under current regulations. In the past, these gaseous releases were typically not well controlled, and the emissions were blown downwind in the release plume. Some gaseous emissions, such as sulfur dioxide, affect the downwind environments through acid precipitation or dry deposition. Metals such as zinc, arsenic, mercury and cadmium are metals that will vaporize when heated in a pyrometallurgical process unit. In retort processing, these metals are captured as gas, then condensed, and the metal processed for use. In the absence of capture and condensation, the gaseous metals are released and condensed downwind from the release plume. Zinc released historically from smelters has had significant impacts on downwind biota as it is phytotoxic at high concentrations. Arsenic also has significant impacts downwind, primarily on faunal receptors.

Particulate Emissions. In the past, emissions from process operations, such as smelting and roasting, were not well controlled and, together with tailings deposition, caused some of the most widespread contamination. Metal smelting, in the absence of adequate air pollution controls, emitted particulates high in lead and other metal contaminants from smoke stacks that would then settle out of the air stream. Although deposition at any distance may have been at a relatively low concentration (particularly as stacks became higher), the long period of deposition (i.e., from decades in some cases to over a century in others) and the biostability of metals have created soil contamination problems of significant proportions. With the advent of air pollution regulations and subsequent air pollution controls (APC), smelter flue residues were deposited onsite in waste piles or landfills. These wastes often have high metal concentrations, high enough that, when technically feasible, the dusts may be returned to the smelter to recover the metal value.

Fugitive Dust. Fugitive dust is produced from mining operations (e.g., blasting), transportation (e.g., loading equipment, haul vehicles, conveyors), comminution (e.g., crushing and grinding), and waste management operations (i.e., waste rock dumping). Wind also entrains dust *from* dumps and spoil piles, roads, tailings, and other disturbed areas. Dust problems from tailings, in particular, may not appear until after closure/abandonment, when the waste material dries out. Only then may high levels of metals (arsenic, for example) trigger concerns. Tailings and waste rock at metal mines usually contain trace concentrations of heavy metals that may be released as fugitive dust to contaminate areas downwind as coarse particles settle out of suspension in the air. Stabilization and reclamation efforts are aimed in part at reducing fugitive dust emissions; remediation often must address the downwind soil contamination.

3.7 Physical Impacts from Mine and Waste Management Units

Mine structures and waste management units pose a unique set of problems for a site manager in planning and conducting remediations at mine sites. Structural problems with the waste units and the mines must be considered from a perspective of both ensuring the safety of remediation workers and alleviating environmental impacts that would result from structural failure and a subsequent release of contaminants.

Slope Failure. Slopes at mine sites fall into two categories: cut slopes and manufactured or filled slopes. The methods of slope formation reflect the hazards associated with each. Cut slopes are created by the removal of overburden and/or ore which results in the creation of or alteration to the surface slope of undisturbed native materials. Changes to an existing slope may create environmental problems associated with increased erosion, rapid runoff, changes in wildlife patterns and the exposure of potentially reactive natural materials. Dumping or piling of overburden, tailings, waste rock or other materials creates manufactured or filled slopes. These materials can be toxic, acid forming, or reactive. Slope failure can result in direct release or direct exposure of these materials to the surrounding environment. Saturation of waste material can also trigger slope failure.

Structural Stability of Tailings Impoundments. The most common method of tailings disposal is placement of tailings slurry in impoundments formed behind raised embankments. Modern tailings impoundments are engineered structures that serve the dual functions of permanent disposal of the tailings and conservation of water for use in the mine and mill. Today, many tailings impoundments are lined to prevent seepage, this is rarely the case at historic mine sites. In addition, modern tailings impoundments are designed to accommodate earthquake acceleration.

The historic disposal of tailings behind earthen dams and embankments raises a number of concerns related to the stability of the units. In particular, tailings impoundments are nearly always accompanied by unavoidable and often necessary seepage of mill effluent through or beneath the dam structure. Such seepage results from the uncontrolled percolation of stored water or precipitation downward through foundation materials or through the embankment. Failure to maintain hydrostatic pressure within and behind the embankment below critical levels may result in partial or complete failure of the structure, causing releases of tailings and contained mill effluent to surrounding areas. Since most modern mines recycle waste from impoundments back to the process, the cessation of this recycling at the closure/abandonment has to be accompanied by other means to maintain safe levels of hydrostatic pressure.

Structural stability depends on the physical characteristics of the waste material (e.g., percent slimes vs. sands in impoundments), the physical configuration of the waste unit, and site conditions (e.g., timing and nature of precipitation, upstream/uphill area that will provide inflows).

Subsidence. Mining subsidence is the movement of the surface resulting from the collapse of overlying strata into mine voids. The potential for subsidence exists for all forms of underground mining. Subsidence may manifest itself in the form of sinkholes or troughs. Sinkholes are usually associated with the collapse of a portion of a mine void (such as a room in room and pillar mining); the extent of the surface disturbance is usually limited in size. Troughs are formed from the subsidence of large portions of the underground void and typically occur over areas where most of the resource has been removed.

Effects of subsidence may or may not be visible from the ground surface. Sinkholes or depressions in the landscape interrupt surface water drainage patterns; ponds and streams may be drained or channels may be redirected. Farmland can be affected to the point that equipment cannot conduct surface preparation activities; irrigation systems and drainage tiles may be disrupted. In developed areas, subsidence has the potential to affect building foundations and walls, highways, and pipelines. However, metal mines are often located in remote areas where there is a lack of development, minimizing this risk. Subsidence can contribute to increased infiltration to underground mines, potentially resulting in increased AMD generation and a need for greater water treatment capacity in instances where mine drainage must be treated. Ground water flow may be interrupted as impermeable strata break down and could result in flooding of the mine voids. Impacts to ground water include changes in water quality and flow patterns (including surface water recharge).

Structures. Structures at mining and mineral processing sites can be a physical hazard for investigative and remediation workers and contain quantities of contaminates. For example, buildings at many mining and mineral processing sites were just shut down when the facility stopped production with the hope that production would be restarted. Because of this many buildings may contain both chemicals used in the process in containers that are no longer intact or quantities of material, such as flue dust or feed product that contain high concentrations of contaminates. In addition to the materials contained in the structure, the structure may be unsafe due to time, weather, and the exposures that occurred during operations, such as the heat of a smelting operations or acid spills from an acid plant.

Mine Openings. Mine openings, both horizontal and vertical, can be a significant physical hazard at an abandoned mine site. In many cases the openings are well known and are a threat to the general population, since the adventurous want to enter them and explore. These mine openings may harbor an number of physical hazards that can injure or kill those who enter, including unstable ground that could collapse or bad air, either insufficient oxygen or containing poisonous gases, such as carbon monoxide. The other physical hazard from mine openings are those that are unknown, particularly vertical shafts. If the opening has been covered, either by an old collapsed building or vegetation, they may pose the threat of falling, sometimes hundreds of feet, to individuals or wildlife who may get to close to the obscured opening.

3.8 Sources of Additional Information

To more fully understand the broad environmental impacts found at mining and mineral processing sites that are on the NPL see Appendix C - Mining Sites on the NPL. Appendix B provides further discussion of acid rock discharge (ARD) and acid mine discharge (AMD) including an annotated bibliography.

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Chapter 4
Setting Goals and Measuring Success

4.1 Introduction

This chapter outlines considerations in setting goals for mine site cleanup and in assessing the success of mine site cleanup initiatives. It covers the coordination between federal and state agencies in determining the goals that need to be met and resolving conflicts between different goals in different agencies. The chapter further discusses how a site manager can "measure" the success of meeting the goals that were set for the site.

4.2 National and Regional Goals.

Mining activities have been an integral part of the economy and culture of our nation since the mid-1800's. Mining and mineral beneficiation operations continue today at numerous locations, largely under the auspices and environmental control of State regulatory agencies and the purview of federal land managing agencies (EPA National Hardrock Mining Framework, 1997). The largest mining-associated environmental response task faced by governmental agencies today involves the tens of thousands of abandoned mine sites which stem from the intense mining and industrial development activities that occurred largely between the 1860's and post-World War II. Since the early 1970's a broad mix of EPA, state and federal natural resource and land managing agencies have been involved in addressing threats to human health and the environment at a variety of sites where hardrock mining, milling and smelting activities have occurred.

Under the auspices of the Superfund program, states and EPA began to address a number of the largest and most environmentally serious sites (e.g., Bunker Hill, ID; Butte-Silver Bow Creek, MT; California Gulch-Leadville, CO; Iron Mountain, CA). Many of these sites were slated for cleanup because the presence of toxic levels of heavy-metal residues generated by mining and industrial operations were a health threat, not only to significant population centers, but were also severely impacting the surrounding watersheds and drainages where cold-water fishery resources are highly valued aspects of recreation and tourism.

In addition to the NPL-site activities over the past one and a half decades, site assessment and inventorying efforts by states, federal land managing agencies and the EPA continue to identify abandoned mine sites and features consisting of smaller smelter and milling operations, draining mine adits, impounded and alluvial tailings, waste rock piles, and related contaminated stream reaches. Comprehensive information has not yet been compiled to completely ascertain the nature and extent of the environmental problems posed by abandoned mine sites, but information is being assembled and reviewed by involved agencies and impact indicators are emerging. Historical databases such as the Minerals Availability System and Mining Industry Locator System compiled by the former U.S. Bureau of Mines, now maintained by the U.S. Geological Survey, as well as water quality assessment reports conducted by states under the Clean Water Act indicate the presence of more than 200,000 abandoned mine sites located within hundreds of watersheds affecting hundreds of miles of streams and fisheries throughout the western U.S. While comprehensive qualitative and quantitative abandoned mine sites site data and impact information is not yet available, experienced professionals estimate, based on inventory efforts, remediation studies, cleanup activities and experience to date, that less than ten percent (10%) of the sites that were actively mined are expected to cause significant adverse impacts to riparian zones and aquatic habitats of receiving streams. Determining which sites are the significant sources of metal-leachates and understanding the range of impacts, as well as judging the relative priority, need and basis for response activity, will be an important aspect of goal-setting for abandoned mine site work at state and local levels.

Under a variety of land management and environmental protection statutes at the federal level, the U.S. Department of the Interior (through the Bureau of Land Management, the Bureau of Indian Affairs, the Fish and Wildlife Service, and the Geological Survey), the U.S. Department of Agriculture (through the Forest Service, and the Natural Resource Conservation Service), the Environmental Protection Agency, and the U.S. Army Corps of Engineers have significant responsibilities in coordinating and implementing the activities necessary to accomplish environmental response to the abandoned mine site problem across the country. States also play a major role in managing releases from abandoned mine sites through implementation of federally delegated programs or specific state authorities. The programs and budgets these federal agencies bring to bear on the abandoned mine site activities will largely occur through the regional, state and local offices and staffs of the agencies. This will enable and assure that as environmental response planning and remediation projects occur, they are done in close collaboration with state and local governments, and meet the goals and needs of the states and local areas.

4.3 State and Local Goals

While the Environmental Protection Agency, the Department of Interior, and the Department of Agriculture work to coordinate their respective efforts, dialogue with state natural resource agencies and local governments needs to be constantly focused on projects which provide the earliest and most tangible environmental benefits to ecosystems and communities. Under the auspices of EPA's National Hardrock Mining Framework policies, EPA regional offices will be participating in discussions between federal, state and local governments to understand the needs, priorities and objectives of abandoned mine sites activities within states and at particular localities and watersheds. These discussions will focus attention on short-term and long-term needs for addressing human-health and ecosystem issues, including adverse impacts to:

- Homesite and municipal water supplies,
- Aquatic resources and improvements,
- Recreational uses and improvements,
- Agricultural water users,
- Industrial water users,
- Residences,
- Workers, and
- Wildlife.

4.3.1 Human Health Impacts

Completion of the current NPL-listed sites will have addressed the most serious human health threats at population centers. However, rising populations and urbanization (both residential and commercial) underway throughout the western U.S. brings new concerns about mine waste exposures to new residents, workers, and recreational users as land redevelopment occurs. States and local governments are becoming increasingly concerned about human health impacts derived from locally-impacted headwater aquifers which are being utilized as well-water sources for mountain homesites, metal-contaminated surface waters which serve as municipal water supplies for larger population centers, new development of commercial/industrial sites, as well as the increased frequency of direct exposures to metal-laden mining residues as people use these sites and watersheds during recreational activities.

4.3.2 Environmental Impacts

As mentioned above, much of the concern with abandoned mine sites impacts are related to recreation and fishery resources and downstream agricultural activities. Abandoned mine sites studies and response actions can occur in the context of drainage basins and watersheds, beginning in the uppermost and often alpine headwaters, extending through lower reaches of valley floodplains, and continuing down into mainstem river drainages where agricultural lands and municipal-industrial users occur. Water quality standards which have been developed by states are the initial targets for meeting clean water objectives; however, in some cases protecting human health and meeting environmental improvement goals can mean going beyond established standards. The process of making these decisions requires considerable input and can result in a very dynamic and sometimes contentious debate and dialogue between a variety of resource users and stakeholders. The values and choices of each of these stakeholders is a very important and necessary part of the goal-setting and decision-making process as determinations regarding the merits, cost-effectiveness and implementing of studies and remediation are made.

4.3.3 Getting it Done

An excellent publication is available to support goal-setting efforts, entitled “Watershed Partnerships: A Strategic Guide for Local Conservation Efforts in the West,” prepared for the Western Governors Association, 1997. The report states:

> Watersheds serve as a useful unit of focus for a number of reasons. They can be aggregated to include large streams and even major rivers or separated into small, local areas. A watershed is a natural integrator of issues, values, and concerns which are clear to see as the stream flows along its course. It exhibits clear evidence of consequences.
>
> Watersheds are a good starting point for people to understand the relationship of people and natural resources in a management system. The current institutional boundaries are generally mismatched to the hydrologic, ecologic, geographic, and economic scope of natural resource problems and the affected communities and interests. Watershed partnerships can help match societal interests to the resource base. Over time, watersheds enhance participants’ shared knowledge to increase the collective competence for anticipated and responding to changes in resource goals... By working together, everyone with an interest in the watershed can solve problems, ensuring healthy land and water. Typically, partners represent wide interests: local communities, various groups, and government agencies.

The report was developed to serve existing as well as new and emerging partnerships. The report includes “collective wisdom from those who have pioneered watershed partnership concepts” and addresses areas of interest in the following sections:

- Foundations for Getting Started,
- How to organize
- What to Think About -- Sooner or Later
- External Factors

4.3.4 Values and Choices

Indirectly, processes for decision-making about what abandoned mine site work to address already have been underway for some time. Under the Clean Water Act (CWA), state water quality regulatory programs have established stream classifications and use attainability designations for most waterways. Accompanying these stream use and classifications are water quality standards that establish the goals and requirements for contaminant concentrations. The CWA also requires the development of Total Maximum Daily Load (TMDL) calculations to meet water quality standards where ongoing impairments are occurring. Similar regulatory procedures and standards exist for air, soil, and groundwater contamination. At NPL sites where CERCLA responses are occurring, not only do projects strive to meet the above regulatory standards (referred to as Applicable or Relevant and Appropriate Requirements, or ARARs), but also site-specific data is used in risk assessments to formulate risk estimates. Subsequent cleanup and remediation decisions are based on selected levels of human health and environmental risk reduction. Whether associated with CERCLA actions or other regulatory and non-regulatory activities occurring in watersheds, agencies and programs undertake a process of reassessing and modifying existing environmental standards.

Modifications to the above “regulatory processes” take considerable effort and are time-consuming. While these regulatory processes will need to be engaged to varying degrees, these are probably not the most efficient or productive forums through which Federal and State agencies and local governments should work to make the strategic environmental response priorities and decisions for the universe of abandoned mine sites at watershed and drainage-basin levels.

As mentioned earlier, collaborative watershed partnerships are more likely to be an effective sounding board for determining the values and choices which will focus abandoned mine site efforts. Closely related to the WGA watershed partnership strategy mentioned earlier, EPA strives to accomplish its efforts through a “Data Quality Objectives Process.” The data quality objectives (DQO) process is a systematic planning effort for ensuring that environmental data will be adequate for their intended use. This process is key to abandoned mine site work in order to integrate the desired goals and objectives with information appropriate for the necessary decisions, and lastly the ability to measure success towards established goals. These discussions and activities will provide an adequate foundation for planning and making defensible abandoned mine site project decisions, and will also provide a basis for measuring success.

4.4 Measuring Success

Much has been said above about establishing national, regional, state, tribal and local goals. The planning and communication described above establish a basis for determining degrees of progress towards the stated goals and a means to identify techniques that will be used to know when the objectives have been met. These results and value-added measurements can include a variety of discrete indicators, including:

- Number of sites or acres that have been addressed,
- How many sources or volume of contaminated media have been remediated,
- Water quality measurements,
- Biological or aquatic toxicological indicators, and
- Budget or schedule compliance.

4.5 Sources of Additional Information

For additional information on setting goals and measuring success at mining and mineral processing sites, see the following documents:

- USEPA, OSW. 9-97. EPA's National Hardrock Mining Framework. EPA 833-B-97-003
- Western Governors' Association. 2-97. Watershed Partnerships: a Strategic Guide for Local Conservation Efforts in the West
- Western Governors' Association. 1998. Abandoned Mine Cleanup in the West: A Partnership Report (1998)

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Chapter 5
Community Involvement

5.1 Introduction

The purpose of this chapter is to discuss community involvement planning for restoration and cleanup work at mine waste sites. Community involvement planning should parallel all aspects of the site cleanup process from the onset of scoping to conclusion of site work. While the relevant public participation requirements of the statutes under which the cleanup is taking place must be met, these activities represent only a starting point for community involvement at many sites. Additional guidance on Superfund community involvement requirements and other community involvement activities can be found in the *Superfund Community Involvement Handbook & Toolkit*[1]. This chapter presents the role of community involvement based on a Superfund site, however the information and issues presented here are also relevant at a non-Superfund mining site.

5.2 Considerations for Community Involvement at Mine Waste Sites

While every community is unique, there are circumstances at many mine waste sites that may require special consideration when planning community involvement. This section will discuss these considerations and suggest community involvement approaches for them.

5.2.1 Community Values and Culture

It is important for the site team to learn about the communities that will be affected by the site cleanup since the values and unique culture of each community impact how area residents react to cleanup efforts. Residents in many communities located near mine waste sites either are currently mining as an occupation or have ties to mining. They are proud of their mining heritage. They may view mine wastes not as eyesores or sources of risk, but as signs of economic vitality--a reminder of the "good old days". Relics of mining--tailings piles and ponds, waste rock piles, cribbing, drainage tunnels–are considered valuable historical features.

Residents in mining communities, like the residents in many other communities, are reluctant to trust agencies and individuals that they are unfamiliar with. It is important to establish contact with local government and community groups as early as possible and to maintain clear and candid communications.

Highlight 5-1
Butte and Walkerville

The Butte Area portion of the Silver Bow Creek/Butte Area site was added to the NPL in 1987. The people of Butte were extremely unhappy about Butte and Walkerville being listed on the NPL. One of the residents' main concerns was that EPA would conduct years of study and they would see no action. Residents believe that EPA comes into a community and states that there are potential health concerns posed by the presence of heavy metals in residential areas and then studies the site for several years. The people of the community, especially parents, are thrown into denial and angry stages of the "grieving" process. However, as EPA conducts the studies and remediation, particularly expedited response actions, the communities concerns are reduced and they begin to cooperate with the Agency and a partnership between the Agency and the residents can develop.

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[1] U.S. Environmental Protection Agency (EPA), December 1998. *Superfund Community Involvement Handbook and Toolkit.* Washington, D.C. Office of Emergency and Remedial Response.

Community Involvement Tips:

These tips presented in this chapter are important to all communities, whether or not the site is a Superfund site. Following these tips will help alleviate the community's concerns about any economic impacts.

Know and Respect the Community. There is no substitute for knowing the community. Rather than taking an inflexible stance that will increase public alienation, the team should focus on joint problem-solving with the community. Spend time in the community so residents get to know team members. Interview residents. Identify the formal and informal opinion-shapers in the community and pay special attention to them. Appreciate the community's heritage. Recognize the mining industry's importance to the community and the nation. One RPM said, "I have memorized the names of all the local mines and read books about local mining history. I've learned the lingo and even joined 'Women in Mining'."

Establish an Ongoing, Accessible EPA Presence. Because these sites frequently are located in areas distant from the EPA regional office, serious consideration should be given to providing for an ongoing EPA presence in the community. At some sites EPA has staffed an office so that it is easily accessible to area residents.

Maintain Ongoing Communication. While no amount of good communication can make up for poor technical decisions and project management, communication can prevent misunderstandings and build credibility when the technical and management decisions are sound. Early, accurate, balanced, and frequent two-way communication should be planned. The site team can benefit from the good will and credibility generated by frequent contact, by the same site manager and other team members, with the community groups, task forces, and individual residents. Generally, one-to-one and small group discussions work best in small mining communities. While it is vital to work with local elected officials, it is also important to identify and communicate through the community's informal networks using unofficial community caretakers and opinion-makers. It takes time to identify the networks and the caretakers that are at their hub, but communicating through these sources is often more effective than through more formal efforts.

Pay Special Attention to Historic Preservation Concerns. Involve the community from the onset in designing the historic preservation plan. Encourage them to participate in historic resource surveys and to prioritize the historic resources identified. Tailor cleanup plans, to the extent possible, to preserving priority historic resources.

Empower the Community; Use Local Expertise. In most communities there is a vast untapped resource of knowledge. Former miners know a great deal about the geology, hydrology and historic mining practices in the area. Staff can profit from this expertise and should encourage the local community to take advantage of its own experts. At some sites, local representatives help agency staff design and implement sampling and monitoring plans.

Involve the Community in Planning and Implementing the Cleanup. At NPL listed sites, encourage residents to apply for a Technical Assistance Grant (TAG). At non-Superfund sites, stakeholder groups might apply for grants like the Regional Geographic Initiative to help fund community-based participation. Technical Outreach Services for Communities (TOSC) is also available for non-Superfund sites. Some communities form Community Advisory Groups (CAG) that take an active role in deciding whether and how wastes in the area should be addressed. It is important that EPA demonstrate its willingness to share control with local groups and be responsive to recommendations from these groups. This is the heart of community-based environmental decision-making. At many sites, staff meet regularly with stakeholder groups that include representatives from the community, PRPs, state, EPA and other stakeholders to discuss site plans and reach informal consensus on them.

Conduct a Demonstration Project. The team should consider a demonstration project in cases where the EPA is proposing soil remediation in residential areas. Residential cleanups are intrusive. Lawns are torn up, trees are leveled, and prized flowers and gardens are uprooted. Property owners' fears about the disruptive nature of the project sometimes are even greater than the reality. They worry about the dust, mud, noise, and mess that the construction will create. They fear that the end result will be a barren yard. Often a small scale demonstration can calm some of these fears. Such a trial run may also result in lessons that can be applied to the full scale cleanup.

Encourage Neighbors to Mentor Neighbors. As residential soil cleanups progress, encourage residents whose properties have been cleaned up to serve as mentors to homeowners whose properties are slated for remediation.

5.3 Risk Perception

At some sites the perceived contradiction between EPA's assessment of a site's potential risk and health tests, like blood lead tests, causes area residents to be skeptical of EPA's contention that mining and mineral processing sites pose a threat to human health. These wastes are familiar, they have been around for years and, in some cases, there is no visible evidence of negative health effects in the community. Yet, EPA risk assessments indicate the wastes pose a *potential* threat. The use of a computer model instead of blood lead tests for determining the need for remediation is unacceptable to some communities. Residents contend that EPA refuses to consider real concrete evidence and, instead, focuses on theoretical abstractions based on assumptions and uncertainty. Sometimes citizens argue that the proposed cleanup will pose more of a health threat than leaving the soil or wastes undisturbed.

Community Involvement Tips:

Use Skilled Risk Communicators. Good risk communication is especially important at mining sites. Site staff should be trained risk communicators.

Provide Early Metals-Awareness Education. It is important to inform citizens of precautions to take in order to reduce exposure to metals, particularly if it will be many years before a cleanup takes place. It is necessary to take measures to protect the public health and to demonstrate the agency's commitment to reducing health risks for the local community. Providing metals-awareness education to local health professionals, educators, day care providers and parents will both help reduce exposure and remind citizens that mine wastes may be a potential threat to health. Educational efforts may include workshops, seminars for college credit, parent-teacher meetings, distribution of flyers to parents and coloring books to children. At one site, a day-care facility teacher developed a song about being safe around lead and taught it to the children.

Work with Local Health Officials. EPA should encourage local health departments, health professionals, and educators to take the lead in educating the community about site risks. In fact, EPA should collaborate wherever possible with local and state environmental officials. EPA can assist the effort by providing both general and site-specific information. However, it is best if local health professionals actually design the program and disseminate the information.

Reduce Immediate Risks. Because the Superfund process can take a long time at large and complicated sites, the time between identification of risk and actual cleanup may be several years. To deal with the perception that the risk is not real because EPA is slow to begin action and to reduce immediate health threats, the team should consider some interim actions such as removals, interim remedial actions, or other expedited cleanups to show tangible results. Removals have been very effectively used at some of the large mining sites in Montana and Idaho.

Involve the Community in Assessing Site Risks. Local residents should help design risk assessments--especially exposure scenarios. They know how their lives might bring them in contact with mine wastes. Local land use plans may help predict future uses of property where mine wastes are located. Exposure scenarios must reflect reality or the community will reject the conclusions of the risk assessment. If health studies have been conducted in the community, relate them to the risk assessment. There are many communication tools that may help explain how risk assessments work including workshops, fact sheets, and presentations to TAG or TOSC groups or CAGs.

5.4 Liability

Fear of liability under the Clean Water Act may prevent stakeholders who are not legally responsible for cleaning up an abandoned mine waste site including governmental entities ("Good Samaritans") from volunteering to participate in discussions or undertake cleanup activities that will provide incremental improvements in water quality. They fear that if their cleanup actions do not result in water quality that meets Clean Water Act standards, they will be held liable. While there is not a legislative remedy for this concern today, the Western Governors' Association is working with Congress on amendments to the Clean Water Act that will address the concern.

There may be Superfund liability concerns at mining and mineral processing sites. The law holds those who generated the wastes potentially liable for cleanup costs. At mining and mineral processing sites, however, many of the generators of historic wastes cannot be located. EPA may pursue mining companies that operated the mine in the past as well as the mining company that currently operates the mine, that may be a major employer in the area, for cleanup costs. This may not seem fair to local residents.

The uncertainty of who will be responsible for cleanup costs weighs heavily on communities. Because entire communities may be within the site boundaries, owners of small businesses and small mining claims may fall within the broad Superfund definition of PRP because they are the current owners of contaminated property. Local governments may own contaminated land or, as is the case at some sites, may have moved or used mining and mineral processing wastes, thus incurring potential liability.

Homeowners may fear that they will be liable for the costs of cleaning up contaminated soils on their property or ground water under it. Lenders may be reluctant to make loans for fear that if they foreclose and take over the property, they will be responsible for cleaning it up. It is prudent to address these concerns up-front.

Community Involvement Tips:

Resolve Liability Quickly. It helps if EPA can resolve the liability question early. Settle as soon as possible with small waste contributors. Let small mining claim owners and owners of contaminated property who did not cause the contamination know where they stand at the onset. The use of prospective purchaser agreements should be considered so that economic activity can continue.

Address Property Concerns. It is important that project staff be sensitive to the community's liability concerns and take steps to respond quickly to clarify liability issues as they arise. Information should be provided to local realtors and lenders describing the cleanup process, lender responsibilities and protections, and EPA's ground-water and residential property owner policies. Staff will need to work with the lending and real estate community at each site to identify the best ways to address concerns about property values and liability. The team may want to consider workshops and/or clearly written fact sheets to explain liability issues, precautions to take before proceeding with property transactions, and options for dealing with contaminated property in property transactions. At some sites, EPA has used 'comfort letters' to ease liability concerns.

5.5 Economic Impacts

Superfund frequently is viewed as a threat to the community's economic well-being. If EPA has named a major employer as a PRP, this contributes to economic concerns. Citizens fear that the additional burden of Superfund may force the company out of business. Current mining and mineral processing activities may, in fact, be hindered. Companies may be reluctant to acquire mining claims and initiate new mining and reprocessing ventures because of the fear of liability.

Highlight 5-2
Silver Mountain Ski Area

The community of Kellogg, ID, wanted to develop a gondola base for the Silver Mountain Ski area within the boundaries of the Bunker Hill Superfund site. The community was concerned about any future liabilities they may incur because of their economic development action for the ski area. EPA negotiated a prospective purchaser agreement with the community that limited their liability and helped facilitate economic development with the Superfund site.

Many mining and mineral processing sites are abandoned facilities which have been dormant for years. The attention Superfund brings to them may cause both perceived and real economic concerns to a currently thriving community. The perceived stigma may stifle economic growth in a number of ways. Contaminated property may not be desirable for further business development. Banks may be reluctant to lend money for development of such properties because of liability concerns. Federal home mortgage and lending agencies such as the Department of Housing and Urban Development (HUD) and Fannie Mae also may be cautious making loans on contaminated property, contributing to a drop in property values. Proposed cleanup actions may threaten the historic mining features of the area, thus jeopardizing efforts to encourage tourism, a fledgling industry in mining areas. These economic concerns sometimes outweigh EPA's claim that the ultimate remediation of contamination will result in economic benefit to the community in the future by improving property values and eliminating threats to waterways and other scenic areas.

Economic concerns can easily become the focus of a great deal of tension between site remediation teams and the local community. Recognizing and attempting to address economic concerns can be crucial to carrying out remedial activities. In many communities the concerns identified above have been addressed by EPA and communities have been able to function normally, notwithstanding Superfund concerns, but it takes work and commitment by EPA and the local community.

Community Involvement Tips:

Use Local Businesses Where Possible. EPA can help local workers get the OSHA 40-hour Health and Safety at Hazardous Waste Sites training and can show local businesses how to bid on Superfund contracts if they are not already familiar with the procedure. At some sites proposed work has been divided up into smaller contracts so that local business can bid competitively on the work.

Explore Partial Deletions from the National Priorities List (NPL). EPA policy allows sites, or portions of sites that meet the standard provided in the NCP (i.e., no further response is appropriate), to be the subject of entire or partial deletion from the NPL (60 FR 55466). A portion of a site to be deleted may be a defined geographic unit of the site, perhaps as small as a residential unit, or may be a specific medium at the site such as ground water, depending on the nature or extent of the release(s). To reduce the site-wide Superfund "stigma," properties within the Superfund site that are known to be free of contamination should be publicly identified.

Resolve Land Use Issues. EPA's Brownfield's Initiative provides mechanisms for removing some of the barriers to economic redevelopment. EPA staff should work with the community to address and resolve future land use issues as early as possible so that cleanup plans can be tailored to the projected future land use.[2] Prospective purchaser agreements may be beneficial both to those who are interested in redeveloping the property and to EPA.[3]

Establish a Process for Responding Realtors and Lenders. Identify a contact person who will respond to inquiries from realtors and lenders about specific properties. Whenever possible, provide comfort letters to property owners whose property has been cleaned up or will not require remediation. Negotiate prospective purchaser agreements with buyers who are willing to undertake cleanup work. These activities take time but the return in community good will is worth it.

5.6 Fiscal Impacts on Local Government

A cleanup may put special strains on the budget of local government. Reduced assessed property valuations lead to decreased property taxes and reduced local government revenues, while cleanup activities may necessitate the expenditure of local dollars for such things as street repairs, street cleaning, and institutional controls. Institutional controls such as land use restrictions are frequently a component of remedies at mining and mineral processing sites. These restrictions may affect the marketability of local properties. Institutional controls may also place limits on excavations, require maintenance of grass cover, etc. Such land use restrictions require long-term public education. Local governments may balk at being responsible for this long-term outreach.

Community Involvement Tips:

Set Up a Trust Fund. At some sites, EPA has required the company responsible for the cleanup to establish a trust fund for long-term monitoring and outreach. At other sites, the agencies have helped establish trust funds to aid the local government.

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[2] See OSWER Directive 9355.7-04, May, 1995. *"Land Use in the CERCLA Remedy Selection Process."*

[3] U. S. Environmental Protection Agency (EPA), June, 1989. *Guidance on Landowner Liability Under Section 107(a)(1) of CERCLA, De Minimis Settlements Under Section 122(g)(l)(b) of CERCLA, and Settlements with Prospective Purchasers of Contaminated Properties.*

Identify Opportunities for Cleanup to Benefit Local Government. At some sites, agency-generated Geographic Information Systems (GIS) data can also provide maps and other information that local government can use for land use planning and property assessment purposes. Aerial surveys used for cleanup planning have also been useful to local governments and other stakeholders for purposes unrelated to the cleanup. At one site where the cleanup called for capping mine wastes, a portion of the cap was used for an asphalt bicycle trail and another section will be a city-maintained sledding hill.

Meet the Political Needs of Local Officials. Small communities expect that their local officials will look after their interests. Local officials feel a responsibility for and receive political benefit from close oversight of agency work. Staff must remember to keep local officials informed and involved throughout the cleanup process.

5.7 Federal Land Managers

Many abandoned mine waste sites are located on federal lands or a mixture of federal and private lands--Forest Service, Bureau of Land Management, National Park Service, U.S Fish and Wildlife Service. When this is the case, federal land managers will be important players in the cleanup process. Sometimes, in fact, they will be the lead agency responsible for overseeing all or a portion of the cleanup using CERCLA authority. In other cases, they may be liable for some of the cleanup work. In still other cases, they are the trustees for natural resources. Multiplicity of roles for multiple agencies may cause confusion in the community unless there is a close working relationship among the federal agencies involved at the site and each agency's role is carefully explained. To gain a better understanding of the authority of land managing agencies and EPA under CERCLA read Executive Orders 12580 and 13016.

Community Involvement Tips:

Involve Stakeholders in Decisions on the Cleanup Process. When a wide range of options are available for addressing the cleanup--different laws, different agencies taking the lead, a combination of private and public responsibilities, etc.--it is important to carefully explain the options and involve the community in the decisions on the cleanup plan.

Clarify Agencies' Roles. Carefully explain the role each federal agency will play at each step in the process.

Include Federal Land Managers in Stakeholder Groups. If a stakeholder advisory group is formed, include federal land managers in the group.

5.8 Uncertainty

The cleanup process can be slow and it may take some time before there is evidence of actual cleanup. Because property values and marketability are sometimes affected, residents want to know whether their properties are in or out of the site boundaries. EPA is frequently unable to give an answer to this question until studies are complete and all data are available.

Citizens want to know if their property will require remediation. They feel they must defer decisions on remodeling, landscaping, gardening, and other activities until they know whether their property is contaminated or when it will be remediated. Again, EPA may not have an immediate answer to their questions. This increases the sense of uncertainty and frustration of the local community.

Community Involvement Tips:

Establish Site Boundaries Early. While making it clear that new information may change the boundaries, the team should clearly describe the areas that are under investigation and should provide information on the location of contaminated areas. When information is not available, residents should be told when it will be collected and made public.

Identify and Reduce Areas of Uncertainty. Staff should clearly identify areas of uncertainty, whether it be extent of contamination, nature of cleanup planned, site risks or liability. They should explain how and when uncertainties will be resolved and immediately communicate new information that will remove uncertainty. Where uncertainties remain, the site team should explain how cleanup plans will be adjusted to take the uncertainties into account.

5.9 Additional Sources of Information

Additional information concerning EPA's Superfund community involvement programs, including a list of publications available can be found on the EPA website at: http://www.epa.gov/superfund/tools/index.htm.

Chapter 6

Scoping Studies of Mining and Mineral Processing Impact Areas

6.1 Introduction

The purpose of this chapter is to discuss the scoping process at abandoned mining and mineral processing sites. The first section of the chapter will present background information on the scoping process in general. Details on the individual tasks associated with the scoping process used under CERCLA can be found in Chapter 2 of the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA.*[1] The terms used in this chapter to identify scoping and activities are those used in the guidance. These procedures will prove valuable whether CERCLA or some other authority guides cleanup activities. The remainder of the chapter will address problems and issues to consider when scoping an abandoned mining or mineral processing site.

6.2 Scoping

The broad project goals for an investigation at an abandoned mine site are to provide the information necessary to characterize the site, define site interactions, define risks, and develop a remedial program to mitigate observed and potential threats to human health and the environment. The purpose of scoping is to:

- Establish a procedure for determining the nature and extent of contamination associated with the site;
- Identify possible response actions that may be required to address contamination at the site;
- Determine whether interim or removal actions are needed to reduce risks, prevent damage, or mitigate current threats; and
- Divide the broad project goals into manageable tasks that can be performed within a reasonable period of time and with a logical sequencing of activities.

Because of these activities, scoping should be conducted for any cleanup project, regardless of the administrative framework being considered for the action. While a mine site cleanup may not require that a traditional RI/FS be developed, the framework provided by that activity may prove useful in scoping and planning. For example, the RI/FS typically includes preparation of the following: a project work plan, a sampling and analysis plan (SAP), a health and safety plan, and a community relations plan.

The Work Plan. The work plan documents the decisions and evaluations made during the scoping process and presents anticipated future tasks. Five elements are included in the typical work plan: (1) an introduction, (2) site background and physical setting, (3) initial evaluation, (4) work plan rationale (including the identification of data needs and data quality objectives), and (5) tasks to investigate and cleanup the site. The information necessary to complete the work plan will become available as the tasks associated with scoping are completed. Additional information on the elements of a work plan can be found in Appendix B of the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA.* At many sites, including large mining or mineral processing sites, the work plan may have to be amended as additional information (data) is acquired. Separate work plans should

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[1] U.S. Environmental Protection Agency (EPA), October, 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*. Washington, D.C. Office of Emergency and Remedial Response.

be prepared for major elements of the site investigation, analysis of cleanup alternatives, and design of cleanup actions.

The Sampling and Analysis Plan. The Sampling and Analysis Plan (SAP) ensures the consistency of sampling and data collection practices and activities over time, and ensures that data needs and quality objectives developed in the work plan are met. A SAP should be developed concurrently with the work plan. The plan should be prepared before any field activities begin, and should consist of two parts: (1) a quality assurance project plan (QAPP), which describes the policies and activities necessary for achieving data quality objectives (DQOs) for the site; and (2) the field sampling plan (FSP), which provides guidance for all field work by defining in detail the sampling and data-gathering methods to be used in the project.[2] The sampling and analysis process and sampling and analysis issues at abandoned mining and mineral processing sites are addressed in greater detail in Chapter 7 of this handbook.

The Health and Safety Plan. Health and Safety Plans (HSP) are frequently included as a part of the work plan, but may be submitted separately. Typical elements of an HSP include: names of site health and safety officers and key personnel; a health and safety risk analysis for existing site conditions; employee training assignments; a description of personal protective equipment used by employees; medical surveillance requirements; a description of the frequency and types of air monitoring, personnel monitoring, and environmental sampling techniques and instrumentation to be used; site control measures; decontamination procedures; standard operating procedures for the site; a contingency plan that meets the requirements of 29 CFR 1910.120 (i) (1) and (i) (2); and entry procedures for confined spaces.

Specific HSP issues for mining sites include physical hazards such as open shafts, subsidence, steep slopes, landslide potential, remoteness of sites, and chemical hazards from contaminants. Structures can present a special hazard at mill sites and abandoned processing facilities (e.g., buildings may be unsafe for entry, or contain high concentration residues). Additional information on the Health and Safety Plan can be found in Appendix B of the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA.*[3]

The Community Relations Plan. Community relations planning is particularly important when the extent of contamination and appropriate response actions are being determined at mining and mineral processing sites where the community is impacted. Community relations activities keep the community informed of site activities and help Superfund personnel anticipate and respond to community concerns. The Community Relations Plan, which documents these activities, should include the following sections: an overview of the plan, a capsule site description, background information about the community, highlights of the community relations program, information about community relations activities and timing, a contact list of key community leaders and interested parties, and suggested locations for meetings and information repositories. Additional information on community relations can be found in Chapter 5 of this reference document.

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[2] Guidance for the selection of field methods, sampling procedures, and custody samples can be acquired from U.S. Environmental Protection Agency. *Compendium of Superfund Field Operation Methods,* 1987.

[3] U.S. Environmental Protection Agency (EPA), October 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA.* Washington, D.C. Office of Emergency and Remedial Response.

6.3 Difficulties in Scoping Abandoned Mine Sites

There are a variety of characteristics of abandoned mine sites that make the scoping and completion of characterization and cleanup activities complex. The following is a discussion of some of the issues that can be encountered in scoping an abandoned mining and mineral processing site.

Size and Location of the Site. Some, although certainly not all, abandoned mine sites have impacts over large areas, especially if mining areas or districts or impacted watersheds are considered. In addition, some abandoned mines sites may be more difficult to characterize and cleanup because of their remote locations, in some cases without road access and/or located at high altitudes areas. The size and location of abandoned mine sites can make remediation planning, site characterization, and actual remediation complex.

Volume of Contaminants. Typical of some abandoned mining operations is the removal of large volumes of waste material during the mining process. Furthermore, beneficiation and mineral processing operations, which are often co-located with mining operations, typically generate very large volumes of process waste. As an example, one tailings impoundment in the now closed Anaconda mine/smelter site near Butte, Montana covers more than 1000 acres and ranges in depth up to 100 feet. These large volumes make traditional remediation (such as excavation, stabilization, and landfilling) economically difficult even if technical issues can be resolved. Furthermore, due to the large volumes, complete removal or remediation of the problem may not be possible, or remediation may take place in a phased approach.

Type of Wastes. There may be numerous different types of waste at abandoned mining and mineral processing sites. These wastes could include tailings, slags, overburden, waste rock, ore stockpiles, and remaining process chemicals. A variety of sampling strategies may be needed to characterize each waste type.

Persistence of the Contaminants. Metals, often a primary contaminant at abandoned mine sites, do not readily decompose or biodegrade into less toxic byproducts as do volatiles and some organic compounds. Therefore, mine sites abandoned for decades or even centuries can still have metal concentrations at levels of concern. Furthermore, metals that are not of toxic concern can generate other problems that can occur for decades, such as acid generation.

Variety of Media Affected. Contamination at abandoned mine sites often affects many media. Surface water and ground water are frequently contaminated by metals leached from mining and mineral processing wastes and by acid generated within the mines or waste units. Soils are often contaminated onsite by historical waste management practices and offsite by fugitive dust and smelter emissions. Sediments within surface waters may also contain contaminants. In addition, the air may be recontaminated during remediation operations or by fugitive dust blown from abandoned waste units. The wide dissemination of contamination at some mining and mineral processing sites generally requires the collection of a large variety of data from several different sources. Information about sources, migration pathways, and human and environmental receptors is generally critical to characterizing the site and formulating plans for possible remediation alternatives.

Historical Mining Areas. Abandoned mine sites are often located in areas where the remnants of mining activity is considered to be historical. The local population is often deeply rooted in the mining and mineral processing activities, and environmental investigations undertaken by site managers must take this into consideration. Historical preservation is an issue at some sites. Historical artifacts, including old mine buildings, mine openings, and associated towns now abandoned, may be located on the site and their continued presence, as well as access to structures, is expected to remain despite remediation activities. Finally, the long history of mining and mineral processing in these areas often poses problems in determining levels of metals naturally occurring in the local water and soils prior to mining activity.

On-going Mining and Mineral Processing. Some abandoned mine sites may be affected by ongoing mining and mineral processing nearby. Often, mines abandoned as uneconomic utilizing past technologies have been reopened using new technologies or when prices rise. In other cases, neighboring claims and associated processing operations continue to operate. Where these new operations or historical neighboring operations are being conducted, sampling, risk assessment, and remediation may have to be modified. Any remedial actions on the site may be affected by ongoing mining and mineral processing operations. Ongoing mining and mineral processing operations can greatly affect both the data collection process itself and the quality of the data collected. Isolating the effects of ongoing operations from waste generated in the past can be challenging. Additional health and safety protocols may have to be taken into consideration if mining and mineral processing activities are occurring on the site. Efforts must be coordinated with mining and mineral processing operators to ensure the safety of remediation teams.

Location in Non-Industrial Areas. Many mining and mineral processing sites are located in areas that otherwise would be considered non-industrial natural resource areas. The Bunker Hill site in northern Idaho, for example, is in forested mountain country; however, large areas of the site have been denuded of most vegetation. Local governments or other entities associated with old mining and mineral processing areas may want a total cleanup because they are seeking an inflow of recreational dollars. They may also, however, want no cleanup because of their desire to avoid the stigma of a Superfund site or they may want to retain the historic features.

Because many abandoned mine sites are located in or near non-impacted environments, the ecological risk assessment can become more important, particularly if the human population around the sites is small or nonexistent.

6.4 Scoping Issues Associated with Mining and Mineral Processing Sites

Abandoned mining and mineral processing sites can present many challenges and issues during scoping. Characterizing mining and mineral processing sites and identifying problems and potential solutions can be very complex, particularly at the large sites where both mining and mineral processing have occurred. The remainder of the chapter will present important issues for consideration when scoping a mining and mineral processing site.

6.4.1 Operable Units

The size of abandoned mining and mineral processing sites can create special challenges for tasks associated with the scoping process. Sites are often far too large to address in a single response action, and the actions selected may require a longer time frame to undertake than is common for other smaller or more contained sites. For this reason, mining sites are often divided into smaller units, which are called Operable Units (OUs), that are then characterized both individually and as part of the whole site. The term Operable Unit has specific meaning under CERCLA, which may differ somewhat from the description in this chapter. Also, because human health may be of critical concern in some areas it may be appropriate to focus on units that impact human health first, with ecological considerations being investigated as a distinct unit.

Establishing Operable Units. While there are no definitive criteria for designating units, many area-specific factors are used: (1) similar contamination of waste material or environmental media (e.g., soils, flue dust, or ground water); (2) similar geographic locations; (3) similar potential cleanup techniques; (4) potentially similar cleanup time frames; and (5) sites that are amenable to being managed and addressed in a single decision making process. As an example, the East Helena Smelter Superfund site, an active smelting operation, has five operable units: (1) process ponds and fluids; (2) groundwater; (3) surface water, soils, vegetation, livestock, fish, and wildlife; (4) slag piles; and (5) ore storage areas.

Prioritizing Operable Units. Once units have been designated, they should be ranked to determine the order in which they will be addressed for remediation. Again, standardized criteria have not been established for determining unit priorities; however, exposure may be a significant factor in assigning priority to sites based on the degree of risk they pose to human health and the environment. See Chapter 8 for more information on risk. An example of response priority criteria for OUs is Shown in Exhibit 6-1.

Exhibit 6-1
Sample Criteria Used to Prioritize Operable Units

At the Clark Fork Superfund site in Montana, EPA used the following criteria to establish response priorities for OUs:

High Cleanup Priority
- High potential for exposure to humans or to the environment;
- Cleanup required to study or address other OUs.

Intermediate Cleanup Priority
- Moderate potential for exposure to humans or to the environment;
- Potential that cleanup efforts could recontaminate OUs located downstream, downgradient, or downwind
- Unusual complexity of problems that could require lengthy evaluation.

Low Cleanup Priority
- Currently low potential for exposure to humans or to the environment;
- Potential for higher levels of exposure in the future;
- Low risk of off-site contamination.

Primary Threats. For each unit, the site manager determines the primary threats and pathways. Primary threats are initially identified during scoping to assist in setting response priorities, to identify needed removal actions, and to prepare appropriate sampling and analysis strategies. They are later confirmed and evaluated during the baseline risk assessment (see Chapter 8 of this reference document) to guide decision-making about potential responses. Examples of primary threats at mining and mineral processing sites are displayed in Exhibit 6-2.

Cleanup Objectives. Based on the primary threats, potential routes of exposure, and associated receptors identified in the site characterization and risk assessment, the lead agency identifies cleanup objectives (called Remedial Action Objectives (RAOs) under CERCLA) for each unit. Objectives consist of medium-specific or unit-specific goals for protecting human health and the environment. Because protection may be achieved by reducing exposure to contaminants (by capping an area, limiting access through institutional controls, or providing an alternate water supply) as well as by reducing the contaminant concentration, objectives for protecting receptors (see Exhibit 6-3) should be expressed both as a contaminant level and an exposure route, rather than as a contaminant level alone. Further, objectives should be expressed in terms of the medium of interest and target cleanup levels (i.e., Preliminary Remediation Goals), whenever possible.

Exhibit 6-2
Primary Threats at Superfund Mining and Mineral Processing Sites

Major Contaminants

Naturally Occurring: Lead, Zinc, Copper (and other heavy metals), Arsenic, Cadmium, Mercury, Antimony, Selenium, and Uranium

Introduced During Extraction, Beneficiation, and Processing: Cyanide, acids, bases, PCBs, asbestos, and others

Sources of Contamination

Mined Areas: Open pits, mine shafts, and tunnels
Impoundments: Tailings, run-off collection, wastewater treatment, and leaching solution ponds
Piles: Overburden, tailings, slag, air pollution control dust
Sediments: Sediments in river beds, mine pits, and drainage channels
Processing: Slag, air pollution control residues, wastewater, treatment sludges, and deposition of stack emissions

Exhibit 6-3
Receptors and Pathways

Human Receptors and Pathways	Ecological Receptors and Pathways
● Inhalation of contaminated/radioactive fugitive dust ● Consumption of contaminated drinking water wells and aquifers ● Ingestion of contaminated fish, vegetables, soil, or wildlife ● External exposure to radionuclides	● Potential fish kills and degradation of aquatic systems from direct contaminant exposure ● Riparian vegetation kills along contaminated streams/rivers ● Wildlife exposure to contaminated soils and waters

If an overall site management plan is prepared, it should reflect the relationships between units and the danger of recontaminating an area where cleanup has been completed. The excavation or movement of contaminated materials at one area of the site may affect air, streams, rivers, or ground water, and may affect locations downwind, downstream, or downgradient. In addition, remediating a heavily contaminated area without remediating the source could result in later recontamination. These considerations should be important ones in making sequencing decisions for investigating response actions where multiple units exist.

6.4.2 Interim Actions

Interim actions may be appropriate for some units to protect human health and the environment from an immediate threat in the short term while a final remedial solution is being developed, or to stabilize a site or units with temporary measures to prevent further migration or degradation. Examples of interim actions taken at mining sites include: providing bottled water or temporary well filters to residents until private wells are reclaimed or water supplies are provided; relocating contaminated material from one area of a site (i.e., residential yards) to a more remote area of the site for temporary controlled storage; and temporarily capping waste piles to reduce fugitive dust until a more permanent remedy can be performed. Interim actions are discussed further in Chapter 9 of this reference document.

6.4.3 Unusual Requirements

There are many statutes that may be applicable to mining and mineral processing sites but would not ordinarily be considered appropriate for other sites (e.g., Endangered Species Act, National Historic Preservation Act, the Archeological and Historic Preservation Act, the Historic Sites, Buildings, and Antiquities Act, etc.). These statutes may be identified as Applicable or Relevant and Appropriate Requirements (ARARs) at CERCLA sites.

In addition, there are certain circumstances under which ARARs may be waived; these are stipulated in the NCP (40 CFR 300.430(f)(1)(ii)(C). Given the possibility of unusual site characteristics at abandoned mining and mineral processing sites (e.g., difficulty with background levels, large size, location, and multimedia effects), waivers may be necessary at these sites. Chapter 11 of this handbook discusses issues for ARARs at mining and mineral processing sites in greater detail. In addition, Appendix D of this handbook provide a general discussion of some of the most common federal ARARs at Superfund mining sites.

6.5 Sources of Additional Information

Additional information on scoping studies can be found in EPA-OERR's October 1988 *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*. Another source of information can be found on the EPA website, including the information at http://www.epa.gov/superfund/whatissf/sfprocess.htm.

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Chapter 7
Sampling & Analysis of Impacted Areas

7.1 *Introduction*

The purpose of this chapter is to introduce concepts and issues related to designing and implementing a sampling and analysis program for characterizing mining and mineral processing site waste management areas. This part of the planning process provides a path to prioritizing remedial actions and setting realistic goals, because it may not be possible to completely remove or remediate areas that may occupy many square miles

Section 7.2 will present general information about the sampling and analysis process. The individual tasks associated with sampling and analysis can be found in Chapters 3 and 4 of the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*[1]. The terms used in this chapter to identify sampling and analysis activities are those used in the guidance. For non-CERCLA actions the site manager is advised to consider CERCLA guidance in the context of site specific needs and circumstances.

Mining and mineral processing sites present many problems and issues that are not characteristic of other sites. Section 7.3 of the chapter will present unique characteristics of mining and mineral processing sites and briefly discuss how these characteristics can affect the sampling and analysis program. The remainder of the chapter will address issues associated with sampling and analysis at abandoned mining and mineral processing sites.

7.2 *Sampling and Analysis*

During the scoping process, any data for the site that is available will be collected, reviewed and analyzed, and the need for additional data defined. A sampling and analysis effort will likely be required to provide this additional data. A sampling and analysis plan (SAP) is a necessary part of the investigation and remediation process. This plan can be revised as sampling and analysis efforts are implemented.

The SAP is a document that specifies the process for obtaining environmental data of sufficient quality to satisfy the project objectives. Defining data quality objectives (DQOs) is the most important preliminary activity in creating an SAP. The DQO process offers site managers a way to plan field investigations so that the quality of data collected can be evaluated with respect to the data's intended use.

The outputs of the DQO process feed directly into the development of the two parts of the SAP: the quality assurance project plan (QAPP) and the field sampling plan (FSP). The FSP describes the number, type, and location of samples and the type(s) of field and analytical analyses; whereas the QAPP describes the policy, organizational, and functional activities necessary to collect data that will stand up to legal and scientific scrutiny. The SAP integrates the DQOs, FSP, and QAPP into a plan for collecting defensible data that are of known quality adequate for the data’s intended use. More information on the tasks associated with generating the SAP can be found in Chapter 2 of the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA.* Problems and issues that arise while creating and implementing the SAP will be discussed in the remainder of this chapter.

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[1] U.S. Environmental Protection Agency (EPA), October, 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA.* Washington, D.C. Office of Emergency and Remedial Response.

7.3 Issues for Sampling at Mining and Mineral Processing Sites

There are several important issues to consider in developing a sampling and analysis plan for an abandoned mining and mineral processing site. Mining sites may pose different sampling and analysis challenges than other hazardous waste sites contaminated by organic compounds and metals. The potential for widespread variable contamination is tremendous and the size of the site and volume of the contaminants can greatly complicate sampling and analysis efforts.

7.3.1 Defining Analytical Data Needs

This section briefly discusses analytical data needs and sources of analytical services for managing a sample analysis effort under the Superfund Program. Site managers of non-CERCLA investigations should select elements appropriate to their specific site. The key component in defining the analytical program needs for a mining and mineral processing site is to talk with fate and transport experts and environmental risk assessment experts to determine the forms of metals and other site contaminates (e.g., cyanide) that should be investigated. A clear understanding of the mining and mineral processing operations that have occurred on the site will greatly contribute to planning the investigation.

The particular type of data that needs to be generated depends on the project needs. The project needs are expressed as qualitative and quantitative DQOs which are developed in the project planning process.

> **Screening data.** Screening data at mining and mineral processing sites can help to reduce initial sampling costs; analyses are conducted by rapid, less precise methods, with less rigorous sample preparation. Screening data provide analyte identification in the absence of historical site information. The x-ray fluorescence (XRF) analytical method is often used for screening data to increase the representativeness of the sampling quickly. See Section 7.3.7 of this chapter for more information on analytical methods and Appendix E for more information on the XRF method.
>
> **Definitive data.** Definitive data are generated using rigorous analytical methods, such as approved EPA reference methods. Data are analyte-specific, with confirmation of analyte identity and concentration.

7.3.2 Understanding Pre-mining Conditions

At certain sites, the sampling plan can provide a useful tool to determine whether a release or threatened release represents conditions altered by human activity. This information could be used to determine whether a response action would trigger the exception contained in CERCLA section 104(a)(3)(A). That section restricts in certain respects the authority of the federal government to take a CERCLA response action in response to a release or threat of release “of a naturally occurring substance in its unaltered form, or altered solely through naturally occurring processes or phenomena, from a location where it is naturally found.” This narrow exception applies where a release or threatened release is unaltered by human activity. Quite often, the impacts of mining are obvious, so a fairly simple sampling plan or site review can demonstrate that the releases are altered and therefore not covered by the exception contained in CERCLA section 104(a)(3)(A). If the exception does not apply, the degree of cleanup is governed by CERCLA section 121 and the NCP. Neither sections 104, 121, or the NCP require the agency to determine the pre-mining metal levels as a limit on the CERCLA response action. A review of natural background levels might in some case be considered in the analysis of ARARs or technical impracticability. In some instances, an investigation of the natural background condition can also assist the agency to determine the feasibility of achieving cleanup goals.

At mine sites, determining the pre-mining baseline condition can be a difficult or impossible task because mining activities often disturb mineralization in profound ways. Mining activities, such as removing overburden, tunnelling into the ground and removing ore, often expose previously protected mineralization to accelerated oxidation. These activities can also change ground water and surface water flow regimes, which can facilitate the release of metals into the environment.

Other factors also complicate efforts to determine pre-mining conditions at disturbed mineralized deposits. In many cases, mineralized areas are highly heterogeneous. Highly variable conditions reduces the ability to determine whether any particular area is undisturbed and representative of pre-mining, site-wide conditions. Moreover, ground water sampling efforts can disturb and expose the mineralization. This disturbance can elevate metal concentrations in the sample well above the levels present in an undisturbed condition, causing misleading results regarding the undisturbed condition. Moreover, efforts to associate releases to particular areas through metal ratios is complicated by seasonal variability and chemical and physical processes that occur as the water moves from the mineralized area to the sampling point. The unique nature of each mineral deposit also limits the ability to rely on undisturbed mineralized areas in other geographic locations as representative of the pre-mining conditions at the subject site.

Mineral processing activities can also complicate the study of pre-mining conditions. Mineral processing operations can deposit mine processing dust and waste over areas several square miles in size.

While statistical methods that rely on site chemistry may not be appropriate at most mine sites, in some cases non-chemical data can be used to infer pre-mining conditions. For example, evidence may indicate that prior to mining a stream supported aquatic life while after mining the stream does not support an aquatic community. This information would indicate that the pre-mining releases were relatively small relative to the post mining condition. Anecdotal evidence from the pre-mining period can also provide information regarding metal concentrations.

If chemical analysis will be used to differentiate unaltered naturally occurring releases from altered releases, it will be important to select appropriate “reference area” locations. A background sampling location should usually be upwind and upstream of the site. In other cases, a nearby watershed, unimpacted by mining, may provide an appropriate site for background water samples. In either case, the site should have soil characteristics and related properties similar to those that would have existed at an undisturbed portion of the site. If several different types of soil or habitats are present at the site, the site manager may need to gather more than one set of background data. The heterogeneous nature of mine sites, coupled with widespread contamination problems associated with mining, can greatly complicate reliance on a nearby reference site.

In selecting a reference area, the risk assessor should also consider anthropogenic contributors other than mining. For example, if a busy highway runs through a proposed background sampling area, the same or a similar highway should be associated with the mine waste site to account for leaded gasoline deposition. Locations that reflect obvious contributions of human activity, such as roadsides, drainage ditches, storm sewers, should generally be judged as inappropriate for collected background samples.

If background sampling is deemed necessary, it will be important to understand early in the process the ways in which the data will be used. For example, to ensure that spatially relevant and statistically significant results can be obtained, the assessor should design a plan to ensure that the assessor collects an adequate number of samples over an appropriate area and in a relevant pattern.

7.3.3 The Importance of Site Characterization

Prior to developing an actual sample collection strategy, proper characterization of the mining and mineral processing site should be conducted including:

Reconstructing pre-mining conditions;

Inventorying what has been deposited above-ground;

Obtaining records to determine the geology of areas where underground mining occurred;

Monitoring the movement of both surface and ground water; and

Estimating the impact of mining and mineral processing disturbances.

A thorough site characterization should include an understanding of the different mining and mineral processing processes that occurred since mining and mineral processing operations began. This type of information can be very helpful in anticipating all of the different types of waste that may be encountered at the site and determining where sampling should occur to obtain accurate data (see Chapter 2 for a discussion of mining and mineral processing processes). For example, milling operations generate very different wastes from smelting operations; and knowing which processes occurred at what time will help direct where samples should be taken and how they should be analyzed. A complete site characterization may also minimize sampling needs, thereby saving time and money.

There is a great deal of information available regarding historical mining and mineral processing sites that is helpful in site characterization. Mining companies may have significant background information from pre-mining exploration as well as information on how the site appeared before mining activities (This information may be important in developing long-term structurally stable cleanup plans). The information collected by the U.S. Geological Survey (USGS) and U.S. Bureau of Mines, now in the Office of Surface Mining (OSM), may be good sources of pre-mining site characterization data. State geologic or mining divisions also can have extensive historic mining databases. Historical production records from the mining and mineral processing operations may be kept by local historical societies. These records could provide tonnages, grades, and concentration methods. State mine inspector reports may also be used as a source of tonnage, grade and information on significant changes in the mining and mineral processing operations. Newspaper articles, books written about the mine or mining district, annual reports of mining and mineral processing companies, and work by government agencies may also provide information that will help determine where to sample, what contaminants to expect, and the range of concentration to anticipate.

Once the history of the mining and mineral processing site is characterized, the sampling strategies selected should be appropriate, based on pre-specified DQOs. Time consuming or expensive sampling strategies for some media may prohibit multiple sampling points; consequently it is important to balance the sampling objectives against the time and costs involved.

7.3.4 Calculating Preliminary Cleanup Goals

Preliminary Cleanup Goals (called Preliminary Remediation Goals (PRGs) under CERCLA) at mining and mineral processing sites can be used to focus cleanup efforts on a risk basis, concentrating sampling efforts in areas posing the highest risk hazards. Site specific cleanup goals can be calculated based on the environmental pathway at the site and the potential receptors. Setting preliminary cleanup goals is useful in focusing early action and site characterization goals while a site specific risk analysis is undertaken and should be included in large site cleanup projects.

Risk analysis efforts can be scaled back for smaller or more remote sites. PRGs may be useful in establishing detection limits required for analytical samples.

7.3.5 Selecting a Qualified Analytical Laboratory

Mining and mineral processing waste samples can pose unique analytical requirements. Samples often have a low pH level; contain several metals, often at high concentrations and varying solubilities; and vary widely in particle size. In selecting a qualified analytical laboratory, it is critical to consider the complexity of the sample matrix which will be analyzed. Site managers should select a laboratory that can handle the specific needs of their site and meet the established DQOs. Portable analytical laboratories , if used should be selected with the same criteria.

If an EPA Contract Laboratory Program (CLP) laboratory is selected, it is important to realize that the lab may not be experienced in analyzing mining and mineral processing waste. The routine sample preparation procedures and the pre-specified detection limits that the CLP process uses may not be applicable for mining and mineral processing waste samples. The site specific conditions will determine if a CLP laboratory is appropriate. These will include the need for specialized services, such as the acid-base account or humidity cells. In addition, if the concentration of contaminants in these samples is expected be orders of magnitude above the detection limit, the sample may not be accurately analyzed with the CLP procedures unless the lab is advised upfront. These factors are important when the site manager is considering what laboratory should perform the sample analyses for their specific site.

7.3.6 Determining the Leachability of Contaminants

The first critical step in selecting analytical methods appropriate to mining and mineral processing sites is the recognition that metal speciation is an important factor affecting the mobility and toxicity of metals at mining and mineral processing sites. Metals form different chemical compounds on the basis of their pH and oxidation-reduction potential, as well as the nature of the aqueous chemical environment. Different metal species form compounds with different solubilities, activities, toxicities, and environmental fates. Identifying these species at mining and mineral processing sites is extremely important in understanding a site, making assessments concerning environmental and human health risks, and arriving at reasonable decisions concerning cleanup actions. Interpretation of fate and transport potentials based on static and kinetic tests depends on the nature of the test (e.g., solvent duration) and the nature of the samples (e.g., tailings [fine particles, more surface area] versus some slag [coarse material, less surface area]).

The fate and transport of various chemical constituents from mining and mineral processing wastes can be evaluated by conducting static and kinetic tests. Tests can be used to determine if a waste is hazardous; the sample results depend upon the material(s) being tested. The most common test used internationally for mining and mineral processing waste samples is the Acid-Base Account. Since the 1970's variations of the Acid-Base Account have been used. These methods are based on measuring the total sulfur content in the sample to determine the amount of acidity that could be produced if all the sulfur were oxidized to sulfate and comparing the amount of acidity to the total buffering capacity of the rock. The test results can be used to determine the potential for metal leaching by computer analysis.

Other test methods are commonly used for conducting mining and mineral processing waste leachability analyses. These tests, however, may or may not be appropriate since they are conducted under saturated conditions (i.e., they do not measure the oxidation potential of sulfur bearing minerals). The primary RCRA test used to characterize waste samples is the Toxicity Characteristic Leaching Procedure (TCLP). Three potential alternatives to the TCLP exist: the Synthetic Precipitation Leaching Procedure (SPLP), which some states reportedly use; the Multiple Extraction Procedure (MEP); and California's Waste Extraction Test (WET). Some states use other methods; for example, Nevada uses the Meteoric Waste Mobility Test (MWMT) to assess the likelihood of acid generation over time. Additional information on the test methods discussed above can be found at the following:

- TCLP - http://www.epa.gov/epaoswer/hazwaste/test/1311.pdf;
- SPLC - http://www.epa.gov.80/epaoswer/hazwaste/test/1313.pdf;
- MEP - http://www.epa.gov.80/epaoswer/hazwaste/test/1320.pdf;
- WET - can be found in the California Code of Regulations, Title 22, Chapter 11, Article 5).

7.3.7 Selecting Analytical Methods

Many methods are available for the analysis of mining and mineral processing waste samples. The *Guide to Environmental Analytical Methods*[2] provides information on analytical methods, such as method detection limits, sample preservation requirements, field sample volumes required, and holding times. Examples of general analytical methods include total constituent analysis, acid digestion, X-ray fluorescence (XRF), and gas chromatography-mass spectroscopy (GCMS). Most of the methods mentioned in the Guide are included in SW- 846[3] EPA's test methods for evaluating solid waste. EPA's waste characterization data on Superfund mining and mineral processing sites[4] provides examples of sampling and analysis methods already used at selected mining and mineral processing sites. Exhibit 7-1 shows examples of analysis methods that have been chosen in the past.

Exhibit 7-1
Sampling and Analysis Methods

Method	**Mining and Mineral Processing Site/Sample Matrix**
Wet Chemistry/XRF	Cherokee County, KS. Galena Subsite: waste samples analyzed for metals
Acid Digestion	Cotter Uranium Mill, Canon City, CO: soil and sediment samples
XRF/ (Inductively Coupled Plasma Emission Spectroscopy (ICP))	Tex Tin Corporation, Texas City, TX: samples analyzed for lead, iron, nickel and tin initially using XRF did not show presence of metals; samples were then extracted with nitric acid and analyzed with ICP to confirm XRF results.

X-ray Fluorescence (XRF) Analytical Method

X-ray Fluorescence (XRF) is a non-destructive analytical technique used to determine the elemental composition of a sample. XRF measures the X-ray fluorescence coming from the inner electron shells of the atom. This is a systematic method and each element has its own "fingerprint". The XRF method measures the radiation coming direct from atoms and not from chemical compounds. The X-ray spectrum generated in the sample will tell which elements are present (wavelength of X-rays) and the amount of these elements (intensity of X-ray wavelength).

XRF is being applied to sites to increase the representativeness of sampling, expedite the activity by performing real-time data analysis to support decision making, and decrease both the time and

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[2] Wagner, R.E., W. Kotas, and G.A. Yogis, 1992. *Guide to Environmental Analytical Methods*

[3] U.S. Environmental Protection Agency (EPA), 1986. *Test Methods for Evaluating Solid Waste (SW-846): Physical Chemical Methods.*

[4] U.S. Environmental Protection Agency, 1991. *Mining Sites on the National Priorities List: Waste Characterization Data.*

cost of these activities. Because of this, XRF is being considered at many abandoned mining sites. As with any method, application of the XRF method depends on the project objectives and associated DQOs. Representativeness and completeness are two of the major advantages of using XRF. On-site, real time chemical analysis can document representativeness and allows critical samples to be collected and analyzed, which typically ensures completeness.

Media that are commonly appropriate for XRF analysis include soils, in particular, but essentially all solids, as well as liquefied solids, such as sludges and slurries. Detection limits extend from mg/kg (parts per million) to the 100 percent range for mobile XRF instruments and from tens to hundreds of mg/kg to 100 percent for field portable instruments.

Field-portable instruments, usually weighing less than 20 pounds (including batteries), can be carried to the sample location. Mobile instruments, however, require line voltage, and are usually placed within a specific building or van near or at the site to generate quality data. Decisions concerning the attainment of an action level can be made quickly at the site. Coupling the use of a field portable and mobile laboratory instruments at a site would allow for almost immediate decisions to be made concerning an action level in the field that can be confirmed by the mobile laboratory. Typically, a representative composite sample from the site area under cleanup action is sent to the laboratory for final documentation of the clean up level.

In most instances, an initial set of site samples is required for calibration purposes. The samples should cover the matrices and concentration range of elements of concern as determined by a total metals analysis by a laboratory. The samples should be prepared by the laboratory using the same protocol that will be used with the XRF at the site.

At the sample location, a field-portable instrument is equipped with a probe that allows considerable flexibility in how a sample is presented to the source. The source may be pressed against the media of interest (soils, tailings, walls, etc.) or a sample cup of material (soil, slurry, sludge, etc.) can be placed on top of the source. Samples may be sieved or pulverized but sample preparation is typically minimal. Field-portable instruments are versatile but have the highest detection limits of the three types of instruments. Typical detection limits with little to no sample preparation are in the 100 mg/kg range, depending on sample matrix. For mobile instruments, sample preparation is part of the analytical schedule and includes sieving and pulverizing. A typical detection limit will range from 5 to 30 mg/kg, depending on the sample matrix. Sample preparation and particle size variance are major potential sources of error.

High expectations and indiscriminate use of the instruments outside the design limits of the unit has sometimes led to discouragement in the application of field-portable XRF instruments. Although a particularly low detection limit may not be achievable in some cases, the instrumentation will usually determine hot spot areas, document that representative sampling has been accomplished, and determine that an action-level for a particular element has been reached in real time at the location. Confirmatory analyses should be performed by a fixed analytical laboratory.

The total extent of XRF application to abandoned mining sites is undoubtedly larger than the published accounts of such applications. Documented use of field-portable XRF instruments start in 1985 with the Smuggler Mountain Site near Aspen, Colorado.[5] The instrument was used to determine action-level boundaries of 1,000 mg/kg lead and 10 mg/kg cadmium in soils and mine waste. The same site was used for the evaluation of a prototype field-portable XRF instrument

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[5] Mernitz, S., Olsen, R., and Staible, T., 1985, Use of Portable X-Ray Analyzer and Geostatistical Methods to Detect and Evaluate Hazardous Materials in Mine/Mill Tailings: Proc. Natl. Conf. on Management of Uncontrolled Hazardous Waste Sites, Washington, DC, pp. 107-111.

specifically for hazardous waste screening[6]. Field-portable instruments have also been used at the California Gulch Site, Leadville, Colorado; Silver Bow Creek and other sites near Butte, Montana; Bunker Hill Site, near Kellogg, Idaho; and the Cherokee County Site, Tri-State Mining District, Kansas for screening purposes during site characterization. A field-portable instrument has been used to screen a large area (21 square miles) to select large, homogeneous volumes of heavily contaminated soils for treatability studies and for Site Comparison Samples at the Bunker Hill Site.[7] Portability and "real-time" basis data were necessary prerequisites. A mobile XRF instrument was used for multi-element analysis of lead, arsenic, chromium, and copper in soils.[8] Detection limits with the x-ray-tube-source and Si(Li) detector were as low as 10 mg/kg. The data were used to map the extent of contamination within a superfund site. Detection limits for field-portable instruments are not low enough to determine cadmium concentrations as low as 10 mg/kg in some areas/matrices, but zinc was found to be a good surrogate indicator element for cadmium in Cherokee County, Kansas.

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[6] Raab, G.A., Cardenas, D., Simon, S.J., and Eccles, L.A., 1987, Evaluation of a Prototype Field-Portable X-Ray Fluorescence System for Hazardous Waste Screening: EMSL, EPA 600/4-87/021, U.S. Environmental Protection Agency, Washington, DC, 33 p.

[7] Barich, III, J.J., Jones, R.R., Raab, G.A., and Pasmore, J.R., 1988, The Application of X-Ray Fluorescence Technology in the Creation of Site Comparison Samples and in the Design of Hazardous Waste Treatment Studies: First Intl. Symposium, Field Screening Methods for Hazardous Waste Site Investigations, EMSL, Las Vegas, NV, pp. 75-80.

[8] Perlis, R., and Chapin, M., 1988, Low Level XRF Screening Analysis of Hazardous Waste Sites: First Intl. Symposium, Field Screening Methods for Hazardous Waste Site Investigations, EMSL, Las Vegas, NV, p. 81-94.

Chapter 8
Scoping and Conducting Ecological and Human Health Risk Assessments At Superfund Mine Waste Sites

8.1 Introduction.

The purpose of this chapter is to highlight some of the unique issues related to risk assessments at abandoned mine waste sites and to provide some guidance to help address these issues. Baseline risk assessments for site investigations provide a basis for risk management decisions. Although risk management decisions help determine the scope of the risk assessment, they should not influence the analytical process utilized in the evaluation. For example, scientific elements of the dose-response evaluation will remain consistent throughout all risk assessment activities. Risk assessments are also conducted to support removal actions that reduce excess risks to health to acceptable levels. This chapter furnishes Site managers and other federal, state, and local authorities with a summary of key issues relevant to mine waste site risk assessments as well as a compilation of references to other helpful resources. In some cases, cleanup activities can be implemented without conducting a baseline risk assessment.

8.2 Supporting Guidance Documents.

EPA Risk Assessment Guidance for Superfund (RAGS), including Volume 1 parts A[1], B[2] and C[3] D[4], and a supplemental volume[5], provide a broad, conceptual framework for conducting human health risk assessments at CERCLA sites. These concepts, while originally developed to address risk assessment issues during CERCLA action, are appropriate to consider in evaluating risk at non-CERCLA sites. Guidance for conducting ecological risk assessments may be found in the Ecological Risk Assessment Guidance for Superfund[6] (ERAGS), the EPA Guidelines for Ecological Risk Assessment[7], the field and laboratory reference guide[8], and in Appendix F of this document. EPA's Office of Emergency and Remedial Response supplies copies of the *ECO Update* intermittent bulletin series of supplemental ecological risk assessment guidance on specific technical and procedural issues. General EPA guidance

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[1] U.S. Environmental Protection Agency (EPA). 1989. *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual, Part A: Baseline Risk Assessment*. EPA/540/1-89/002.

[2] U.S. Environmental Protection Agency (EPA). 1991. *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual, Part B: Development of Risk-based Preliminary Remediation Goals.* EPA/540/R-92/003.

[3] U.S. Environmental Protection Agency (EPA). 1991. *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual, Part C: Risk Evaluation of Remedial Alternatives.* EPA/540/R-92/004.

[4] U.S. Environmental Protection Agency (EPA). 1998. *Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual, Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments*. Office of Emergency and Remedial Response, Publication 9285.7-01D

[5] U.S. Environmental Protection Agency (EPA). 1991. *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors.* OSWER directive 9285.6-03.

[6] U.S. Environmental Protection Agency (EPA). 1997. *Process for designing and conducting ecological risk assessments*. EPA/540-R-97-006, June 5, 1997.

[7] U.S. Environmental Protection Agency (EPA). 1998. *Guidelines for Ecological Risk Assessment*. EPA/630/R-95/003F.

[8] U.S. Environmental Protection Agency (EPA). 1989. *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference*. EPA/600/3-89/013.

documents that address risk-related issues include Superfund Accelerated Cleanup Model (SACM) information[9], guidance addressing data useability in risk assessments[10], data quality objectives[11], and risk characterization[12].

Other guidance specific to particular issues or regions may be obtained through regional offices. Contact the regional EPA office associated with a given site to determine if regional guidance is available, as well as to determine the appropriateness and applicability of utilizing guidance documents from other regions on particular issues. For example, OSHA and related work place regulations (e.g., ACGIH, NIOSH) do not apply to environmental contamination, exposure to non-workers, or to workers outside of their controlled job setting. EPA and OSHA have an MOU on this subject and some regions have guidance for handling joint occupational and environmental exposures and resulting risks. Reference and guidance documents are also available from other federal agencies (e.g., USGS) and from various state agencies (e.g., California Environmental Protection Agency).

Contact information and electronic versions of some EPA publications are available online through the world wide web at http://www.epa.gov and new publications are available from the U.S. EPA Office of Research and Development at http://www.epa.gov/ORD/whatsnew.htm.

8.3 Overview of Mine Waste Site Risk Assessment Features

Several features of mine waste sites may be unique among hazardous waste sites and should receive consideration in the baseline risk assessment. This section addresses issues which are relevant to both ecological and human health risk assessment.

8.3.1 Site Characteristics

Physical Features. Features prevalent at many mine waste sites that may influence the approaches taken in the risk assessment include the size of the site, current and future land uses, the number of contaminants present, media contaminated, and the vertical and horizontal extent of contamination. Mine waste sites may occupy areas comparatively larger than those of other hazardous waste sites. Two examples of influences on the risk assessment are: (1) A large area is more likely to include greater portions of a particular terrestrial organism's home range and to possibly include more than one type of ecosystem and (2) Some former mine sites are current residential areas while others are very remote and have little likelihood of becoming residential.

Contaminant Distribution. Contamination is commonly ubiquitous across mine waste sites and includes a large volume of contaminants. Such widespread contamination often requires multiple pathway exposure evaluations in the risk assessment. It may be helpful to identify and focus on contaminants and/or exposure pathways that will drive the risk assessment; however,

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[9] U.S. Environmental Protection Agency (EPA). 1994. *Risk Assessment Tools for the Superfund Accelerated Cleanup Model.* Office of Solid Waste and Emergency Response. November. PB94963226.

[10] U.S. Environmental Protection Agency (EPA). 1992. *Guidance for Data Useability in Risk Assessment, Parts A and B.* Office of Solid Waste and Emergency Response. Directive 9285.7-09A&B. (PB92963356 and PB92963362.)

[11] U.S. Environmental Protection Agency (EPA). 1993. Data Quality Objectives Process for Superfund Interim Final Guidance. EPA/540/R-93/071.

[12] U.S. Environmental Protection Agency (EPA). 1995. Memoranda from Carol Browner regarding *EPA Risk Characterization Program/EPA Risk Characterization Policy and Guidance*. Office of the Administrator. March 21.

each contaminant of concern must be addressed and associated risks must be characterized to ensure that planned cleanup activities will be comprehensive. In some cases, this process may involve a screening-level risk assessment which precedes a more in-depth risk assessment.

8.3.2 Comprehensive Risk Assessment Considerations

Several issues are comprehensive because they are important in both ecological and human health risk assessments. This section discusses three such important issues: 1) Background Contaminant Concentrations, 2) Exposure Pathways, and 3) Bioavailability.

Defining Background. Naturally high background concentrations of metals are an important consideration at mine sites. Chapter 7 discusses background sampling in the initial sampling and analysis plan; the EPA Data Useability Guidance, cited earlier in this chapter, may also be consulted for assistance with planning a background sampling design. To ensure that appropriate "reference area" locations are chosen for background sampling, risk assessors must consider both natural and anthropogenic contributors. A background sampling location should usually be upwind and upstream of the site, and must have soil characteristics and related properties similar to those at the site. If several different types of soil or habitats are present at the site, more than one set of background data may need to be gathered to ensure that appropriate comparisons are made. A nearby watershed, unimpacted by mining, may provide an opportunity to collect background samples.

Natural background concentrations of metals in mining areas may occasionally be elevated above risk-based values or regulatory criteria and standards. Risk-based values are those concentrations at or above which an unacceptable human health or ecological effect may occur. Regulatory levels, including applicable or relevant and appropriate requirements (ARARs, discussed in Chapter 7) may or may not be risk-based values. If naturally occurring background concentrations exceed risk-based or regulatory values, the risk assessment may separately present risks caused by site contributions from natural background levels. The risk assessment should always present cumulative risk estimates. This enables risk managers to gain perspective and make better cleanup decisions.

Anthropogenic contributors to a background sampling site should be similar to those connected with the mine waste site. Both site samples and background samples should be representative of the areas under consideration. For example, if a busy highway runs through a proposed background sampling area, the same or a similar highway should be associated with the mine waste site to account for leaded gasoline deposition. Locations which reflect obvious contributions of human activities, such as roadsides, drainage ditches, storm sewers or the like, could be judged as inappropriate for collecting background samples. These areas may reflect secondary sources of contamination and not be representative of the greater area under consideration. In rare cases, a roadway contaminated during the transport of mining materials may be an area of concern. It is important that the intended applications of the background data in the risk assessment are determined early in the process to ensure that an adequate number of samples over an appropriate area and in a relevant pattern are collected to allow, as applicable, for spatially relevant and statistically significant results. Usually, per ERAGS Appendix D (Statistical Considerations), a 1-tail t-test is adequate to compare background with site concentrations, provided that independent representative samples from proper locations are evaluated. EPA guidance on the determination of inorganic content in soils and sediments[13] is also available.

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[13] U.S. Environmental Protection Agency (EPA). 1995. Engineering Forum Issue: Determination of Background Concentrations of Inorganics in Soils and Sediments at Hazardous Waste Sites. Office of Solid Waste and Emergency Response. December. EPA/540/5-96/500.

Exposure Pathways and Sources. Risk assessments at mine waste sites commonly require evaluation of exposures from multiple sources and exposure via multiple pathways. Multiple pathway assessments for terrestrial ecological receptors may include surface water ingestion, incidental ingestion of soil, or ingestion of contaminants taken up by plants. For human health assessments, multiple exposure pathways may include dermal contact with soil or water, incidental ingestion of soil or dust, inhalation of dust, and ingestion of ground or surface water. Multiple contaminant sources, such as nearby off-site tailings piles and roadways constructed of slag or waste rock, may also contribute to risks incurred by mobile populations with large home ranges as well as human beings that live and play in various areas of the site. Concurrent occupational and residential exposures are particularly relevant for those contaminants that are encountered both on the job and at home. Exposure sources may also include exposures from lead-based household paints and occupational metal exposures. Such analyses may later support multi-media risk reduction options strategies. EPA recommends the development and use of a conceptual site model (as described in RAGS, Section 3.6) to link releases from contaminant sources to environmental media which will be contacted by potential receptors under current and future land-use scenarios.

Bioavailability. When estimating the internal dose of a given contaminant, several factors are evaluated: source exposure concentration, intake rate, and the fraction of contaminant which is biologically available to that organism. Considerations of the particle size and mineralogy, the oxidative state of the metal, physical accessibility (e.g., whether or not it is encased by another compound which is not able to be broken down by an organism's digestive system) can modify an organism's internal dose. Data for assessing bioavailability may come from animal testing or from validated laboratory (*in vitro*) procedures. Only tests with biological systems can provide bioavailability values. Other non-animal experimental procedures may provide information regarding "bioaccessibility," or the potential for uptake based on physical or chemical features. TCLP, EP-TOX, chemical equilibrium computer models and other non-animal tests provide little useful information about bioavailability in living systems. In 1997, industry-initiated research was begun to evaluate the use of *in vitro* methods; however, scientific peer review and validation have not been completed at this writing. For lead exposure estimates, EPA’s Technical Review Workgroup for Lead (TRW) can provide the latest estimates of bioavailabilty.

With respect to human exposure, bioavailability can be defined as "absolute" or "relative". It is important for the bioavailability units of measure to properly correspond to the toxicity units of measure. Consult your regional risk assessor for a complete explanation of these terms and how they affect the risk assessment.

8.4 Ecological Risk Assessment

Understanding the ecological risk posed by a mine site is critical to making sound cleanup decisions. For a CERCLA cleanup Section 300.430(e)(2)(I)(G) of the NCP states that during Remedial Investigations and Feasibility Studies, "environmental evaluations shall be performed to assess threats to the environment, especially sensitive habitats and critical habitats of species protected under the Endangered Species Act." In addition, as described in Chapter 7, numerous federal and state statutes and regulations concerning environmental protection contain potential ARARs for Superfund sites.

Mine sites are unique from other sites in ways that can influence the size, scope, and detail to adequately characterize ecological risks. These sites can cover large areas and often affect large portions of eco-regions. In historic mining districts mine site impacts can contribute to degraded environmental conditions throughout a watershed. Moreover, they may be located in more remote areas, on federally owned land that is otherwise relatively pristine. Guidance on the role of natural resource trustees is particularly applicable for mine waste sites[14]. Mine waste sites are contaminated primarily with heavy metals and may also be impacted by operational contaminants including cyanide, acids, and PCBs. These sites may to be located in areas with soil and waters containing high background levels of metals and low pH that can complicate interpretation of soil, sediment, and surface water sampling results. Furthermore, cleanup options tend to be limited by the magnitude of problems and physical alterations to the landscape.

The following sections discuss ecological risk assessment issues associated with mine waste site investigations. For a more complete discussion of the ecological risk assessment process, and some suggestions regarding methods for approaching specific situations, consult the ERAGS, as well as Appendix F of this handbook. Helpful examples of ecological risk assessments prepared for large mine sites include: Bunker Hill in Idaho, Kennecott (terrestrial) in Utah, Sulphur Bank Mercury in California, Carson River Mercury in Nevada, and California Gulch (aquatic) in Colorado.

8.4.1 Identification of Potential Chemical and Physical Stressors

The major threat to the environment from mine sites is heavy metal contamination, including "acid mine drainage". See also Chapters 2 and 3 for an overview of mine site operations and a discussion of mine waste site activities that contribute to ecological and human health risk. Physical habitat alteration may also adversely affect environmental receptors. Sections 8.4.3 and 8.4.4 discuss some of these alterations and potential impacts. Additionally, Section 8.3.2 discusses background concentrations and is relevant to ecological as well as human health risk assessment. Background concentrations may be used in the determination of contaminants of potential concern for a site. Site contaminant concentrations may also be compared to toxicity-based reference values.

Some metals commonly found at mine waste sites such as zinc, iron, copper, and manganese are essential micronutrients for both wildlife and humans; they can be, however, toxic at higher levels. Bio-accumulation of metals presents greater problems for fish and wildlife at higher trophic levels, but this usually only occurs with organic metals such as methyl mercury.

8.4.2 Problem Formulation

Ecological risk assessments require clear definitions of the receptors and transfer pathways being assessed. Identifying impacts common to mine waste sites and placing them into a Conceptual Site Model facilitates a focused and efficient ecological risk assessment. For each functional unit, relevant assessment endpoints must consider spatial and temporal issues.

Spatial Issues. The large size and potential ecological complexity of a mine waste site may require assessment of several functional ecosystems. Both the relative and absolute magnitude of the contaminated area and of smaller specific areas that are critical to site ecosystems should be examined. The impacts of small scale contamination on highly valued habitats (e.g., tailing piles in wetlands or streams) and of broad scale contamination on other habitats should each be evaluated. Key elements associated with the spatial scale include multiple types of releases (e.g., tailings, drainage, smelting dross and emissions) and associated transport mechanisms. Home ranges are a critical spatial concern. Different types of home ranges (e.g., hunting areas, roaming areas) may be considered based on the way a given organism is likely to encounter mine waste contaminants (e.g., food chain exposure or

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[14] U.S. Environmental Protection Agency (EPA). 1992. *ECO Update: The Role of Natural Resource Trustees in the Superfund Process.* Volume 1. Number 3. Office of Emergency and Remedial Responses. PB92963369.

incidental soil ingestion). Selected home ranges must be compared with identified contaminated areas.

Temporal Issues. Ecological parameters are controlled by temporal factors. Seasonal events such as snowmelt, runoff, and swollen creeks and rivers can serve as major energy inputs that mobilize contaminants and contribute to higher levels of transported solids. Low flow, high temperature periods should be evaluated as times of likely contaminant-motivated stress to organisms, which may result in increases to organism metabolism and contaminant concentrations. Receptor foraging behaviors can vary during migration and spawning times. The analysis should consider receptor behaviors and life stages which may adversely enhance toxicity. For example, salmon eggs are more sensitive to toxicity from metals than adult fish.

Endpoints. Endpoint selection will direct planning of the ecological risk assessment and help place results in context. Identification of potential endpoints may be initiated with a description of the general functional groups in the ecosystem. Environmental media and exposure routes of mine waste contaminants should be identified during preparation of the Conceptual Site Model. Toxicological modes of action for site-specific contaminants of concern should also be considered. Based on this information and the spatial and temporal issues identified above, species and processes, within identified functional groups, that appear to be most valued, most sensitive, or that meet other site-related criteria (e.g., organisms that are hunted or fished, threatened or endangered raptors) can be selected for evaluation in the risk assessment. Final selection species and process assessment endpoints and measurement endpoints involves additional considerations.

Careful selection of "assessment endpoints" will help define subsequent supporting measurements. Each assessment endpoint will associate with one or more measurement endpoints to facilitate evaluation of exposure and risk. Choice of endpoints should be reflective of the complexity (e.g., organism interdependence) and diversity (e.g., variety of plants, animal and aquatic life) of the ecosystem. Risks to threatened and endangered species may be assessed through their incorporation into the Conceptual Site Model. Other decisions which should be made prior to data collection include definition of data objectives, explicit measurement selection, establishment of acceptable levels of uncertainty, and data quality control and analysis procedures. Since background metals concentrations at mine waste sites tend to be high, it is important to define a "significant risk level".

8.4.3 Characterization of Ecological Effects

Terrestrial Impacts and Risks. At some sites (e.g., Bunker Hill in Idaho), air transport of particulate matter from smelting operations and acid emissions (SO_2, NO_2 derived from H_2SO_4 and HNO_3) resulted in widespread contamination of surrounding soils, vegetation loss and stress, via acid rain and phytotoxicity, over hundreds or thousands of acres. Soils with high residual metal levels may not support native vegetation. Sites also may have large areas of degraded or lost vegetation following massive physical alterations of terrain and subsequent erosion. Vegetation coverage may serve as one measurement endpoint when evaluating an area's ability to support herbivorous terrestrial organisms. Vegetative loss may itself serve as an assessment endpoint for evaluating the overall ecological state of the site with soil metal concentration as one of its supporting measurement endpoints. Increased levels of zinc in soils can cause a decrease in microbial levels and in lichen growth. Decreased lichen growth can indicate the soil's ability to sustain vegetation. Risk to other terrestrial-linked receptors should be taken into account, even if the receptor's home range extends beyond the site boundaries.

Aquatic Impacts and Risks. Extensive degradation of aquatic ecosystems has occurred at many mine waste sites. Degradation of riparian vegetation has resulted in bank destabilization, erosion and sedimentation of water bodies. Run-off from tailings piles often lowers the pH of surface waters and increases levels of metals in sediments and the water column. Metal precipitates are often formed from acid mine drainage which adsorb to sediments and disrupt the benthic community. Run-off events from snow melt and storms can result in pulses of acids and toxic substances at critical life stages for resident fish and invertebrates. High acidity from mine acid drainage or storm water run-off at mine waste sites results in mobilization of metals in water, potentially causing detrimental effects to the aquatic community including fish kills. If fish tissue samples are to be used as a measurement, an adequate supply of fish for sampling should be verified at the time of assembling the sampling and analysis plan. At the older mine waste sites, tailings sometimes were dumped directly into surface waters or washed into surface waters in the initial years of mining operations. The concentration of metals in waste piles tends to be higher at older sites because the older methods of ore processing were not as efficient. At many mine waste sites, it is difficult to identify the key sources and events which cause continued contamination of surface waters. Other aquatic issues to consider include effects on benthic invertebrates and related impacts via the food chain, food chain exposures to aquatic birds and mammals, bioavailability of contaminants in sediments, chemical, and physical properties of the water that influence contaminant toxicity.

8.5 Human Health Risk Assessment

The following section discuss human health risk assessment issues associated with mine waste sites. The intent of this section is to highlight issues not specifically addressed in RAGS and other guidance.

8.5.1 Contaminants of Potential Concern

Human health risk assessments at mine waste sites focus primarily on issues addressing risks to humans from heavy metals and process chemicals. Heavy metals such as lead, zinc, copper, arsenic, cadmium and mercury as well as radionuclides, PCBs, and cyanide have been identified in soils near mine waste sites. Contamination may occur via wind blown dust, the use of mine wastes for landscaping, road building or foundations for home building, transport by surface waters or spillage during mining activities. Comparison of measured contaminant concentrations to undisturbed background concentrations and preliminary remediation goals may help to identify site-specific contaminants of potential concern. Some EPA regional offices have developed lists of preliminary remediation goals based on default assumptions for screening purposes. Contact your regional risk assessor for more information. There is also a soil screening levels guidance document available[15].

Lead. Up to the current time, lead has been the an important contaminant of concern at Superfund mine waste sites associated with residential use. EPA guidance[16] recommends the cleanup goal of a soil lead concentration such that a child would have an estimated risk of no more than 5% of exceeding a blood lead concentration of 10 g/dl. In August 1998, EPA issued clarification to the 1994 Revised Interim Soil Lead Guidance for CERCLA sites and RCRA Corrective Action Facilities. The full text can be found at the following web page: http://www.epa.gov/epaoswer/hazwaste/ca/index.htm#p&g.

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[15] U.S. Environmental Protection Agency (EPA). 1994. Soil Screening Guidance. Office of Solid Waste and Emergency Response. EPA/540/R-94/101.

[16] U.S. Environmental Protection Agency (EPA). 1998. *Clarification to the 1994 Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities* (a.k.a. "The Lead Directive"). Office of Solid Waste and Emergency Response. August. Directive # 9200.4-27. EPA/540/F-98/030.

The July 14, 1994 OSWER directive (The Lead Directive) indicates that a level of 400 ppm lead in soil be used as a level of contamination above which there may be enough concern to warrant site-specific study of risks. The EPA utilizes the Integrated Exposure Uptake Biokinetic (IEUBK) Model[17] to predict blood lead concentrations in children chronically (longer than 90 days) exposed to lead contaminated sources including soil, food, water, dust, air and drinking water, and to develop agency guidance. The IEUBK Model is discussed in the following section on Exposure Assessment, 9.5.2.

EPA has a Technical Review Workgroup (TRW) with expertise in the field of lead risk assessment. The TRW is comprised of senior scientists from multiple EPA regions and program offices (e.g., OSWER, NCEA and OPPTS). The TRW is supported by OSWER and its work is directed by TRW members. The TRW can be contacted through regional risk assessors and provides support for the use of the IEUBK model as well as assistance in other lead risk assessment issues.

In addition to the TRW, EPA has established the Lead Site Workgroup (LSW), composed of risk managers and risk assessors from the Regions and Headquarters, as a resource to develop agency guidance on risk management issues, and to provide the Regions with site specific consultations[18]. Through the efforts of the LSW, the Clarification to the 1994 Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities was issued. The Lead Site Consultation Group (LSCG), composed of Division Directors and senior managers from Regions and Headquarters provides general direction to the LSW. The LSW and the LSCG can be contacted through regional Mine Sites Coordinators or through regional OSWER contact persons who address risk issues.

Guidelines regarding lead-based paint hazards in housing are available from HUD[19]. When evaluating indoor dust for its potential to contribute to lead exposure it is important to evaluate the contribution of lead based paint. It is particularly important to evaluate the presence of lead-based paint in older communities. The LSW is preparing risk management position papers which also provide guidance for the evaluation of soil and dust exposures when lead-based paint may be present.

Other Metals. Not all mine waste sites have lead as the primary contaminant of potential concern. It is not unusual for several metal contaminants to be present. Arsenic, cadmium, mercury and antimony may also be present. Although not a metal, cyanide may be a contaminant due to its use as a process chemical.

Radionuclides. Examples of radionuclides and their decay products that may be present at mine waste sites include thorium, radium, radon, and uranium. The risk assessment should not include the risk to background levels of radiation. Only the incremental risk to the contaminants must be considered. Further information for determining PRGs for radionuclides is provided in RAGS part B.

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[17] U.S. Environmental Protection Agency (EPA). 1994. *Guidance Manual for the IEUBK Model for Lead in Children.* Office of Solid Waste and Emergency Response, Washington, DC. EPA/540/R-93/081.

[18] U.S. Environmental Protection Agency (EPA). 1996. Memorandum from Stephen D. Luftig regarding *Administrative Reforms for Lead Risk Assessment*. Office of Solid Waste and Emergency Response. April 17.

[19] U.S. Department of Housing and Urban Development (HUD). 1995. *Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing.* June.

Organics. Organics may include VOCs (e.g., TCE), SVOCs (e.g., PAHs), PCBs, and fuel oil constituents. Volatile organics can introduce the inhalation pathway via exposures directly on site or from ground water transport to shower water supply. Individuals may be exposed to organics via ingestion or dermal contact with contaminated water or soil. Although organic contaminants are not usually dominant at mine waste sites, when they are present they may introduce significant risks that must be considered in the assessment. PCBs and asbestos may also be present at abandoned facilities.

8.5.2 Exposure Assessment

This section discusses some unique issues associated with assessing exposures to humans at mine waste sites. Exposure pathways and sources include inhalation of fugitive dust, soil ingestion, dermal contact with soil, indirect exposure through plant and animal uptake (and subsequent consumption by humans or animals), and ingestion of and dermal contact with contaminated ground water. Risk assessors may find useful information for assessing indirect exposures in RCRA guidance[20]. Mining pits, shafts, and boreholes may provide conduits through which groundwater contaminants migrate from shallow to deep aquifers that may contaminate drinking water. Recreational surface waters used for fishing and swimming can be contaminated from storm water run-off, leaching from waste piles and ground water to surface water migration routes. Plumbing, occupational exposure, and home hobbies should also be assessed as potential sources of lead in evaluating overall community exposure potential, as well as the individual level.

Measurement of Indoor Dust and Outdoor Soil and Dust. Much of the exposure to site-related metals may occur from contact with indoor dust, and outdoor soil and dust. In sites with current residential use, site specific characterization of contaminants in indoor dust may provide valuable information regarding the sources of contamination and significantly influence remedial or removal activities. For example, the presence of lead-based paint, if determined to a source of contamination, could affect remedial or removal activities.

The Integrated Exposure Uptake Biokinetic Model (IEUBK). The U.S.EPA uses the IEUBK model to predict childhood blood lead concentrations at lead contaminated sites. The IEUBK uses a predictive, integrated, multi-source and multi-exposure route approach to estimate the probability of exceeding user-chosen blood lead concentrations. The model results assist the site manager in developing final cleanup goals which are protective of the typical child. The model provides soil lead concentrations that represent the 95% upper confidence limit on the mean soil lead concentration goal. The IEUBK model should not be used for predicting blood lead concentrations in populations other than children who may be chronically (greater than 90 days) exposed to lead contamination. The TRW (or regional risk assessor) should be consulted to ensure the consistent and appropriate use of the IEUBK model. The LSW has prepared risk management position papers to provide guidance to ensure consistent management at mine waste sites.

The 400 ppm level of concern, presented in the Lead Directive, was derived using the IEUBK model in conjunction with a set of default assumptions. Site-specific data or default parameters under appropriate circumstances may be substituted. Contact the TRW (or regional risk assessor) for assistance.

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[20] U.S. Environmental Protection Agency (EPA). 1994. Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities, Draft. April. EPA/530/R-94/021.

Estimating Adult Exposures. A methodology for assessing adult lead exposures is available[21]. In this methodology, soil/dust exposures to the adult female are evaluated and the blood lead concentration in the fetus of the pregnant adult female are estimated.

8.5.3 Toxicity Assessment

Because mine waste sites can be very large and contaminant concentrations heterogeneous, several different exposure scenarios may be indicated. Based on current or proposed site use, it may be appropriate to develop exposure point concentrations which permit evaluation of acute as well as chronic toxicity. In EPA Superfund risk assessments both cancer and non-cancer health effects should be evaluated for all contaminants as well as the risks of exposures to mixtures. Guidance is available for applying toxicity values from EPA's Integrated Risk Information System (IRIS)[22] on the World Wide Web at the following address: http://www.epa.gov/iris/.

8.5.4 Health Studies

In addition to baseline risk assessment activities or removal risk assessment activities, mine waste sites may have coinciding epidemiologic or human health studies. Such studies do not replace the need for risk assessment, and are only useful where the data provide sufficient resolution for documenting both the presence and absence of exposure or adverse health. Results of human health studies may be used in developing a site cleanup strategy responsive to the community's health protection needs. Occasionally, the results of community health studies may reveal an imminent health threat and trigger a removal action. Health studies have been conducted by the PRP, the Agency for Toxic Substances and Disease Registry (ATSDR), local health districts, and state health departments.

If a related health study is to be conducted, EPA should be involved in both the design of the study and the final interpretation of study results. During the scoping of the health study plan, the community's ability to implement a health program should be taken into consideration. All technical (but not managerial) analyses associated with the health study should generally undergo peer review. In lead risk assessments, structural equation modeling of the health study results may help distinguish the contributions of different sources of human exposure. However, structural equation modeling is resource and time intensive; it contains variability and uncertainty, and potential benefits should be carefully weighed against the cost before proceeding. Structural equation modeling may also discriminate among various activities which influence human activity patterns and therefore exposures. For example, health intervention and education, or even an increased awareness of contamination, commonly result in avoidance behaviors (e.g., increased hand washing and dust removal or using alternate play areas) which could result in decreased exposure. Although these are neither consistent nor permanent remedies for reducing or eliminating exposures, such activities can influence the results of health studies and may be identified by structural equation modeling.

In some cases, results from health studies based on children’s blood lead analyses have not been the same as IEUBK model predictions. There are several adequate scientific explanations for this observation which the risk manager may choose to verify through further investigation. The TRW or regional risk assessor can provide assistance in both the design of blood lead studies and in further investigations. Health studies for lead exposures have been conducted for the following Superfund mine waste sites: Bunker Hill in Idaho, Coeur d'Alene

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[21] U.S. Environmental Protection Agency (EPA). 1996. *Methodology for Assessing Risks Associated with Adult Exposure to Lead in Soil.* Technical Review Workgroup for Lead. Office of Solid Waste. October.

[22] U.S. Environmental Protection Agency (EPA). 1993. *Use of IRIS Values in Superfund Risk Assessment.* PB93963360.

Basin in Idaho and California Gulch in Colorado. Health studies for arsenic exposures have been conducted at Anaconda site in Colorado and Asarco/Tacoma site in Washington state (these sites included smelters).

8.6 Probabilistic Analysis

All risk assessments, both ecological and human health, should present an analysis of uncertainties associated with the risk evaluations. One approach to quantitatively address uncertainties is probabilistic analysis. Monte Carlo simulation, a type of probabilistic analysis, produces multiple risk descriptors instead of single numerical values to provide a range of risk estimates. Monte Carlo simulation calculates outcomes based on those situations with inherent variability and informational uncertainty. It also can present the degree of uncertainty quantitatively. Probabilistic analyses should only be applied when critical parameters have valid distributions of values available and when the parameters of concern effect a significant impact (as determined through sensitivity analysis) upon the risk results. A sensitivity analysis of parameters and range values should be presented. A primary difficulty in using probabilistic analyses in risk assessment is the ability to identify relevant databases for the development of appropriate distributions. Some guidance on the use of probabilistic analyses in risk assessment is available from EPA[23] [24]; regional guidance may also be available.

8.7 Risk Characterization

The risk characterization section of the risk assessment encompasses the presentation of ecological and human health risks in the context of their magnitude, significance, uncertainty, and implications for current and future site uses. It is a critical point in directing remedial action plans and hence, must be comprehensive and clear. The EPA Administrator's 1995 memoranda on risk characterization, cited above, explain these concepts in more detail. These memoranda also recommend that risks be provided in terms of a range from average exposures to upper bound exposures.

8.8 Risk Communication

A plan for risk communication should be developed simultaneously with scoping and work plan development. The plan should not only consider residents, landowners, and trustees, but should also include other stakeholders in federal, state and local agencies (including EPA regional offices). Information regarding community relations is provided in Chapter 6 of this document. Because PRPs may be involved in CERCLA activities in more than one EPA region, communication among site managers and risk assessors in different regions is important.

Communication strategies should be further coordinated between EPA and the PRPs. In some cases the PRPs may sponsor a health study on area workers or community residents. In such situations, it is essential that communication of risk and health information provided simultaneously by EPA and the PRP should strive to minimize confusion and stress on the recipients of this information.

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[23] U.S. Environmental Protection Agency (EPA). 1992. Memorandum from F. Henry Habicht regarding *Guidance on Risk Characterization for Risk Managers and Risk Assessors.* Office of the Administrator. Washington, DC. February 26.

[24] U.S. Environmental Protection Agency (EPA). 1997. *Guiding Principles for Monte Carlo Analysis.* EPA/630/R-97-001, March 1997.

8.9 Removal Actions

Risk assessments that support removal actions are usually separate from the baseline risk assessment for the longer term cleanup decisions; however, such risk assessments may help to direct, and possibly become a part of, the baseline risk assessment which supports the remedial investigation. Because the time frame of a removal action is rapid, so is the accompanying risk assessment. Consequently it commonly focuses on one or a limited number of contaminants and exposure pathways. It may account for only a human receptor group or only ecological receptors, or it may address both together. For example, risk of a catastrophic or a large scale event affecting critical ecological habitat may require immediate action, supported by an abbreviated but adequate risk assessment. For large and complex sites, once a removal action and supporting risk assessment are completed, in most cases a baseline risk assessment will be required for the overall site.

The decision to implement a removal action or a remedial (long term) action is a risk management issue. Although not part of risk assessment, information regarding educational and health intervention programs are included here because it specifically addresses the exposure and toxicity issues discussed in this chapter. Educational and health intervention programs can be an integral part of site management strategies. If communities are educated they can help to protect themselves while final cleanup actions are selected and implemented. Therefore local and state health departments should be consulted early in the process to recommend strategies for achieving early risk reduction. ATSDR can also be a partner in these efforts.

8.9.1 Health Effects

The health effect of concern for a removal action may be based on a chronic health effect that adversely affects a large number of people (or ecological receptors) or a particularly sensitive group (e.g., young children). It is also possible that the health effect of concern for a removal action may be based on acute adverse health effects requiring more immediate medical intervention. In contrast, the baseline risk assessment conducted during the remedial investigation may need only to focus on a long term health effect. At present, EPA does not have a database that provides acute human health toxicity criteria analogous to the Integrated Risk Information System (IRIS), which provides chronic human health criteria. Site managers and risk assessors should determine if particular acute toxicity criteria have already been adopted in their region, or may coordinate with regional toxicologists to develop their own criteria, or consult with the Superfund Technical Support Center at the National Center for Environmental Assessment in Cincinnati.

8.9.2 Risk Management Considerations

During the initial scoping, work plan development and sampling and analysis plan for the removal action risk assessment, the site manager and risk assessor should consider needs for risk evaluations which may follow the removal activity. To the extent possible, removal, site investigation, and long term cleanup activities should be coordinated and complementary. This will help to avoid redundancy, promote efficient use of resources, and ensure that no contaminants or exposures are inadvertently omitted from the risk evaluation.

In planning these efforts, recognize that education and health intervention programs have limits. They cannot protect everyone, and the protective benefits can be lost if the program should become ineffective. Such programs are best utilized early in the process of mitigating risk at a site. In general, EPA recommends that engineering controls be the principal tool for risk reduction for final site management strategies because it provides a more permanent response than ordinary reclamation activities or transient behavioral modifications. Local health officials can be instrumental in identifying particular segments of the community that may be the most vulnerable. They can help focus targeted cleanup actions where education and health intervention cannot be relied upon to provide the needed protection to vulnerable members of the community. Health intervention can be an important component of an overall site management strategy.

8.10 Sources of Additional Information

Additional information on the risk assessment process can be found at various EPA websites, including http://www.epa.gov/oerrpage/superfund/programs/risk/index.htm, which discusses risk assessment in the Superfund program. On this webpage there are links to webpages that discuss human health risk assessments, ecological risk assessments, the “tools of the trade”, and forms to contact EPA with specific questions.

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Chapter 9
Site Management Strategies

9.1 Introduction

This chapter presents options that a site manager may consider for managing risk at abandoned mining and mineral processing sites. The site manager may be a State, Federal, or local authority or a private landowner and is most likely managing the site under a number of regulatory and non-regulatory programs. As with any remediation project, strategic planning is critical in abandoned mine characterization initiatives as well as clean-up activities. As part of this strategic planning, the site manager, depending on the specific statutory authority used, the level of resources needed to protect human health and the environment from impacts from an abandoned mine, and the level of resources needed to address those impacts must strike a thoughtful balance in establishing an effective site management strategy.

9.2 Managing for Risk Reduction

Generally, the ultimate goal of all characterization and clean-up activities at abandoned mine or mineral processing sites is the reduction of risk. As discussed in Chapter 6--Scoping Studies, the broad project goals for an abandoned mine-site investigation are to provide the information required to characterize the site and define the risks, and subsequently to develop a program to mitigate risks to human health and the environment.

Risk is comprised of three elements: a source, a receptor, and an exposure pathway by which the receptor is exposed to the hazards from the source. The following describes an example of these elements at mining sites.

> **Source.** At an abandoned mine site, the source may be a waste unit, such as a tailings impoundment, an area of contaminated soil or sediment from which contaminants may be released, or the actual mine pit or underground workings.
>
> **Exposure pathways.** The classic pathways for exposure at an abandoned mine site are transport via air (e.g., fugitive dust), ground water (e.g., contaminated plumes), or surface water (e.g., run-off). There are situations at mine sites wherein the pathway is a flow of solid (e.g., waste rock pile slump) or semisolid (e.g., tailings released from an impoundment) waste materials released from a waste unit.
>
> In addition to these types of exposure pathways that take the hazard from the source to the receptor, the receptor may actually come to the source for exposure (direct contact). Examples of this include migratory wildfowl landing on contaminated ponds or children playing in contaminated soils; both situations have been observed at abandoned mine sites.
>
> **Receptors.** Historically, the primary receptors of concern at abandoned mine sites have been humans. This includes people living or working at the mine site, visitors to the site, and people living downgradient of the site.
>
> Additional receptors now also drive the site manager’s response, including aquatic species (e.g., fish and invertebrates); terrestrial wildlife (e.g.; invertebrates, birds, and mammals), and floral populations. Often at abandoned mine sites these environmental receptors have been affected in the past and may no longer be present at the time the

actions are taken. Furthermore a whole new ecosystem may have been created by the changes at the mine site. In other cases, for example, where a threat of release is present (e.g., an abandoned tailings dam that about to fail), the floral, terrestrial, and aquatic populations may be in actual and imminent risk of impact.

The importance of using risk-based goals and objectives in developing the risk reduction strategy lies in the ability to reduce risk by addressing all or any one of the risk elements. A hazard from a source that has limited pathways to a distinct receptor population may be controlled simply by eliminating that pathway. For example, an area of metal-contaminated soil may have only fugitive dust or direct exposure as its pathway to any receptor; a covering of clean soil and sod over the soil may virtually eliminate this pathway. While this example does not account for the potential for soil biota to move the contaminants into the food chain, the reduction of major risk pathways (i.e.; fugitive dust and direct exposure) may be considered sufficient for the goal of minimizing risk.

In more complex cases commonly found at abandoned mine sites, the site management strategy must address the source, pathway, <u>and</u> receptors; and most likely multiples of each. For example, both a mine pit and a tailings impoundment may be active hazard sources, while fugitive tailings dust, metal-contaminated groundwater, and acidified surface water may be moving the hazard offsite, thus impacting human and environmental receptors.

To complicate the strategy more, the historic nature of many abandoned mine sites means that exposures have been occurring over time and cumulative effects may need to be taken into account. For example, human populations may have bioaccumulated contaminants. Likewise, ecological resources may have been severely impacted to a point that they are no longer present. An example of this is the effect that dusts laden with zinc, a phytotoxin, have had in eliminating vegetation downwind from certain historically active pyrometalurgical operations. Other examples may be fish populations eliminated from surface waters impacted by acidic or toxic runoff from abandoned mines.

9.3 Categories of Activities that Address Risk Elements

In devising a response strategy to minimize risk, site managers should address the different elements of risk (i.e., source, exposure pathway, and receptor) using one or more of several broad categories of response actions. A variety of actual technological applications, engineering controls, or other activities may be used within each of these response categories. These technologies are discussed in Chapter 10 of this handbook.

Managing the Source. The source of contamination may be addressed by reducing, either in part or entirely, the actual source material through removal (e.g., excavation and removal of chemical-containing drums) or certain types of treatment (e.g., reprocessing of tailings). Because of the large volume of source material (e.g., tailings, waste rock, and smelter slag) that may be of concern at abandoned mine sites, source removal and/or treatment is often infeasible, thus requiring the site manager to strategically focus on collection, diversion, and containment (e.g., capping) activities.

Managing Exposure Pathways. Controlling exposure pathways at abandoned mining and mineral processing sites may be performed by implementing a variety of collection, diversion, or containment activities. These engineering controls often take the form of some sort of capping (e.g., preventing air release or direct contact), damming (e.g., stopping/diverting surface water runoff), or constructing slurry walls (e.g., groundwater management).

An additional management strategy and one of particular importance to managing abandoned mines is control of waste management units (e.g., shoring up tailings impoundment dams or waste rock side dumps that are in danger of failing). This effort prevents the transport of waste materials to new, non-managed locations, as well as preventing the contamination of soil and sediment, wetlands, surface water, and groundwater.

In addition to the control, diversion, and containment responses, exposure pathways may be managed by cleaning up the contaminated media, especially groundwater and surface water which are active transport media (certain contaminated media, such as soil and sediment, are more often considered sources from which air and water may be contaminated and contaminants subsequently transported).

Managing the Receptor Exposure. Controlling the hazard to receptors, whether human or environmental, may include a variety of risk abatement or remediation activities. Individuals may be removed (e.g., evacuated or relocated) if exposure pathways or sources cannot be addressed, this is uncommon. Typically this action is not performed unless extremely high risk is present, a situation not typical of abandoned mine sites. In fact, at many large Superfund mine sites, residents live within the sites and are expected to remain. This presence of human populations, however, may suggest that health intervention and education should be considered to manage exposure until sources and exposure pathways have been controlled.

Similarly, in the case of environmental receptors, population studies may be performed to assess the impacts and risk to the local flora and fauna. In cases where the environmental receptors are significantly reduced or eliminated by historical exposure, the environmental populations may be reintroduced (e.g., restocking, revegetating) or habitat reestablished such that natural repopulation may occur. An example of the latter is stream reconstruction, which is common in parts of the West, during which watersheds are returned to their natural states (e.g., heavy sedimentation removed, riffles and other structure rebuilt, associated wetlands reconstructed). Note that certain stabilization and media cleanup activities may be used to focus on wildlife rather than human health. Examples of this are wildlife fencing to route migratory mammals around mine areas, or draining or netting contaminated ponds to keep waterfowl from the water.

9.4 Time-Based Responses

Armed with the understanding of the categories of responses employed to address specific risk elements, the site manager should further develop the strategic management plan by incorporating the factor of time. In general, site managers should first consider whether any time-critical actions are necessary. If the time critical actions do not completely minimize the risk or are not selected, the site manager should then design a long-term response to remediate the site, and determine whether any expedited response action may be appropriate in the interim (i.e., while long-term response are studies and selected). These three time factors are described as follows:

Time-critical actions. These are immediate actions necessary to address an actual or threatened release. These typically involve removing or stabilizing a threat to human health or the environment.
Interim responses. These are activities that are not time critical but for various reasons (e.g., community needs/desires, because of risk abatement, or to address new findings) need to be performed before a formal study and remediation can be completed. Typical of an interim action are stabilization activities or health-based expedited response actions.

Long-term responses. These responses typically include comprehensive site characterization and evaluation of a variety of long-term clean-up activities. This type of action often requires significant time for the characterization step and to address long-term remediation needs (e.g., permanent reduction of toxicity, mobility and volume of contamination through treatment).

9.4.1 Time-Critical Actions

The first consideration for addressing contamination is the determination of whether or not any immediate threats exist at the mining or mineral processing site. Immediate threats may be an actual, ongoing, or threatened release. Should some immediate threat be identified, the site manager should consider taking action to reduce the immediate risks.

Time-critical actions are characterized by a need for a rapid response to address the immediate threat. Expedited characterization and incremental cleanups are the norm. Under certain regulatory scenarios, these actions are mandated to be short term. Although generally short term, under certain circumstances these actions can be extended. States may use time-critical actions under their own jurisdiction in order to address an immediate threat to its citizens or resources.

Characterization activities, while expedited to address the circumstances, are just as important in planning for time-critical actions as for long-term cleanup actions. The evaluation of threat includes some form of risk analysis, either formal or estimated under the auspices of "best professional judgement." This evaluation should take into account the potential for release (a moot point if the release is on-going), the potential for migration, and the presence and vulnerability of the receptors. Characterization activities potentially include monitoring, assessment, evaluation, and other information gathering activities.

Highlight 9-1
Butte and Walkerville

CERCLA removal actions have been extensively used at the Silver Bow/Butte NPL mine sites. Time-critical removal actions begun at the site in 1988 were based on two facts. First, the cities of Butte and Walkerville are partially located within the site boundaries so exposure potential was high; second, elevated levels of lead and arsenic were detected in the mine waste and in residential yard soils. Based on the potential health effects from the lead and arsenic, EPA believed it was essential that the waste dumps be removed from residential neighborhoods *quickly* rather than waiting for the long term remediation effort to unfold.

Once an immediate threat is identified and/or confirmed, a number of actions may be taken to reduce the risk posed by that threat. Risk reduction activities may include removal or stabilization activities such as removal of sources materials (e.g., excavation and disposal of contaminated materials or waste), removal of contaminated media (e.g., removal of soil contaminated by metals from smelter emissions), reinforcement of containment units (e.g., shoring up tailings dams in danger of failing), or construction of containment structures (e.g, damming ditches or waterways to create reservoirs to contain contaminated runoff). Highlight 9-1 illustrates the use of removal activities in the Butte and Walkerville mining areas in Montana.

With increasing frequency, site managers are likely to be asked to address impacts from abandoned mines sites that pose an immediate risk to the environment. Highlight 9-2 is a brief discussion of how time-critical action in the form of release containment was used at the Talache Mine Site in Idaho.

Highlight 9-2
Talache Mine Site

In May, 1997, a large tailings pile failed at the Talache Mine in Idaho (last operational in the 1960's), releasing tailings containing high concentrations of arsenic and other heavy metals. The tailings washed over and impacted approximately 45 acres of woodlands, 25 acres of wetlands, and 3,000 feet of stream bed. IDEQ, initially took the lead in directing the clean-up of the site, by entering into a “consent decree” with the landowner. Among other stipulations, the landowner was required to immediately implement (during the summer of 1997) a number of “interim corrective actions” to help prevent the migration of additional tailings into the creek the following spring.

It should be noted here that CERCLA also gives EPA the authority to address threats at sites that are not closed or abandoned. This may be of particular importance in the mining sector where mine sites may be inactive rather than abandoned because of the economics of the metals markets. Should a release be justifiably regarded as imminent or substantial threat of release (i.e., a tailings dam failure pending), a Federal or a State agency may step in and take time-critical action to mitigate the risk.

9.4.2 Interim Responses

After considering time-critical activities, site managers should consider whether any opportunities exist for conducting activities that, while not time critical or directed at eliminating the source of contamination, may temporarily decrease exposure from certain pathways. Interim response actions may take any number of forms depending on the needs of the site manager to control or mitigate a situation.

Control, diversion, and containment activities typically focus on controlling exposures or the migration of a release. These activities may be traditional engineering controls (e.g., slurry walls, caps) or may utilize less traditional means (e.g., phytostabilization--see Highlight 9-3). These actions do not necessarily result in a facility being returned to ambient conditions; contamination may still be present and additional investigations or remediation may be required. As long as the containment measures are maintained, however, stabilized facilities commonly do not present unacceptable short-term risks to human health or the environment. This allows site managers the opportunity to shift their resources to health or environmental concerns elsewhere on the site (See Exhibit 9-1 for a review of EPA’s RCRA Corrective Action program’s Stabilization Initiative).

Highlight 9-3
Phytostabilization

An example of stabilization is phytostabilization, the planting of tolerant grasses on tailings to reduce or eliminate contaminated fugitive dust emissions. This process is considered a stabilization activity because the contaminants are still in the tailings impoundment and the grass does not serve as an isolating cap. The impacts on downwind receptors from the fugitive dust are, however, reduced or eliminated.

Exhibit 9-1. RCRA Perspective

The Program	EPA Office of Solid Waste Corrective Action program
The Problem	Early implementation of the RCRA Corrective Action program focused on comprehensive cleanups at a limited number of facilities. These final cleanups were difficult and time- consuming to achieve. The emphasis on final remedies at a few sites diverted limited resources from addressing releases and environmental threats occurring at many other sites.
The Need	EPA sought to achieve an increased overall level of environmental protection by implementing a greater number of actions across many facilities rather than following the more traditional process of pursuing final, comprehensive remedies at a few facilities.
The Solution	In 1991, the Agency established the Stabilization Initiative as one of the primary implementation objectives for the Corrective Action program.
The Goal	EPA seeks to increase the rate of corrective actions by focusing on near-term activities to control or abate threats to human health and the environment and prevent or minimize the further spread of contamination.

Whereas the goal of control, diversion, and stabilization activities is to control or abate threats to human health and the environment and prevent or minimize the further spread of contamination, Expedited Response Actions (ERAs) may go beyond that goal in that they may include programs to address the actual health or environmental impacts caused by the contamination at issue. A leading example is the lead monitoring and abatement program put in place as part of the Superfund response activities at the Silver Bow/Butte NPL mine site in Montana (See Highlight 9-4). In this particular case one of the potentially responsible parties (PRPs) funded the program. In other cases (e.g., in the absence of any established PRPs), the State or land management agency may need to establish the funding.

Because of the nature of ERAs in addressing health or environmental impacts during an interim period while final action is being formulated and evaluated, they may often run concurrent to risk assessments done as precursors to full-scale remediation. It is important that the ERAs be a component of, or at least consistent with, anticipated final remedies.

Highlight 9-4
Butte/Walkerville ERA Action

In 1994, EPA, in conjunction with the State of Montana and the City of Butte, MT, conducted an Expedited Response Action (ERA) to address elevated levels of lead in residential areas of the City of Butte and the Town of Walkerville. The ERA is a multi-pathway approach which includes: a blood lead surveillance for children less than 72 months old; a lead education/ awareness program for the communities; identification/ monitoring of specific lead sources including lead paint, indoor dust, soil and drinking water; abatement/mitigation of identified sources of lead; establishment of a Lead Advisory Committee; and the cleanup of source area (waste rock dumps and other related mine waste) in residential areas.

This ERA was necessary because a ROD would not be completed until 2001 and there was concern about the elevated blood leads in Butte and the potential for exposure to children from lead sources. This five year project will be evaluated in the Record of Decision (ROD) for the site in 2001 to determine if these actions are addressing the lead sources on this site.

9.4.3 Long-Term Responses

The third strategic consideration for mine-site cleanup is long-term remediation and restoration. These actions are not time-critical and, while linked to or consistent with interim measures, they are not interim in nature. Long-term responses are the final comprehensive cleanup, or if cleanup is deemed unnecessary or uneconomical, the final stabilization and monitoring efforts. Long-term responses also include restoration activities such as revegetation, rebuilding of wildlife habitat, and restocking of fish and wildlife.

The framework of the long-term response varies depending on regulatory and programmatic requirements, the site specific conditions, and the degree of risk posed to human health and the environment. The following activities are generally undertaken to varying degrees.

Scoping. This is the initial planning phase during which available data is collected and reviewed, regulatory requirements evaluated, work teams and community involvement planned and any required health, safety and/or environmental impact plans developed (see Chapter 6 for more on this subject).

Site Characterization. During this phase additional information may be acquired by implementing sampling or analysis programs, or more regular long-term monitoring (see Chapter 7 for additional information regarding sampling and analysis).

- **Risk Assessment.** During this phase the risks to human health and the environment are evaluated (see Chapter 8 for additional information regarding risk analysis). In addition, a risk assessment may be used to evaluate the potential effectiveness of certain response activities.

Response Selection. During this phase the types of appropriate responses, both broadly (see Section 9.3 above), and specifically (See Chapter 10 for additional information regarding Remediation and Cleanup Options) are selected. Typically a range of responses are available and should be evaluated. Highlight 9-5 presents the CERCLA evaluation criteria, some or all of which may be included in non-CERCLA response evaluations, depending on legal requirements or site specific needs.

Response Evaluation. During this phase the responses that were implemented are assessed based on monitoring of the results.

Highlight 9-5
CERCLA Evaluation Criteria

CERCLA established specific statutory requirements for remedial actions; remedial actions must; 1) be protective of human health and the environment; 2) attain Applicable or Relevant and Appropriate Standards, Limitations, Criteria, and Requirements (ARARs) or provide grounds for invoking a waiver; 3) be cost-effective; 4) utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable; and 5) satisfy the preference for treatment that reduces toxicity, mobility, or volume as a principal element or provide an explanation in the ROD as to why it does not.

EPA, subsequently developed nine evaluation criteria to address these statutory requirements and the additional technical and policy considerations that have proven important for selecting among remedial alternatives. These criteria are: 1) Overall Protection of Human Health and the Environment, 2) Compliance with ARARs, 3) Long-Term Effectiveness and Permanence, 4) Reduction of Toxicity, Mobility, and Volume, 5) Short-Term Effectiveness (during implementation), 6) Implementability, 7) Cost, 8) State or Support Agency Acceptance, and 9) Community Acceptance.

Note that these elements of a long-term remediation effort are typical of the Remedial Investigation and Feasibility Study (RI/FS) and Record of Decision (ROD) development conducted under CERCLA NPL site remediations and the RCRA Facility

Assessment (RFA) and Corrective Measures Study (CMS) conducted under the RCRA Corrective Action remediations. As an alternative, a NEPA approach may be considered as presented in Exhibit 9-2 below.

Exhibit 9-2. Insight from a Similar Review Process

The Program	National Environmental Policy Act of 1969 (NEPA) review process
The Comparison	Because of the broad similarities between the remedial investigation/feasibility study (RI/FS) process and the NEPA review process, EPA has determined that CERCLA/SARA is functionally equivalent to NEPA.
Consideration Issues	Specifically, NEPA requires Federal agencies to consider five issues during the planning of major actions: 1) the environmental impact of the proposed action; 2) any adverse impacts which cannot be avoided with the proposed implementation; 3) alternatives to the proposed action; 4) the relationship between short and long-term effects; and 5) any irreversible and irretrievable commitments of resources which would be involved in the proposed action.
The Plan	Generally, the NEPA EIS process produces a document that is similar to a CERCLA RI/FS REPORT or Record of Decision (ROD). Both processes result in a decision document outlining the basis for selection of a preferred alternative

9.5 Strategic Planning Considerations

9.5.1 ARARs

Throughout any remedial action undertaken pursuant to CERCLA at an abandoned mining and mineral processing site, the site manager must consider compliance with CERCLA ARARs. ARARs are Federal, State, and local standards that are directly applicable or may be considered relevant and appropriate to the circumstances on the site. The National Contingency Plan, at 40 CFR 300.5, defines ARARs as:

> Applicable requirements-- Those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable.
>
> Relevant and appropriate requirements-- Those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that while not 'applicable' to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable or relevant and appropriate.

These standards are an inherent part of the scoping process, but also affect the long-term remediation, especially in the setting of cleanup standards as well as in meeting other environmental land use regulations (e.g., regulation pertaining to wetlands and water resources, floodplains, endangered and threatened species/critical habitats, coastal zones, cultural resources, wild and scenic rivers, wilderness areas, and significant agricultural lands).

The consideration of these ARARs should begin in the initial scoping process and be considered throughout design and implementation of the remedial action. Since many abandoned mining and mineral processing sites are located in areas that otherwise may not be considered industrial, some of the ARARs that need to be considered are not common to other sites. For example, a mining site which is located close to a wilderness area with habitat for endangered species and buildings that have been placed on the register of historic places may pose some significantly different management concerns than a site located in a major city. Because of this, the site manager must be aware of all potential ARARs and constantly considering other Federal, State, and local laws, regulations, and policies that will impact the actions at the site. A discussion of Federal ARARs can be found in Appendix D.

9.5.2 State and Other Agencies

The site manager needs to become familiar with the Federal, State, Tribal, and local land management agencies involved with mining and mineral processing site and affected resources. The site manager should identify the appropriate agencies and personnel who should be involved with the remediation process at the mining or mineral processing site as soon as possible. These agencies should be kept involved during planning characterization and clean-up activities that involve the area with which they are concerned.

The NCP in addressing removal actions, states that “EPA shall consult with a state on all removal actions to be conducted in that state.” The NCP clearly delineates state involvement in removal actions on 40 CFR 300.525, where the requirements are described and agreements with EPA discussed. A primary role described for states in 40 CFR 300.525(d) is regarding ARARs, where it states:

> States shall be responsible for identifying potential state ARARs for all Fund-financed removal actions and for providing such ARARs to EPA in a timely manner for all EPA-lead removal actions.

The NCP, in addressing remediation efforts, addresses requirements and agreements regarding state involvement in the RI/FS process, and the selection of remedy, and remediation design and remedial action (40 CFR 300.515(e-g)). State involvement the RI/FS process specific to ARARs are specifically Section 300.515(d), wherein subsections (1) and (2) address identification of ARARs and subsections (3) and (4) address waivers for ARARs.

The NCP, at 40 CFR 300.515(b) stipulate what requirements an Indian tribe must meet in order to be afforded the same treatment as states under section 104 of CERCLA.

9.5.3 Brownfield Initiative

An emerging management tool that may be available to the site manager is the Brownfield Initiative. This program encourages the cleanup and reuse of property that may require environmental cleanup before it can be redeveloped (i.e., brownfields). In the past, redevelopment of these properties often was avoided due to concern about environmental liabilities. Under CERCLA's liability structure present and future owners of contaminated properties can be held liable for cleanup even if they did not cause the contamination. The Brownfield Initiative is an emerging EPA effort to reduce, wherever possible, the barriers to redevelopment of contaminated properties. Where abandoned mine sites are in an area in which the property may have some redevelopment potential (e.g., the city of Butte, Montana has a number of abandoned mine sites within the city's boundaries), site managers should explore opportunities to use the Brownfield Initiative to assist their planning and remediation activities. Additional information can be obtained from the EPA Brownfields website, http://www.epa.gov/swerosps/bf.

9.5.4 Enforcement Considerations

Storm water runoff and discharge of other drainage from inactive and abandoned mines is often subject to State or Federal regulatory program requirements. Historically, these programs have been applied infrequently at inactive or abandoned mines. For example, while adits at inactive and abandoned mines often have discharges that are technically subject to CWA's NPDES requirements, most do not have a permit. Similarly, storm water discharge permits are required at many mines but have never been applied for or issued. In order to develop an effective site management strategy site managers should evaluate the discharges from a mine in the context of applicable State and Federal regulations. In those instances where the mine site has demonstrated contribution to environmental problems, enforcement of existing regulations should be considered an essential element of mitigating risk. Making owners and operators accountable for the discharges from their facilities should always be considered early in the site management strategy development process.

In those instances where current owners or operators are unwilling to comply with provisions of the CWA (or an applicable State statute) addressing mine-site run-off the site manager may want to consider enforcement actions to compel private parties to be responsible for the environmental impacts of their facilities. For those mine sites where the current owner is unable to meet current regulatory requirements the site manager may want to evaluate the feasibility of invoking State or Federal statutes that look to the historic site owner or manager to take responsibility for damaging releases to the environment. CERCLA is the Federal statute that may be applicable in such instances; many states have similar authorities.

Other regulatory programs (discussed in Chapter 11) may also be applicable to environmental concerns at mine sites. Such programs vary considerably among states. The site manager is advised to develop a site specific enforcement strategy in partnership with other Federal and State agencies having jurisdiction over releases from the site. Developing an effective enforcement strategy can be an effective way of meeting the environmental challenges presented by inactive and abandoned mine sites, and is fundamental to meeting public expectations that owners and operators take responsibility for their facilities.

9.6 Additional Sources of Information

Specific procedures and guidance for EPA's removal program are set forth in a ten-volume series of guidance documents collectively titled, *Superfund Removal Procedures* (The chapter on Removals in EPA's *Enforcement Project Management Handbook* summarizes this guidance.) These stand-alone volumes update and replace Official Solid Waste and Emergency Response (OSWER) Directive 360.3B, the single-volume *Superfund Removal Procedures* manual issued in February 1988.

More information on the RCRA Stabilization Initiative is available in the 1991 guidance memorandum, *Managing the Corrective Action Program for Environmental Results: The RCRA Facility Stabilization Effort*.

CERCLA Compliance with Other Laws Manual, Part I, Overview, RCRA, Clean Water Act, and Safe Drinking Water Act. U.S. Environmental Protection Agency (EPA), August, 1988. Washington, D.C. OSWER Directive 9234.1-01.

CERCLA Compliance with Other Laws Manual, Part II, Clean Air Act and Other Environmental Statutes and State Requirements CERCLA Compliance With Other Laws Manual Part II. U.S. Environmental Protection Agency (EPA), August, 1989. *,* Washington, D.C. OSWER Directive 9234.1-02.

Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. U. S. Environmental Protection Agency (EPA), October, 1988. Washington, D.C. Office of Emergency and Remedial Response.

EIA Guidelines for Mining, U.S. EPA, September 1994. Washington D.C. Office of Federal Activities.

Abandoned Mine Lands Preliminary Assessment Handbook, California Environmental Protection Agency, January 1998, Department of Toxic Substance Control.

Rules of Thumb for Superfund Remedy Selection, U. S. EPA, August 1997, Office of Solid Waste and Emergency Response

A Guide to Preparing Superfund Proposed Plans, Records of Decision and Other Remedy Selection Decision Documents, U. S. EPA, July 1999, Office of Solid Waste and Emergency Response.

Draft EPA and Hard Rock Mining: A Source Book for Industry in the Northwest and Alaska, U. S. EPA, November 1999, Region 10 Office of Water

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Chapter 10
Remediation and Cleanup Options

10.1 Introduction

The purpose of this chapter is to assist the user with a basic understanding of the types and availability of remediation technologies for mining and mineral processing sites. An understanding of the technologies available for mine site cleanup should help the site manager design a successful and cost-effective site management strategy.

Following a background section (Section 10.2) the chapter addresses four general topics: conventional technologies (Section 10.3); innovative/emerging technologies (Section 10.4); institutional (i.e., non-engineering) controls (Section 10.5); and sources of information regarding available technologies (Section 10.6).

Several appendices address innovative ways to clean up mining and mineral processing sites.

> Appendix B includes information and references addressing conventional and innovative remediation of Acid Mine/Rock Drainage.
>
> Appendix G provides more specific information regarding conventional mine remediation technology.
>
> Appendix H contains a discussion of innovative technologies in EPA's SITE Program that may be applicable at mining and mineral processing sites.
>
> Appendix K includes Information and references to Best Demonstrated Available Technologies (BDATs) as developed under the RCRA Land Disposal Restriction program.
>
> Appendix L presents efforts under the Mine Waste Technology program to find innovative remediation techniques.
>
> Appendix M includes additional remediation references, addressing RCRA Corrective Action program, general groundwater remediation, and remediation of cyanide heap leach operations.

10.2 Background

EPA, other Federal agencies, States, and Tribes have been managing investigations and cleanup activities at mining and mineral processing sites for over two decades. A large number of cleanup technologies have been successfully employed in the remediation and management of mining wastes. Because of the unique problems associated with the cleanup of mining and mineral processing wastes, new technologies, as well as new approaches to utilizing older technologies, are constantly being developed. Progress in understanding the behavior of contaminants has led to a series of new technologies being developed to address Superfund sites in general and mining and mineral processing sites in particular.

It is important that the site manager understand differences in the types of remediation technologies when evaluating them. Certain emerging technologies may be effective on a small scale but may not have been tested in a large-scale application. In other cases, the site manager needs to be aware that innovative technologies tested on one type of waste or media may not be directly applicable to other types of mining and mineral processing site waste or media. For the purpose of this discussion, two broad categories of technologies (i.e., conventional and innovative/emerging) characterize the universe of available and applicable remediation solutions. A third category, institutional controls, will be discussed as it relates to more traditional non-engineering controls.

Conventional Technologies. These are technologies with a successful track record in mine site cleanup, or technologies that are considered standard practice for mine site management. Such approaches have been widely applied to remediation of mining and mineral processing sites, as well as other waste management units. Lime treatment for acid wastes is an example of conventional technology.

Innovative/Emerging Technologies. Two types of technologies are included in this category. Innovative technologies include processes or techniques for which cost or performance data is incomplete and the technology has not yet been widely applied. An innovative technology may require additional field scale testing before it is considered proven and ready for commercialization and routine application at mine sites. Emerging technologies typically are even earlier in the development process. While they are potentially applicable at mine sites, additional laboratory or pilot-scale testing to document effectiveness is highly recommended. Current initiatives at EPA and other Federal agencies encourage the consideration of innovative/emerging technologies in site remediation.

Institutional Controls. For the purpose of this discussion, institutional controls are non-engineering site management techniques or strategies used to protect human health and the environment. Examples of institutional controls include fencing, zoning, health education, easements and other deed restrictions, and interior cleaning (i.e., removing contaminated dust from interior of residences). These controls can be an integral part of an overall site management strategy.

Information addressing the conventional and innovative/emerging technologies includes the following (described below): a basic description, a relative-cost analysis, and a general effectiveness evaluation as described below. Exhibit 10-1, found at the end of this chapter, summarizes this information.

> General cost information is presented as well in the form of a comparison to the other technologies; cost information is based on 1998 data. The costs are presented as low, medium, high, or very high. These costs do not include site-specific considerations that may significantly impact the costs, including availability of power, materials, manpower and/or equipment.
>
> The general effectiveness of the technology at mining and mineral processing sites is presented. Because the major contaminants of concern at most mining sites are metals, the effectiveness discussion for each technology on that contaminant class. Local site conditions can significantly impact the actual effectiveness at each mining and mineral processing site.

In many cases the remediation process will utilize multiple technologies to develop a treatment train (e.g., a series of technologies used in sequence in the remediation process). Conventional technologies, innovative/emerging technologies, and institutional controls may all be used in a integrated management strategy. As an illustration, a contaminated area may be bioremediated, with associated contaminated ground-water being pumped and treated chemically, followed by filtration, and solidification and landfilling of the sludge, utilizing fencing to restrict access to the landfill and contaminated area and creating an easement to access certain areas.

10.3 Conventional Technologies

The fundamentals of conventional treatment, collection and diversion technologies are discussed in this section. In addition, those management techniques that remove the contaminant from the site, such as the sale of useable materials or decontamination of structures, are included as conventional technologies.

10.3.1 Treatment Technologies

For the purpose of this discussion, treatment technologies are those technologies that either change the composition of the contaminant to form other compounds that are less dangerous to human health or the environment, or limit contaminant mobility by physical or chemical means.

Chemical Treatment. In chemical treatment, reagents are used to destroy or chemically modify organic and inorganic contaminants, converting hazardous constituents into less environmentally damaging forms. Typically, chemical treatment is used as part of a treatment train, either as a pretreatment technique to enhance the efficiency of subsequent processes or in post-treatment of an effluent. One of the common uses of chemical treatment at mining and mineral processing sites is the use of lime to neutralize acid rock drainage (ARD) and to precipitate the metals. The cost of chemical treatment ranges from low to high depending site conditions, including the chemicals that are used and the nature of the products that are produced by the chemical treatment. As an example, if the sludge that precipitates after the addition of lime is disposed as a solid waste, the additional cost of disposal would bring the cost into the high range. In many cases the operating and maintenance (O&M) costs will be significant over the life of the remediation.

Larger chemical treatment operations may benefit from a high density sludge (HDS) treatment system. A HDS process significantly reduces the volume of sludge compared to a basic lime treatment by recirculating sludge and lime. For example, at the Iron Mountain Mine site in California, a HDS treatment system reduced the costs associated with treatment by more than 15 percent while at the same time doubling the expected useful life of the on-site landfill and producing a more chemically and physically stable sludge.

Stabilization. Stabilization refers to processes that reduce the risk posed by a waste by converting the contaminants into a less soluble, less mobile, and, therefore, less hazardous form without necessarily changing the physical nature of the waste. [Site managers should be aware that the term “stabilization” is also used to describe interim remediation activities (e.g., capping) that may be used to stabilize a site in order to minimize further releases prior to actual clean up.] An example of stabilization as a treatment is the pH adjustment of a sludge which results in making the contaminants in the sludge less mobile. The cost of stabilization will be in the medium to high range depending on treatment required for stabilization. The effectiveness of stabilization is dependent on the nature of the materials to be stabilized and the subsequent storage or disposal. Cement-based stabilization is often used for many metals to comply with the treatment requirements of the Land Disposal Restrictions (LDRs).

Solidification. Solidification refers to processes that encapsulate waste in a monolithic solid of high-structural integrity. Solidification does not necessarily involve a chemical interaction between the waste and the solidifying reagents, but involves a physical binding of the waste in the monolith. Contaminant migration is restricted by vastly decreasing the surface area exposed to leaching and/or by isolating the waste within an impervious capsule. Encapsulation may address fine waste particles (microencapsulation) or large blocks or containers of wastes (macroencapsulation). There is, however, inherent risk that the stabilized solidified waste matrix will break down over time, potentially releasing harmful constituents into the environment. An example of the solidification technology involves the use of cement to solidify contaminants into a large block. The cost of solidification ranges from medium to high depending of the steps required to encapsulate the waste. A simple encapsulation into a large concrete block would be an example of the medium end of the cost range. The effectiveness of solidification is dependent on the potential for the solid to break down over time and allow the encapsulation to be breached.

Thermal Desorption. Thermal desorption refers to treatment alternatives that use heat to remediate contaminated soils, sediments, and sludges. Thermal desorption is used to separate a contaminant from the containing media. The off-gas from the desorption unit typically must be further treated. Temperatures utilized for thermal desorption of metals is high enough that other contaminants, such as volatile organic compounds, may actually undergo thermal destruction, as discussed below. Thermal desorption is not commonly used at mining and mineral processing sites since the common contaminants at these sites, metals, are not easily heated to their gas-phase. The cost of thermal desorption is in the range of medium to high and the effectiveness at most sites is poor since there may be only a limited quantity of chemicals in the soils that can be easily heated to their gas-phase.

Thermal Destruction. Thermal destruction is a treatment alternative that uses heat to remediate contaminated soils, sediments, and sludges. Thermal destruction typically uses higher temperatures to actually decompose the contaminants, potentially with no hazardous contaminant residues requiring further management. Thermal destruction is not commonly used at mining and mineral processing sites since the process does not destroy metals, the most common contaminant. The cost of thermal destruction is in the range of medium to high and the effectiveness is limited to those materials that can be destroyed.

Vapor Extraction. Vapor extraction is an *in-situ* process that uses vacuum technology and subsurface retrieval systems to remove contaminant materials in their gas-phase. Vacuum extraction of vapors from contaminated soils and subsurface strata has been successfully employed to remove volatile compounds from permeable soils. Typically, sites considered for vapor extraction-based technologies are those where chlorinated solvents or petroleum products, such as gasoline and other fuels, have spilled or leaked into the subsurface. Vapor extraction is not commonly used at mining and mineral processing sites since metals that are the typical target contaminant are not in a gas-phase in soil. The cost of vapor extraction is in the range of medium to high and the effectiveness at most sites is poor unless a significant quantity of chemicals are present within the soils in the vapor phase.

Solvent Extraction. Solvent/chemical extraction is an *ex-situ* separation and concentration process in which a nonaqueous liquid reagent is used to remove organic and/or inorganic contaminants from wastes, soils, sediments, sludges, or water. The process is based on well-documented chemical equilibrium separation techniques utilized in many industries, including the mining and mineral processing industry. In the mine-site remediation, one type of solvent/chemical extraction technology (i.e., leaching) is used extensively, primarily because of the application of accepted mining and beneficiation technologies to the remediation field. The cost of solvent extraction is in the range of low to high depending on site characteristics, which include: the media necessary to extract the contaminants, the system to recover the solution with the contaminants, the process to remove the contaminants from the solution, and the handling and disposal of the spent waste or soil. The effectiveness of solvent extraction is good if the contaminants can be extracted by the liquid reagent.

Soil Washing. The *ex-situ* process of soil washing employs chemical and physical extraction and separation techniques to remove a broad range of organic, inorganic, and radioactive contaminants from soils. The process begins with excavation of the contaminated soil, mechanical screening to remove various oversize materials, separation to generate coarse- and fine-grained fractions, and treatment of those fractions. Surficial contaminants are removed through abrasive scouring and scrubbing action using a washwater that may be augmented by surfactants or other agents. The soil is then separated from the spent washing fluid, which carries with it some of the contaminants. The recovered soils consist of a coarse fraction, sands and gravels, a fine fraction, silts and clays, and an organic humic fraction, any or all of which may be contaminated. The washed soil fraction may be suitable for redepositing on site or other beneficial uses. The fines typically carry the bulk of the chemical contaminants and generally require further treatment using another remediation process, such as thermal destruction, thermal desorption, or bioremediation. The costs of soil washing would range from medium to high similar to "soil flushing" discussed below, however the costs are impacted by the controlled method of recovering the liquid and the excavation costs to remove the soil. The effectiveness of soil washing is determined by the ability of the washing liquid to remove the contaminants.

Soil Flushing. The *in-situ* process of soil flushing uses water, enhanced water, or gaseous mixtures to accelerate the mobilization of contaminants from a contaminated soil for recovery and treatment. The process accelerates one or more of the same geochemical dissolution reactions (e.g., adsorption/ desorption, acid/base reactions, and biodegradation) that alter contaminant concentrations in ground-water systems. In addition, soil flushing accelerates a number of subsurface contaminant transport mechanisms, including advection and molecular diffusion, that are found in conventional ground water pumping. The fluids used for soil flushing can be applied or drawn from ground water and can be introduced to the soil through surface flooding or sprinklers, subsurface leach fields, and other means. When the contaminants have been flushed, the contaminated fluids may be removed by either natural seepage or a ground water recovery system. Depending upon the contaminants and the fluids used, the soil may be left in place after the soil flushing is completed. The cost of soil flushing ranges from medium to high depending on the means of applying the flushing fluid and the method of recovery of the fluids used. The effectiveness of soil flushing is dependent on the characteristics of the soil and the fluid used for flushing. If the fluid can mobilize the required contaminants and be recovered, the technology can be effective. There often is a problem, however, with either mobilizing the contaminants or recovering the fluid that limits the effectiveness. In contrast, another concern is that contaminants may be highly mobilized with the subsequent possibility of contaminating ground water.

Decontamination of Buildings. Decontamination of buildings and other structures through various extraction and treatment techniques may be necessary at certain mining and mineral processing sites. The purpose of decontaminating the structures may be to meet the requirements of historical preservation and/or to assist the community in attracting new industry. Decontamination may be as simple as pressure washing a building or more complex, involving partial removal techniques. As an illustration, if the contamination is a dust settled throughout the building, a simple washing may remove the contamination; if, however, the contaminant saturated wooden members of the structure, some of all the wood may have to be removed in order to decontaminate the building. The cost of decontaminating buildings and other structures is dependent on the techniques needed to complete the decontamination efforts. The effectiveness of decontamination of buildings is site specific and will be determined by what the contaminants are being addressed and how effective the technique is in removing them.

10.3.2 Collection, Diversion, and Containment Technologies

Collection, diversion, and containment technologies are used at sites where treatment technologies cannot control the contaminants to an acceptable level. These engineering controls include technologies that contain or capture the contaminants to reduce or minimize releases. This section discusses some of the containment technologies available to site managers.

Landfill Disposal. Landfills are waste management units, typically dug into the earth, but including above ground units that are not exposed on the sides (i.e., not freestanding waste piles), that accept waste for permanent placement and disposal. While landfilling is a conventional disposal technology, it has had its share of recent innovations. Landfills may be lined to contain leachate, drained with a leachate collection system, and capped. The cost of landfills can range from medium to high at mining and mineral processing sites depending on the site conditions that impact the design, including low permeability cover, low permeability liner, leachate collection, and leachate treatment. The O&M costs of leachate treatment or cap maintenance can be significant. The effectiveness of the landfill is dependent on the design. A landfill that can isolate the waste is effective. Should the cap or liner be breached, however, the effectiveness will be greatly diminished. On-site landfills should be designed to meet site specific cleanup goals and address applicable regulatory considerations.

Cutoff Walls. Cutoff walls are structures used to prevent the flow of ground water from either leaving an area, in the case of contaminated ground water, or entering a contaminated area, in the case of clean ground water. Types of cutoff walls include: slurry walls, cement walls, and sheet piling.

> **Slurry walls** are basically trenches refilled with a material (e.g., bentonite slurry) that combines low permeability and high adsorption characteristics to impede the passage of ground water and associated contaminants. The cost of slurry walls is in the medium range, with depth being a factor on the cost due to equipment limitations. The effectiveness of slurry walls is dependent on the ability of the wall to get a seal on the bottom (i.e., by contact with an impermeable soil or rock layer) to keep the ground water from flowing under the slurry wall. Similarly, effectiveness is affected by construction of the slurry wall with no gaps or other points for by-pass.
>
> **Cement walls** are similar to the slurry walls, except that instead of a low permeability clay-type slurry, a cement-based slurry is used. Construction may be by trench and fill as with the slurry wall construction. Alternately, construction may utilize a larger excavation in which forms are constructed to pour a concrete wall after which the excavated area around the wall is backfilled. The backfill may be with a high permeability material used to capture and channel the ground water flow (e.g., for recovery if contaminated, or to prevent its contamination). The cost of the cement walls is greater than the slurry walls especially if the wall is formed in place, with a cost range of medium to high. This increased cost however may buy an increase in effectiveness.
>
> **Sheet piling** is a technology that is often used to install a cutoff wall. Sheet piling has been used in the past to funnel ground water to a treatment cell for treatment and is regularly used as a temporary cutoff wall during the remediation period. The cost of the sheet piling is in the medium to high range, with the high range utilizing a better mechanism to seal the joints between the sheets. The effectiveness of sheet piling is similar to the slurry wall, however there is a greater potential of the wall to have leaks at the joints.

Pumping Groundwater. A pump-and-treat process for addressing groundwater contamination is a combination of an extraction technology (pumping) and a subsequent treatment technology; this discussion focuses on the pumping portion of the combination. The treatment, which can vary by contaminant, could be any of the other technologies discussed above. The pump-and-treat technology has been the preferred method of remediating contaminated ground water. The cost of the pumping portion can range from medium to high, including, but not limited to, the number and spacing of wells, the volume to be pumped, and the depth to ground water. The long-term effectiveness of this procedure is limited for certain contaminants, especially some metals, in certain soil types. Consideration must be given to such factors as desorption rates and chemical properties of the contaminants themselves.

Capping. Capping is typically used to cover a contaminated area or waste unit to prevent precipitation from infiltrating an area, to prevent contaminated material from leaving the area and to prevent human or animal contact with the contaminated materials. An example of preventing releases is the growing of vegetation on tailings to prevent fugitive dust from blowing off and being transported downwind. A example of preventing human contact is the removal and replacement of a specified depth of soil in a residential area which has been used to protect the residents from the contaminated subsoils.

Capping could include: surface armoring, soil/clay cover, soil enhancement to encourage growth, geosynthetic or asphaltic cover system, polymetric/chemical surface sealers, revegetation, concrete and synthetic covers. The cost of caps can range from low (e.g., planting grasses) to high (e.g., synthetic caps) depending on the cap selected. The cap may or may not be effective in achieving multiple performance objectives, for example; a cap designed to minimize erosion, however, may not be an effective cap to minimize infiltration and *vice versa*.

Detention/Sedimentation. Detention/sedimentation controls are used to control erosion and sediment laden runoff. “Treatment” generally consists of simply slowing the water flow and reducing the associated turbulence to allow solids to settle out. Settling may be allowed at natural rates; in other cases flocculants may be added to increase the settling rate. The settled sediments may be removed and disposed; if the sediment is contaminated then treatment may be required. The cost of detention and sedimentation is generally in the range of low to medium, depending on the O&M costs to remove the settled solids. The detention/sedimentation basins can be effective if they can be designed to allow the proper amount of settling time; however, in some cases the solids settle at a very slow rate and a portion of the solids leave the settling basin.

Settling Basins. Settling basins may be used to contain surface waters so that contaminated sediments suspended in the water column can be treated, settled, and managed appropriately. Dissolved contaminants and/or acid waters may be contained as well to allow for treatment or natural degradation (e.g., contained cyanide will degrade naturally). As the impoundment fills with the solids that have settled out, solids must be removed and disposed of in order for the impoundment to continue working effectively. The cost of operating settling basins is in the low to medium range, depending on the construction of the impoundment and dam. For example, a lined impoundment will cost more than an unlined impoundment. The O&M costs of the settling basin could be significant over the life of the basin to remove and dispose of any settled solids. Properly designed settling basins can be effective in removing suspended solids from surface waters.

Interceptor Trenches. Interceptor trenches are trenches that have been filled with a permeable material, such as gravel, that will collect the ground water flow and redirect it for either *in-situ* or *ex-situ* treatment. Interceptor trenches are often used to collect and treat ground water and prevent it from leaving a containment area, such as a landfill. The initial cost of interceptor trenches is low to moderate depending on the availability of materials. However, the O&M cost can be significant if the liquid flowing through the trench precipitates material that will plug the trench, thus minimizing the permeability and requiring the permeable material to be cleaned or replaced. Interceptor trenches are effective at capturing ground water flow if the permeability of the media in the trench is greater than the native material.

Erosion Controls. Erosion controls are those engineering controls used to eliminate or minimize the erosion of contaminated soils by either air or precipitation (i.e., stormwater or snow melt). Erosion controls include:

> **Capping or covers** (as discussed above), particularly in the form of revegetation, polymer/chemical surface sealers, armoring and soil enhancements. The caps or covers for erosion control, in general, are lower than the costs of caps to limit infiltration. The cost range of the erosion control caps is low to medium. The O&M costs of the cap could be significant, particularly if the cap or cover can be easily damaged. For example, if revegetation is selected, then the O&M costs will include revegetating areas where the vegetation does not grow, or is damaged by factors which could include natural conditions such as drought or insect invasion. The effectiveness of the caps or covers to prevent erosion is dependent on site conditions, however the caps or covers should generally prevent the erosion of soils by either water or air.
>
> **Wind breaks** are used to minimize the erosion of soils and dusts by the wind and can include planting of trees and other vegetation to reduce the wind velocity, and/or the installation of fences. The cost of wind breaks is generally in the low to medium range. The effectiveness of wind breaks is dependent on the prevailing wind. In general, wind breaks are not as effective at eliminating airborne dust as the caps or covers.
>
> **Diversions** (as discussed below) are used to control surface water around areas that have a high probability of erosion. An example of this would be construction of a diversion ditch to capture runoff which prevents the flow from reaching a steep slope, where it could cause erosion.

Diversions. Diversions are engineering controls that are used to divert ground water or surface water from infiltrating waste units or areas of contamination, thereby preventing the media from being contaminated and pollutants from leaching and migrating. Two types of diversions are run-on controls and capping:

> **Run-on controls** prevent surface water from entering waste units or areas of contamination and becoming contaminated. For example, surface waters may be diverted to avoid contact with stockpiled waste rock. This would prevent the water from becoming acidified. Examples of run-on controls would include retaining walls, gabion dams, check dams (both permanent and temporary), and diversion ditches. The costs of run-on controls are low to medium depending on the method used for the diversion. The use of run-on controls to divert surface water away from areas of contamination is effective in reducing the quantity of water that requires treatment.
>
> **Capping** is the placement of synthetic liners or impervious earthen materials (typically clay) to prevent precipitation from infiltrating waste materials or severely contaminated areas and leaching contaminants into the ground water. This allows water to be captured and diverted elsewhere. The cost and effectiveness of caps are discussed above.

Stream Channel Erosion Controls are used to minimize the mobilization and transport of contaminated sediments by streams within the site. At many mining and mineral processing sites, historic transport of contaminated sediment into the stream has occurred. Many sites have areas where these sediments have been deposited along stream shores and beds. Stream channel erosion controls can be used to minimize the remobilization and transport of these sediments, often during periods of high flows. Technologies to control stream channel erosion often include both erosion controls and diversions such as channelization or lining of stream channels, diversion dams and channels (construction of diversion dams and or channels to reduce flow to contaminated areas and ground water recharge areas, to reduce water velocity, trap sediment and divert clean water), riprap, and gabions. The cost of these controls can range from low (e.g., revegetation of stream banks) to high (e.g., diversion to an engineered channel) depending on the site conditions. Some of the technologies may be temporary until other remediations are completed. The O&M cost to the erosion controls could be significant, especially with damage from flood events.

10.3.3 Reuse, recycle, reclaim

Sale of Useable Materials. Sale of materials that can be utilized by other is another management approach that the site manager may employ. The useable materials could include: finished product in the unlikely case that any remains on site; supplies of materials that remained unused at the site; feedstocks, ore or concentrate that remains on site; demolition debris for reprocessing; and/or waste materials for reprocessing. The cost from this technology may be either low or positive. In evaluating the cost of selling useable materials, the cost should be compared to the cost of disposal to ensure that the cost of selling the material minus any money received is actually less than the cost of disposal. Recycling or reusing these materials is an effective means of eliminating contaminants, although there generally are limited materials that should be sold.

Remining/Reprocessing. Remining is the process of taking mine "waste" material and running it through a process to recover valuable constituents. Remining typically utilizes the same mining and beneficiation processes discussed in Chapter 3 to extract metal contaminants from tailings or other waste materials. For example, tailings may be reprocessed to recover metals that remain, by any or all of the following methods: gravity separation (if there is a difference in the specific gravity of the desired mineral and the rest of the tailings), flotation, or leaching.

The cost of remining/reprocessing may range from profitable to high depending on the cost of the remining/reprocessing minus the value paid for the metals or other materials. The "new tailings" can be placed in an engineered containment facility which generally is more desirable than the existing facility, thereby minimizing the potential of releases to the environment. The "clean tailings" may also have other beneficial uses, depending on the characteristics of the tailings. The effectiveness of the remining and reprocessing can vary significantly depending on the site. In general, however, it is very effective for the portion of the waste that is reprocessed.

10.4 Innovative/Emerging Technologies

The following treatment technologies are considered to be innovative/emerging technologies. The discussion is intended to provide examples; innovative and emerging technologies are continually evolving and information addressing these technologies will necessarily be obtained from individuals and organizations with ongoing characterization and remediation activities, investigations, or research.

Bioremediation, for the purpose of this discussion, refers to the use of microbiota to degrade hazardous organic and inorganic materials to innocuous materials. Certain bacteria and fungi are able to utilize, as sources of carbon and energy, some natural organic compounds (e.g., petroleum hydrocarbons, phenols, cresols, acetone, cellulosic wastes) converting these and other naturally occurring compounds to byproducts (e.g., carbon dioxide, methane, water, microbial biomass) that are usually less complex than the parent material. At metal contaminated sites, such as mining and mineral processing sites, the addition of biological nutrients has been demonstrated to stimulate natural microorganisms to operate a natural process for biological attenuation and stabilization of heavy metals. The cost of bioremediation is in the range of medium to high; as the technology evolves the cost may decrease.

Phytoremediation is the use of plants and trees to extract, stabilize or detoxify contaminants in soil and water. The phytoremediation process generally describes several ways in which plants are used to remediate or stabilize contaminants at a site. Plants can break down organic pollutants or stabilize metal contaminants by acting as filters or traps. The three ways that phytoremediation works are: phytoextraction, rhizofiltration, and phytodegradation.

> **Phytoextraction**, also termed phytoaccumulation, refers to the uptake of metal contaminants by plant roots into stems and leaves. Plants that absorb large amounts of metals are selected and planted at a site based on the type of metals present and other site conditions that will impact the growth. The plants are harvested and either incinerated or composted to recycle the metals. The cost of phytoextraction is in the low to medium range depending on site conditions and the costs of disposal of the harvested plant material. The O&M costs may be significant if the plants need to be harvested for many years. The effectiveness of phytoextraction has been good for some metals where there are shallow, low levels of contamination; the technology is, however, considered innovative for most metals.
>
> **Rhizofiltration** is used to remove metal contamination in water. The roots of certain plants take up the contaminated water along with the contaminants. After the roots have become saturated with metals, they are harvested and disposed. The cost of rhizofiltration is in the low to medium range depending on site conditions and the cost of disposal of the harvested plant material. The O&M costs may be significant if the plants need to be harvested for many years. The effectiveness of rhizofiltration is not yet determined as the technology is considered innovative.
>
> **Phytodegradation** is a process in which plants are able to degrade organic pollutants. Phytodegradation is not currently used for inorganic contaminants.

Vitrification. Vitrification is a solidification process employing heat to melt and convert waste materials into glass or other crystalline products. Waste materials, such as heavy metals and radionuclides, are actually incorporated into the relatively strong, durable glass structure that is somewhat resistant to leaching. The high temperature also destroys any organic constituents with byproducts treated in an off-gas treatment system that generally must accompany vitrification. The cost of vitrification is very high and has not been commonly used at mining and mineral processing sites. The effectiveness of the vitrification is dependent on the material that is treated. If a glass like product can be made, the ability to isolate the waste is very effective.

10.5 Institutional Controls

Institutional controls are non-engineered solutions (e.g., fencing and signing, zoning restrictions) that are used to protect human health and the environment by controlling actions or modifying behavior. Institutional Controls are part of risk management and a potential part of the response. Risk should be evaluated for present site conditions and the various altrnative future uses. It is in this latter element that the risk levels of specific future land uses and institutional controls can be evaluated. Where residential exposures do not currently exist and may not occur in the foreseeable future, institutional controls may be adequate to protect against human health exposures (though active remediation still may be required for environmental risks). In general, Institutional Controls can include, but not limited, a number of activities as described below. The user is advised to consult the Institutional Controls: A

Reference Manual, US EPA Workgroup on Institutional Controls - Workgroup Draft 1998 and/or Institutional Controls: A Site Manager's Guide to Identifying, Evaluating and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups, Draft March 2000, OSWER 9355.0-74FS-P, EPA 540-F-00 for further details on institutional controls.

Restricting Access is often used to minimize access to areas where there may be an exposure. Erecting fenced, posting signs, utilizing guards or security services, and using fines for unauthorized access all may assist in restricting access. The cost of fencing can be significant if the area is quite large and O&M costs can also be significant if the fences need constant maintenance to repair damage, either from natural causes or breaches. Fences can be effective at restricting access; they may, however, in some circumstances encourage the curious to trespass. The cost of posting signs is low and maintenance costs are generally low. Effectiveness of the signs, however, is generally poor. While fining trespassers may be utilized, the cost of enforcement may be significant if additional guards have to be employed. The levying of fines generally has a limited effectiveness.

Deed Restrictions/Notices place legal restrictions on the use of and transfer or sale of the property and provide the prospective purchaser with a notification of any requirements that must be met on the property. The cost of implementing the deed restrictions/notices is low. The effectiveness of any of these deed restrictions/notices depends on the support of the local government and/or the entity (i.e., easement holder) authorized to enforce controls. In addition, the motivation to enforce these regulations may diminish as time passes after completion of the cleanup.

Zoning or Other Regulations restrict activities that could cause an exposure. The local government must enact and enforce the regulations. The cost of implementing the regulation is low, however the costs of enforcing the regulations can be very expensive, especially to a local government that may be depressed (i.e., because of a reduced tax base from loss of the mining enterprise being addressed). The effectiveness of any of these regulations or zoning requirements depends on the local government and community. The motivation to enforce these regulations may diminish as time passes after the completion of the cleanup. Examples of regulations include: restricting use of off-road vehicles in an area where the use could damage the remediation and allow contaminants to be released by erosion (e.g., air or surface water); speed limits for unpaved roads to limit the amount of dust that would be generated; or load limits on roads to keep the surface from breaking down. An example of a zoning regulation would include a regulation that would keep areas of the mining and mineral processing site industrial or commercial.

Limited Future Development in a remediated area would require that future development not damage the remedy or increase the exposure. The cost of implementing this is low; as with the cost of zoning, however, it requires the community and local government to accept the limitations. The effectiveness of this control is dependant on the local government willingness to mandate and enforce limitations.

Regulatory Requirements are those requirements that are needed to keep the remedy in place. They can be very important at a mining and mineral processing site that includes a residential community. Examples of regulatory requirements include drilling permits, excavation permits, or construction permits in areas where there is contamination at depth. The permits would ensure that all activities where contaminated soils are exposed would follow certain procedures to minimize any exposure or re-contamination of clean soils. The costs of implementing and managing these procedures would range from medium to high depending on how the permits are issued and tracked. The effectiveness of this system depends on the source of funding for the permit process and the willingness of the community and local government to accept the requirements.

Procedures for Soil Disposal are a set of procedures to handle and dispose of any contaminated soils that are removed during normal activities, such as repairs to infrastructure (e.g., roads and utilities) and development and expansion of existing houses and buildings. The cost of these procedures will vary depending on requirements for handling and disposal. In general, the costs would be anticipated to be in the medium to high range. The effectiveness of these procedures is dependent on the acceptance of the community. If the procedures are considered to be onerous or difficult, they probably will not be effective.

Health Education Programs are used to inform and educate the community of the risks from the contaminated media. This can be a difficult task in an established community that does not perceive a risk. The costs of the health education program can range from low to high depending on what is included in the program. For example, if health intervention and monitoring are included as part of the program the costs will be high. The effectiveness of the health education program is dependent on community acceptance.

Interior Cleaning is a more effective way to remove contaminated dusts and soils from a house. However, the cost of the cleaning every home can range from medium to high. If the sources of the dusts and soils have not been removed, the home can become recontaminated in a short time. Programs to encourage interior cleaning can assist in reducing the risk from contaminated dusts and soils that have entered the home, either via airborne dust or tracked in by people or animals. An example of such a program was employed at the Bunker Hill Superfund site in northern Idaho in which the program loaned vacuums with HEPA filters to local residents. The costs of the programs are generally low, however the effectiveness varies based on community acceptance.

10.6 Sources of Information and Means of Accessing Information Regarding Available Technologies

Identifying innovative technologies or cross-applying technologies from conventional sites to mining and mineral processing sites can be difficult as the technologies and their applications are constantly changing and improving. It is extremely important that the site manager know how to access information regarding these technologies. One goal of this handbook is to provide the site manager with a roadmap to this information; the second goal is to encourage the site manager to build a network of contacts. A network of individuals and organizations that can answer questions and provide information regarding technologies is critical in the development of remediation alternatives. This network may include government, academic, and private sector entities. Former and current mine-site remediation managers are an extremely valuable source of practical information regarding problems encountered at mining and mineral processing sites and solutions, including both successful and unsuccessful methods. Program and enforcement staff at EPA Headquarters and the ten EPA Regional Offices, as well as State offices can assist site managers with understanding and addressing a variety of issues related to Superfund, Applicable or Relevant and Appropriate Requirements (ARARS), other standards, limitations, criteria, and other programs and initiatives. Other Federal agencies, including the Department of Energy, the Department of Defense, the Department of Agriculture, and the Department of Interior, are active in developing remediation technologies and assisting mining operations. Universities and university-led centers (e.g., combinations of government, academic, and private sector entities) are actively exploring new opportunities in remediation technologies. Finally, private sector entities are developing technologies, although the nature of their business may limit easy access to innovative technologies outside of a business relationship.

Building these contacts into a network will assist the site manager in addressing all aspects of the site investigation and cleanup. To help begin this process, Appendix I of this reference document includes a list of contacts for EPA staff working with mining and mineral processing related issues.

In addition, the Internet websites identified in Appendix J allows the user to electronically access a vast amount of data regarding remediation technologies and related topics. Other sources of information have been analyzed and collected in the appendices as well. These appendices are intended to provide the user with a guide to the many sources of information regarding remediation technologies that are currently available. Some of the sources of information available include: hotlines, libraries, universities and research centers, the Internet, computerized bulletin boards, and technical documentation.

EPA has developed a large number of areas with information of potential use in identifying remediation technologies. These include Web pages, a compendium of Superfund guidance and technical documents, rule-making dockets, and various media- and program-based offices (e.g., the Office of Water and the Superfund Office).

Exhibit 10-1
Remediation Technologies Matrix

Technology	Type[1]	Media	Cost[2]	Effectiveness	Comments
Bioremediation	I/E	S	M-H	Innovative technology.	
Capping	C	S, sludges, wastes	L-H	Effective	
Capping (Erosion)	C	S, SW, A	L- M	Depends on site conditions, generally effective	O&M costs could be significant if the cap or cover is damaged.
Cement Walls	C	GW	M-H	Effective	
Chemical Treatment	C	SW, GW	M-H	Effective	O&M cost may be significant.
Decontamination	C	Structures	L-M	Depends on site conditions and contaminants	
Deed Restrictions	IC	Land	L	Depends on community acceptance	
Detention/ Sedimentation	C	SW	L-M	Effective	
Fencing	IC		L-M	Fencing can be effective at restricting access if the fences are maintained.	O&M costs can be significant, particularly for long stretches of fence.
Fines	IC	S, SW, GW, A	L	Depends on community acceptance	
Health Education Programs	IC	S,A,GW,SW	M-H	The effectiveness of any health education program depends on the community acceptance.	Needs local enforcement and support to be effective.
Interceptor Trenches	C	GW	L-H	Effective in capturing GW if the permeability is greater than native material	Significant O&M costs if the GW materials precipitate and reduce the permeability, requiring the media to be replaced or cleaned.
Interior Cleaning	IC	S, A	M-H	Can be very effective for removing the exposure to contaminants in interior dust.	Re-contamination is possible if sources have not been remediated.
Landfill Disposal	C	S, Solid Waste	M-H	Effective as long as the cap or liner are not breached.	May have significant O&M costs to maintain cap or treat leachate.

Type: C = Conventional; I/E = Innovative/Emerging; IC = Institutional Control
Media: S = Soil; GW = Ground Water; SW = Surface Water; A = Air
Cost: L = Low; M = Medium; H = High; VH = Very High

Exhibit 10-1
Remediation Technologies Matrix

Technology	Type[1]	Media	Cost[2]	Effectiveness	Comments
Limited Future Development	IC	Land	L	Depends on community acceptance	
Phytoextraction, Phytodegredation	I/E	S	L-M	Has been successful for some metals	May be considered innovative.
Programs to Encourage Interior Cleaning	IC	S, A	L	The effectiveness depends on community acceptance.	Some community members will not participate.
Pump and Treat	C	GW	M-H	Depends on site conditions and contaminant characteristics	
Regulatory Requirements	IC	S		The effectiveness depends on community acceptance.	Needs a source of funding to implement the permit issuing and tracking system.
Remining/ Reprocessing	I/E	S, Wastes	L-H	If all the material can be removed, this is a very effective technology; only a limited amount of material may, however, be available for remining.	Depends on the characteristics of the material to be reworked. Recovering salable metal may offset remediation costs. The time to reprocess large amounts of material could be significant and may not be acceptable.
Rhizofiltration	C	SW, GW	L-M	Innovative technology	
Run-on Controls	C	SW	L-M	Effective	
Sale of Useable Materials	C	feedstocks, wastes	L	Good	Limited to those materials that there is a market for.
Settling Basins	C	SW	L-H	Effective in removing suspended solids	May have significant O&M costs over the life of the dam.
Sheet Piling	C	GW	M-H	Effective	May have “leaks” in the wall
Signs	IC	S, SW, Waste Units	L	Signs have a very limited effectiveness	O&M costs can be significant if the signs keep “disappearing”
Slurry Walls	C	GW	M	Effective	May have “leaks” in the wall.
Soil Disposal	IC	S	M-H	The effectiveness depends on community acceptance.	Greatly depends on the handing and disposal requirements

Type: C = Conventional; I/E = Innovative/Emerging; IC = Institutional Control
Media: S = Soil; GW = Ground Water; SW = Surface Water; A = Air
Cost: L = Low; M = Medium; H = High; VH = Very High

Exhibit 10-1
Remediation Technologies Matrix

Technology	Type[1]	Media	Cost[2]	Effectiveness	Comments
Soil Flushing	C	S	M-H	Site conditions affect fluid's ability to mobilize contaminants	May be a concern with contamination of ground water.
Soil Washing	C	S	M-H	Site conditions affect fluid's ability to mobilize contaminants	
Solidification	C	S, sludges, wastes	M-H	Depends on the ability of the solid to break down over time.	
Solvent Extraction	C	S, wastes, sludges	L-H	Depends on the solutions' ability to extract contaminants	
Speed Limits	IC	A, S	L	The effectiveness depends on community acceptance.	Needs local enforcement and support to be effective.
Stabilization	C	S, sludges, wastes	M-H	Dependent on the nature of material to be stabilized.	
Stream Channel Erosion Control	C	SW	L-H	Effective	O&M costs can be significant.
Thermal Destruction	C	S, sludges, wastes	M-H	Poor for metals	Not common at most mining and mineral processing sites.
Thermal Desorption	C	S	M-H	Depends on site characteristics and contaminants	Not common at most mining and mineral processing sites.
Vapor Extraction	C	S	M-H	Depends on site characteristics and vapor phase contaminants	Not common at most mining and mineral processing sites.
Vehicle Limits	IC	S	L	The effectiveness depends on community acceptance.	Needs local enforcement and support to be effective.
Vitrification	I/E	S, Solid Waste	VH	Effective	Not common at mining and mineral processing sites.
Wind Breaks	C	S	L-M	Fair to good effectiveness	
Zoning	IC	S	L-M	The effectiveness depends on community acceptance.	Needs local enforcement and support to be effective.

Type: C = Conventional; I/E = Innovative/Emerging; IC = Institutional Control
Media: S = Soil; GW = Ground Water; SW = Surface Water; A = Air
Cost: L = Low; M = Medium; H = High; VH = Very High

Chapter 11
The Regulatory "Toolbox"

11.1 Introduction

This chapter discusses the primary tools available to EPA project managers in developing strategies for investigation and cleanup of an abandoned mine site. These same tools may also be available to other federal agency and state personnel. In addition, there are a variety of other tools available to state and federal resource managers and regulators that are not discussed in this text. The site manager is encouraged to refer to additional agency or state resources to choose the best tools for a given site.

Regulation of mining activities occurs via a complex web of sometimes overlapping jurisdictions, laws, and regulations covering several environmental media. Land ownership and tenancy issues further complicate regulatory issues. Each abandoned mine site faces a somewhat unique set of regulatory requirements, depending on State statutes or regulations; whether it is on Federal, State, Tribal or private land; local regulations; and the specific environmental considerations unique to the site. Although this chapter focuses on the various tools provided by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and its remediation process, especially as it relates to the unique characteristics of mine site remediation, the use of other tools should be considered where appropriate. An overview of some of the other tools available to the site manager are included in the later sections of this chapter.

11.2 Background

Historically, CERCLA has been used as a tool to implement cleanup activities at a large number of mining and mineral processing sites across the country. CERCLA authorities have been used for cleanups ranging from the removal of drums of hazardous substances from long-abandoned sites, to major privately funded cleanup actions at sites on the National Priorities List.

The joint and several liability provisions of CERCLA are powerful tools in compelling private parties to conduct cleanup actions at many sites. The availability of federal money to conduct work when efforts to induce privately funded cleanups fail allows EPA an independent ability to respond to public health and environmental threats. The cost recovery provisions of CERCLA make it possible for the government to be reimbursed for the cleanup costs it incurs.

CERCLA is a very flexible tool for addressing the environmental risks posed by mining and mineral processing sites. Other chapters of this document discuss technical aspects of conducting cleanup work at mining and mineral processing sites. Equally important, however, are the policy and administrative decisions regarding how CERCLA or other authorities can best be utilized to implement site cleanup. If CERCLA is selected as an administrative tool to implement site characterization and cleanup, it is critical to develop an overall strategy to determine how CERCLA can best be utilized for cleanup of a mining or mineral processing site, or a watershed affected by mining or mineral processing. Other programs at EPA, appropriate state agencies, tribes, local government, and other federal agencies also need to be involved in determining how best to develop an integrated site management strategy.

11.3 CERCLA Jurisdiction/Applicability

11.3.1 Jurisdictional Conditions

CERCLA applies any time there is a release or threatened release of: 1) a hazardous substance into the environment or 2) a pollutant or contaminant "which may present an imminent and substantial endangerment to the public health or welfare." The term "release" is defined broadly in the statute, including any type of discharging or leaking of substances into the environment. This also includes the abandonment of closed containers of hazardous substances and pollutants or contaminants.

The definition of hazardous substance is extremely broad, covering any "substances," "hazardous constituents," "hazardous wastes," "toxic pollutants," "imminently hazardous chemicals or mixtures," "hazardous air pollutants," etc., identified under other federal environmental laws, as well as any substance listed under Section 102 of CERCLA. The fact that a substance may be specifically excluded from coverage under one statute does not affect CERCLA's jurisdiction if that substance is listed under another statute or under Section 102 of CERCLA. A comprehensive list of these substances is provided in 40 CFR 302.4. From a mining perspective, certain sulfates are not listed, and thus may be excluded from the broad coverage of "hazardous substances." Contaminants such as sulfates, however, can be covered under the more limited provisions of CERCLA relating to "pollutants and contaminants," as will be discussed below. It should be noted that although all mineral extraction and beneficiation wastes, and some mineral processing wastes are excluded from RCRA Subtitle C regulation by the Bevill Amendment, these wastes may be addressed under CERCLA.

11.3.2 Media

CERCLA is not media-specific. Thus, it may address releases to air, surface water, ground water, and soils. This multi-media aspect of CERCLA makes it possible to conduct environmental assessments and design cleanup projects that address site contaminants in a comprehensive way.

11.3.3 Constituents

CERCLA covers almost every constituent found at mining and mineral processing sites. Exceptions include petroleum (that is not mixed with a hazardous substance) and responses to releases of a naturally occurring substance in its unaltered form. It should be noted, however, that the latter exception does not include any of the releases typically dealt with at mining sites, such as acid mine drainage, waste rock, or any ore exposed to the elements by man.

11.4 Implementation Mechanisms

11.4.1 Permits

CERCLA does not include any formal permit mechanism. CERCLA was essentially designed as a tool to address problems in a "relatively" short period of time. It was not intended to be an ongoing "regulatory or permit" authority; thus, an infrastructure was not set up for long-term regulatory compliance (e.g., more than 30 years).

Section 121(e) of CERCLA waives any requirement for a federal, state, or local permit for any portion of a removal or remedial action that is to be conducted entirely on site. Typically, however, that action must be performed in accordance with the substantive environmental requirements of the regulatory authority for which the permit was required. EPA usually has taken the position that "on-site" includes a discharge to surface water within the site boundaries, even though the water eventually flows off site. Some concern has been expressed regarding the extent to which this waiver is valid after the CERCLA action is completed. The Section 121(e) exemption is essential for ensuring that EPA can carry out remedial actions in a timely manner.

11.4.2 Review/Approval

Typically, no review or approval is afforded under Superfund at new or existing facilities unless there is a release or threat of release addressable under CERCLA. However, once jurisdiction is established, the Agency has the capacity to review and approve any plans that address or affect that release (See the Administrative and Injunctive Authorities section below).

Section 108(b) of CERCLA does give the Administrator the authority to promulgate regulations that would require adequate financial assurance from classes of facilities that is consistent with the degree and duration of risk associated with the production, transportation, treatment, storage, or disposal of hazardous substances. The statute describes ways in which the financial responsibility can be established (insurance, guarantee, surety bond, letter of credit, or qualification as a self-insurer), and authorizes EPA to specify policy or other contractual terms, conditions, or defenses for establishing evidence of financial responsibility. EPA has not, as yet, used this authority.

11.4.3 Response Authorities

CERCLA's main strength is its response authorities. EPA can either use the Superfund (funded primarily by an industry tax) to perform response (removal or remedial) activities (Section 104) or require private parties to perform such activities (Section 106). CERCLA gives EPA the flexibility to clean up sites based upon site-specific circumstances. EPA's cleanup decisions are based upon both risk assessment and consideration of "applicable or relevant and appropriate requirements" (ARARs). As long as the jurisdictional prerequisites have been met, CERCLA gives EPA the ability to perform any activity necessary to protect public health and the environment.

CERCLA provides EPA with the authority to perform "removal" actions, and "remedial" actions. Assessments evaluate contaminants of concern, exposure pathways, and potential receptors. The assessment process includes the review of all available information as well as sampling for any other necessary information. The process is broad in its application and is a powerful tool in evaluating environmental risks posed by a site. Removal actions can be performed on mining and mineral processing sites of any size in an emergency situation (e.g., implementation can occur within hours) or over a long period of time. Removal actions are subject to limits on time (12 months) and money ($2,000,000) under the statute; however, these limits are subject to broad exceptions. For example, the Agency has implemented removal actions costing in the tens of millions of dollars at mining and mineral processing sites.

Remedial actions are typically long-term responses performed at those sites placed on the National Priorities List. Remedial actions may be performed at non-NPL sites only if they are privately financed. Remedial actions are not subject to the time or dollar limitations imposed on removal actions, but require a more detailed and formal decision process. Unlike removal actions, however, remedial actions to be implemented with Superfund dollars (when there are no viable responsible parties) require a 10% state share in costs and a state assurance of operation and maintenance before remediation can commence.

Land management agencies, such as the Forest Service and BLM have CERCLA response authority, particularly when the site is not listed on the NPL. The land management agencies and other natural resource trustees, such as the National Marine Fisheries Service and the Fish and Wildlife Service, also have Section 106 order authority, to be exercised with EPA concurrence, when response is needed on federal land or is needed to prevent an adverse impact on natural resources.

11.4.4 Standard Setting

Under the current statute, CERCLA has no uniform national standard-setting authorities. The NCP, at 40CFR300.430(e)(9)(iii)(A-H), lists nine criteria, through which EPA can set site-specific standards for clean-up and maintenance to minimize risk and satisfy ARARs.

ARARs, discussed below in Section 11.4.5, can be a very useful tool, as they give the Agency the authority to impose standards that would not otherwise be applicable, if those standards are determined to be relevant and appropriate under the circumstances. Of particular interest in the mining context, EPA has the authority to use appropriate regulations adopted under RCRA Subtitle C despite the fact that most mining wastes are excluded from regulation under RCRA Subtitle C by the Bevill Amendment. Nonetheless, EPA can only require attainment of the substantive aspects of relevant and appropriate standards, not the procedural requirements.

11.4.5 Applicable or Relevant and Appropriate Requirements

Under Section 121(d) of CERCLA, remedial actions must comply with substantive provisions of federal environmental laws and more stringent, timely identified state environmental or facility siting laws. Removal actions must comply with ARARs also, but only to the extent practicable. “Applicable” requirements are those federal or state laws or regulations that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. “Relevant and appropriate” requirements are not "applicable," but address problem or situations similar enough to those at the CERCLA site that their use is well suited to the site. State requirements are not considered ARARs unless they are identified in a timely manner and are more stringent than federal requirements.

ARARs are contaminant, location, or action specific. Contaminant specific requirements address chemical or physical characteristics of compounds or substances on sites. These values establish acceptable amounts or concentrations of chemicals which may be found in, or discharged to, the ambient environment.

Location specific requirements are restrictions placed upon the concentrations of hazardous substances or the conduct of cleanup activities because they are in specific locations. Location specific ARARs relate to the geographical or physical positions of sites, rather than to the nature of contaminants at sites.

Action specific requirements are usually technology based or activity based requirements or limitations on actions taken with respect to hazardous substances, pollutants or contaminants. A given cleanup activity will trigger an action specific requirement. Such requirements do not themselves determine the cleanup alternative, but define how chosen cleanup methods should be performed.

EPA has published a manual outlining all potential federal ARARs that may be requirements at Superfund sites. Published in two parts, the manual is entitled *CERCLA Compliance with Other Laws Manual*, Part I, August 1988, and Part II, August 1989, and is available at EPA libraries. In addition, Appendix D discusses ARARs that are commonly utilized at mining and mineral processing sites.

11.5 Compliance/Enforcement

11.5.1 Administrative and Injunctive Authorities

CERCLA Section 106 provides for the issuance of administrative order or injunctive relief under the following conditions: (1) there may be an imminent and substantial endangerment to the public health or welfare or the environment; (2) because of a release or threat of a release; (3) of a hazardous substance; (4) from a facility. See CERCLA Section 106. (Note there are conflicting opinions regarding authority under Section 106 for ordering cleanup of pollutants and contaminants.) EPA typically only issues orders to parties that are potentially liable under CERCLA Section 107. The scope of liability under CERCLA is broad. Anyone fitting the following categories is liable under CERCLA: 1) current owner (including lessees) or operator of the facility; 2) past owner or operator at the time of the disposal of hazardous substances in question; 3) anyone who arranged for the treatment, transportation, or disposal of the hazardous substances in question; and 4) any transporter of the hazardous substances in question if the transporter chose the disposal location. Liability is strict. That is, if the party falls into one of the above four categories, it is liable, regardless of "fault." Liability for the government's response costs is joint and several so long as the harm is "indivisible," i.e., there is no rational basis for apportionment. The burden of proof as to whether harm is indivisible is on the defendant, not on the government. Liability is retroactive, thus CERCLA can reach those responsible for disposal activities prior to enactment of CERCLA.

Mining and mineral processing sites generally qualify as CERCLA facilities. A facility is defined as "any building, structure, installation, equipment, pipe or pipeline...well, pit, pond, lagoon, impoundment, ditch...or any site or area where a hazardous substance has been deposited, stored, disposed of, or placed, or otherwise come to be located...." Consequently, nearly any feature of a mine site fits within the definition of "facility." EPA has the discretion to define "facility" as broadly or narrowly as necessary to fit site-specific requirements. If the jurisdictional requirements are met, EPA may either proceed directly with an administrative order or request the U.S. Department of Justice to seek injunctive relief from a federal District Court. Historically, the vast majority of work performed under these provisions has been done administratively. Judicial intervention is relatively rare.

EPA has broad authority under CERCLA to require response actions. At existing facilities, EPA could enjoin production activities or order changes to those activities (unless the activity is a discharge pursuant to a federally permitted release). EPA can require the implementation of institutional controls meant to reduce the endangerment posed by the presence of hazardous substances or the removal of such substances to a more appropriate location (which must meet ARARs and the off-site rule). EPA has broad discretion to choose response actions most appropriate for particular sites (See Response Authorities above), provided such actions are not "inconsistent with" the National Oil and Hazardous Substances Pollution Contingency Plan (commonly referred to as the National Contingency Plan or NCP).

11.5.2 Cost Recovery

CERCLA Section 107 provides for the recovery of certain costs expended by the government in responding to environmental contamination from responsible parties (as defined above). These response costs must be incurred as a result of a release or threatened release of a hazardous substance from a facility. In order for the United States, a state, or Indian tribe to recover costs under this provision of CERCLA, the costs incurred have to be "not inconsistent" with the NCP. Liability for response costs is strict, joint and several, and retroactive. The burden of proof as to whether harm is indivisible is on the defendant, not on the government.

Like most recovery provisions in the law, EPA's cost recovery authority does have a statute of limitations. For removal actions, EPA must commence its cost recovery action within three years of completion of the removal action (unless the removal action proceeds into a remedial action). For remedial actions, EPA must commence its cost recovery action within six years of the initiation of physical on-site construction of the remedial action.

EPA has developed a "prospective purchaser" policy which affords a party interested in the purchase of contaminated properties with protection from CERCLA liability by entering into a settlement with the United States. Application of the policy can be difficult, as there are many criteria that must be met, including a federal interest in the contaminated property, substantial benefit to the Agency, the safety of continued operations, risk to persons at the site, municipal interest, environmental justice, etc. From a mining site perspective, however, it may be a worthwhile option to consider.

11.5.3 Civil Penalties

CERCLA imposes a fine of $25,000 per day for failure to comply with an order issued under CERCLA (Sections 106(b) and 109). In addition, if EPA spends Superfund dollars performing work where a responsible party has failed to perform such work under order, that party may be liable for punitive damages in an amount equal to three times the costs incurred by the United States. (Section 107(c)(3)). When EPA enters into consensual agreements with responsible parties for the performance of work, it may also require stipulated penalties for the responsible party's failure to adhere to the requirements of the agreement.

11.5.4 Criminal Penalties

Criminal penalties exist under only two provisions of CERCLA. The first is for failure to provide notification of a release of a reportable quantity of a hazardous substance (Section 103(b)); the second is for destruction of records that are supposed to be maintained under the Act (Section 103(d)).

11.5.5 Information Collection

Section 104(e) allows for investigations, monitoring, surveys, testing, and other information gathering appropriate to identify the existence and extent of a release or threat thereof; the source and nature of hazardous substances or pollutants or contaminants; and the extent of danger to public health or welfare or the environment. Studies that may be conducted using the information gathering authorities of section 109 may include planning, legal, fiscal, economic, engineering, architectural, or others studies necessary or appropriate for planning and directing response actions, recovering costs, or enforcement.

Specifically, Section 104(e)(2) requires that parties provide EPA with all information or documents relating to (A) the identification, nature, and quantity of materials generated, treated, stored, or disposed of at a facility; (B) the nature and extent of a release or threatened release of a hazardous substance, pollutant, or contaminant; and (C) the ability of a person to pay for or perform cleanup.

Section 104(e)(3) provides the Agency with the authority to enter any place where a hazardous substance or pollutant or contaminant (A) may have been generated, stored, treated, disposed of, or transported from; (B) or from which there is a release or threatened release of a hazardous substance; (C) or any place where entry is needed to determine the need for response, the appropriate response, or to effectuate a response.

Section 104(e)(4) gives EPA the authority to inspect, and obtain samples from, any location or containers of suspected hazardous substances, or pollutants or contaminants.

If a party refuses to consent to EPA's information collecting activities, the Agency may issue orders and/or seek court intervention providing for the collection of information and provision of access. Access may be granted through a warrant (where short-term access is necessary) or by court order (for long-term or intrusive access circumstances).

CERCLA Section 103 also requires any person who is in charge of a facility from which a hazardous substance is released to report that release if it equals or exceeds the reportable quantity for that hazardous substance listed pursuant to Section 102 of the Act. Section 103 also requires any owner or operator of a facility, owner at the time of disposal at a facility, and transporter who chose to dispose of hazardous substances at a facility to notify EPA of the existence of such facility if storage, treatment, or disposal of hazardous substances have occurred at such facility. Thus, Section 103 provides broad authority for requiring the submission of information necessary to identify the location of sites needing EPA's attention.

11.6 Other Superfund “Tools”

11.6.1 Funding

The Superfund is funded by both a tax on the chemical industry and some smaller contribution of appropriated funds. The Superfund typically has enough money available to perform necessary investigatory and cleanup activities. CERCLA does contain fund-balancing criteria to ensure that the fund does not deplete its resources on any one site. Cost recovery by the government is a critical element of ensuring the adequacy of Superfund.

11.6.2 Natural Resource Damage Provisions

CERCLA Section 107(a)(4)(C) provides for the recovery of damages for injury to, destruction of, or loss of natural resources, including the reasonable costs of assessing such injury, destruction, or loss. "Natural resources" as defined at CERCLA Section 101(16) means "land, fish, wildlife, biota, air, water, ground water, drinking water supplies, and other such resources belonging to, managed by, held in trust by, appertaining to, or otherwise controlled by the United States...any State or local government, any foreign government [or] any Indian tribe... ." EPA is not responsible for recovering "natural resources" damages due the federal government, as this responsibility generally lies with those agencies that administer federal lands or are resource trustees. (See Section 107(f)(1) and (2) and 122(j).)

Highlight 11-1
ARCO Natural Resource Damage Settlement

In November 1998, ARCO settled their Natural Resource Damage Claims with the Federal government, State of Montana, and the Confederated Salish and Kootenai Tribes. The agreement sets forth terms under which ARCO will pay to remediate and restore Silver Bow Creek. In addition, ARCO resolved the State and Tribes natural resource damage claims for the Clark Fork River Basin.

11.6.3 Good Samaritan Provisions

Section 107(d) of CERCLA provides exceptions to liability for those rendering care or advice at the direction of an On-Scene Coordinator (OSC) or in accordance with the NCP. A private party who is not otherwise liable at the site, and provides advice or care at the direction of an OSC in accordance with the NCP, will be exempt from liability for any costs incurred as a result of actions or omissions by that party unless those actions or omissions are negligent.

State and local governments are exempt from liability under CERCLA for actions taken in response to an emergency created by the release or threat of release of hazardous substances from a facility owned by another person. Such exemption does not cover gross negligence or intentional misconduct. As with private parties, the state or local government cannot take advantage of this provision if it is otherwise liable for the release.

11.6.4 Native American Tribes

Section 126 of CERCLA provides that Indian tribes shall be afforded substantially the same treatment as states with respect to CERCLA's notification, consultation on remedial actions, information collection, health authorities, and consultation consistent with the National Contingency Plan. Section 104(d) of CERCLA also authorizes the Agency to enter into cooperative agreements with tribes. Section 107 also gives tribes equivalent authority as given to states and the federal government to recover response costs and damages to natural resources.

11.7 Limitations

11.7.1 Federally Permitted Release

EPA's ability to address environmental problems at mining and mineral processing sites may be limited when a release of concern has been granted a permit under a federal government program listed in Section 101(10). Even though such a release can be addressed under Section 104 of CERCLA (i.e., EPA may still perform any necessary remediation), EPA's authority to recover costs for such activities is removed (Section 107(j)) and its authority to order others to do the work is questionable.

11.7.2 Pollutants and Contaminants

As described above, some contaminants, such as sulfate, do not fall under the definition of "hazardous substance." These contaminants can be captured under the definition of "pollutant and contaminant," but the authority afforded the Agency under Section 104 of CERCLA to address such contaminants is significantly less than that afforded under Section 106 to address hazardous substances. EPA may not be able to order responsible parties to address pollutants and contaminants or be able to recover costs incurred in responding to their releases.

11.8 Ability to Integrate with Other Statutes

CERCLA is a powerful tool for investigation and cleanup of mining and mineral processing sites. Its applicability at mining and mineral processing sites is broad, and can often be used when other environmental statutes have failed to address environmental problems. CERCLA also can provide synergistic effects when combined with other statutes because of its 1) retroactive, joint, and several liability; 2) remedial capabilities through Superfund financing; and 3) site-specific flexibility through risk assessment and ARARs analysis. When evaluating the use of CERCLA at a site also consider integrating its use with other authorities to achieve the best mix of cleanup tools for each site.

11.9 Federal Facilities and Other Federal Issues

CERCLA Section120 subjects federal agencies (e.g. USFS, BLM, NPS, and DOD) to CERCLA requirements. CERCLA requirements are similar for federal and private facilities; however, CERCLA Section120 set out certain additional requirements applicable to federal facilities. For example, Section120 requires that EPA establish the Federal Agency Hazardous Waste Compliance Docket listing federal facilities that are or may be contaminated with hazardous substances. EPA then evaluates the facilities on the docket and, where appropriate, places facilities on the NPL. If a federal facility is placed on the NPL, Section120(c)(1) requires the federal agency that owns or operates the facility to commence an RI/FS within six months of the facilities placement on the NPL. Upon completion of the RI/FS, Section120(c)(2) requires the federal agency to enter into an interagency agreement (IAG) with EPA for completion of all necessary remedial action at the facility. Under CERCLA Section120(e)(4), IAGs must at a minimum include the selection of the remedy, the schedule for the completion of the remedy and arrangements for long-term O&M of the facility.

As a matter of practice, EPA and the responsible federal agency often agree to enter into an IAG during the initial study phase (RI/FS) or just after the placement of a facility on the NPL. States are encouraged to become signatories to IAGs where possible.

Funding for remedial actions at federal facilities generally must come from the responsible federal agency's appropriations because, with limited exceptions, CERCLA Section111(e)(3) prohibits the use of Fund money for remedial actions at federal facilities.

Executive Order 12580 delegates and the President's CERCLA authorities among the various federal agencies. Under EO 12580, DOD and DOE have been delegated most of the President's Section104 response authorities for releases or threatened releases of hazardous substances on or from facilities under their "jurisdiction, custody or control". Other federal agencies have been delegated Section104 authorities for releases or threatened releases of hazardous substances on or from facilities under their jurisdiction, custody or control that are not on the NPL. EPA has been delegated the balance of the President's CERCLA response authorities (except for releases or threatened releases to the coastal zones, Great Lakes waters, ports or harbors, which are delegated to the Coast Guard). Executive Order 13016 amended EO 12580 to authorize certain federal agencies (including land manager agencies) to issue administrative orders under Sections 106 and 122 (with EPA concurrence) for releases or threatened releases at their facilities.

Thus, federal land manager agencies are authorized to address non-NPL mine sites on their property much in the same way EPA is authorized to address privately owned mine sites. Including issuing Section106 orders for response actions or performing response actions themselves and seeking cost recovery from PRPs. Because of the limitation on the use of Fund money in Section111(d)(3), the federal land manager agencies must rely on its own appropriations. The federal agencies most often associated with these sorts of actions are the Department of the Interior through the Bureau of Land Management (BLM) and the Department of Agriculture through the U.S. Forest Service (USFS). Both of these agencies are moving forward with a variety of programs to identify and characterize abandoned mines and processing facilities on lands under their jurisdiction. Mining sites often cross boundaries between federal and private ownership. Such "mixed ownership" sites require the presence of EPA since, although agencies other than EPA may issue Section 106 orders for response action on federally owned lands. Federal Land Managers will wish to help make decisions in devising remediation at mixed ownership sites, especially where long-term operation and maintenance of a remedy may be required. EPA may also wish to explore having federal land managers undertake some CERCLA enforcement actions using other authorities.

Because of their overlapping authorities, appropriate coordination must occur between EPA and the applicable federal agencies at mining and mineral processing sites. For a site which is located partly on federal and partly on privately owned land, a Memorandum of Understanding (MOU) may be used to define specific roles and responsibilities of each agency. In some cases it may be appropriate under an MOU to divide responsibilities, focusing CERCLA activity only on certain prescribed units. Whichever administrative vehicle is utilized, it is important to divide responsibilities in ways that make technical sense and in order to use federal dollars wisely.

11.10 Other Regulatory Tools

CERCLA is undoubtedly the most flexible and useful regulatory tool for addressing environmental problems at mining sites. CERCLA is not limited to a particular media, such as water, but it applies to all media; it provides flexible funding for cleanups, through payment for or direct implementation of cleanups by responsible parties or by the government; and it provides for the study and implementation of site-specific approaches to environmental problems. EPA and other federal agencies will often utilize CERCLA when attempting to address environmental problems at mining sites. However, in certain situations, other regulatory tools may also be appropriate. These are discussed briefly, and compared to CERCLA below. A detailed discussion of these authorities is contained in Appendix C of EPA's National Hardrock Mining Framework.

11.10.1 Clean Water Act

After CERCLA, the Clean Water Act (CWA) is probably the next most widely used regulatory tool for addressing environmental problems at mining sites. Section 402 of the CWA authorizes EPA or delegated states to regulate "point source discharges" of "pollutants" to "waters of the United States." Each discharge must be permitted. Section 404 of the CWA provides authority for regulating the discharge of "dredged or fill material." Many mine sites suffer from the uncontrolled discharge of acidified water, which becomes contaminated as it flows through abandoned mine workings. Section 402, in particular, may be of use as EPA or states try to control this flow. Under Section 309 of the CWA, EPA or states may proceed administratively or judicially against "any person" discharging without a permit or in violation of a permit. Thus, if a mine site is discharging contaminated waters, and if a responsible person can be identified, EPA or a delegated state may be able to address the problem.

On the other hand, the utility of the CWA as a regulatory tool is limited compared to CERCLA. Where CERCLA applies to all media, the CWA applies to water only. Further, the CWA regulates only "discharges" to "waters of the United States" from "point sources." In 1990, EPA promulgated the regulatory definition of industrial activity to include inactive mining operations. Under the stormwater program, runoff from mining operations requires a permit if it comes into contact with overburden, raw material, intermediate products, finished product, byproduct, or waste products located on the site of such operations. Also, action under the CWA to address water contamination depends on the existence of owner or operator who is responsible for obtaining a permit.

11.10.2 Resource Conservation and Recovery Act

RCRA governs the management of solid and hazardous wastes under two regulatory tracks. RCRA Subtitle D addresses "solid" wastes, while Subtitle C addresses "hazardous" wastes. In October, 1980, Congress excluded from regulation under Subtitle C "solid wastes from the extraction, beneficiation, and processing of ores and minerals" until such time as required studies were completed and reported to Congress. Referred to as the "Bevill amendment," this provision effectively excludes "extraction" and "beneficiation" and 20 specific "processing" wastes from regulation as "hazardous" wastes. Most processing wastes continue to be regulated under Subtitle C, provided they meet the requirement set forth in 40 CFR 261.24 for consideration as "hazardous" wastes, because they exhibit the toxicity characteristic.

Perhaps more useful for dealing with mining wastes are the requirements of Section 7003 of RCRA. A "miscellaneous" provision under RCRA, Section 7003 allows EPA to address any "imminent and substantial endangerment to health or the environment" arising from the past or present handling, storage, treatment, transportation or disposal of any solid waste or hazardous waste. The release need not be at a facility otherwise subject to RCRA regulation, and its application to solid waste as well as hazardous waste makes it available for mining waste despite the Bevill exclusion. In many respects, Section 7003 order authority is comparable to orders under Section 106 of CERCLA and may be issued to current or former handlers, owners, operators, transporters, and generators. EPA may issue an administrative order or seek an injunction in federal district court to stop the practice causing the danger and/or take any other action necessary. Violators of an administrative order under Section 7003 may be penalized up to $5,000 per day. Although the operation of Section 7003 of RCRA is similar to that of Section 106 of CERCLA, RCRA does not contain funding mechanisms allowing for government funding of cleanups.

11.10.3 Toxic Substances Control Act

The Toxic Substances Control Act (TSCA) allows EPA to regulate the manufacture (including import), processing, distribution, use, and disposal of chemical substances. Under TSCA, EPA may require health and environmental effects testing by manufacturers, importers and processors of chemical substances, which include organic and inorganic substances occurring in nature, as well as chemical elements. TSCA also authorizes EPA to require record keeping and reporting of information that is useful for the evaluation of risk, regulate chemical substances that present an unreasonable risk of injury to health or the environment, take action to address imminent hazards, require notification to EPA by prospective manufacturers of new chemicals, and make inspections or issue subpoenas when needed to implement TSCA authorities.

In practice, the most useful tool under TSCA has been the regulations pertaining to polychlorinated biphenyls (PCBs) promulgated under Section 6 of TSCA, as codified in 40 CFR Part 761. The mining industry has traditionally used high levels of PCBs as the dielectrics in transformers and capacitors, which are commonly found wherever there is a high electrical power demand. Transformers and capacitors can be found in any phase of surface or underground mining operations and the ore beneficiation process. PCB equipment has been replaced in many mines and all mines built after the ban on production of PCB equipment should no longer be using electrical equipment containing PCBs.

The disadvantages of TSCA at mining sites as compared with CERCLA are that its applicability is limited, and it contains no funding mechanisms that may be used where a viable responsible party is not present.

11.10.4 Miscellaneous Requirements

Other federal regulatory requirements which may be of some use for addressing environmental problems at mine sites include the Clean Air Act, the Emergency Planning and Right to Know Act, and the Safe Drinking Water Act. These are not discussed here as they are of relatively limited use to site managers when they are addressing environmental problems at mining sites. Although not discussed here, these provisions are discussed in detail in Appendix C of EPA's National Hardrock Mining Framework. In addition to the federal regulations discussed here, there are numerous State, Tribal, and local regulations that can be utilized by the site manager.

11.11 Non-Regulatory Tools

In addition to the federal regulatory tools previously described in this chapter, there are a number of non-regulatory tools that may be available to the site manager. Non-regulatory approaches available to address environmental challenges posed by mining are typically employed to complement existing regulatory programs in addressing mining impacts; however, there have been some instances where they have been used independently of any regulatory framework. While current regulatory programs can often be adapted to address the environmental problems posed by mining, they can be cumbersome, expensive to administer, and understaffed. Non-regulatory tools have been developed to take advantage of the incentives created by a backdrop of enforcement oriented regulatory programs, or to coordinate these programs to maximize their overall impact. For example, when cleanups precede active enforcement of regulatory programs they may be easier and less expensive to implement. While recognizing that each non-regulatory effort is unique, there are certain themes that are common to the most successful efforts.

The purpose of this discussion of non-regulatory tools include the following:

Illustrate the key traits of effective non-regulatory tools. Sometimes these will be based on tools that have a regulatory connection, although the emphasis will be on the non-enforcement aspects of those authorities.

Using specific case examples, point out areas where these tools have filled gaps in the current regulatory framework.

Highlight model policies and approaches that could be the basis for future regulations or legislation.

Point out the main limitations or non-regulatory approaches.

While recognizing that each non-regulatory effort is unique, there are certain themes that are common to the most successful ones, both site specific and non-site specific. They include the following.

Active participation by principal stakeholders, including a recognition of the environmental problems and a willingness to take on the issues. This typically includes federal, state and local governments, tribes, industry, citizens, and affected landowners. Participation does not necessarily mean funding, but it does mean cooperation.

Creative use of limited funding resources, promoting coordination and research on mining issues. While little public money is specifically earmarked for mine site cleanup, other programs, such as EPA's CWA Section 319 funds, have been successfully used to fund portions of cleanup projects. State programs, local contributions, and private funding by responsible parties have all been tapped for assessment and cleanup projects. Technology demonstrations have sometimes been used to get seed money to develop a new cleanup approach. These include the University of Montana's Mining Waste Institute, a variety of groups comprising the Mining Information Network, and the Western Governors' Association (WGA).

Site specific flexibility, in adapting non-regulatory tools to fit the specifics of the site and the interest of the stakeholders.

Pollution prevention, efforts supported by federal and state agencies, tribes, and other stakeholders limiting the generation and use of waste materials.

Prioritization of cleanup projects, often on a watershed basis, as a way of allocating limited resources and focusing on worst cases first.

Regulatory discretion as a tool to promote creative problem solving and early implementation of cleanup projects. For example, having a site listed as a Superfund site might reduce local involvement.

11.11.1 Key Characteristics of Non-regulatory Tools

Most non-regulatory approaches contain one or more of the following characteristics.

11.11.1.1 Financial

Financial support often comes from a variety of sources when non-regulatory approaches are used. Funds are often leveraged, and budgets are typically lean. Examples include the following.

Staff Resources. Non-regulatory approaches often take a large amount of staff time and energy to implement.

RCRA 7007 and 8001 Grant Funds. Section 7007 funds are grants for a wide range of training programs, for either states or individuals. Section 8001 funds cover research, training, and other studies related to solid and hazardous waste. Funds in both of these sections cover potentially a wide range of projects and have been used extensively to fund mining research and technical assistance throughout all EPA media program offices as well as the Office of Enforcement. Funding in recent years has been as high as $2.5 million, in FY 95 it is expected to be $500,000. In FY 89 and FY 90 most of the money went to support WGA related activities; now funds are used for a variety of media related projects. Categories of funding typically include research at the Colorado School of Mines on mine waste, funding to maintain an environmental network, and funding to regions on mining related projects.

CWA Section 319 Funds. Section 319(h) established a demonstration grant program to assist states in implementing specific projects to demonstrate effective NPS control projects. Approximately $1,000,000 per year is spent through this mechanism on inactive mine projects, with oversight in the EPA Regional offices. Types of activities funded include: education, staff development, technical assistance, project demonstration, and ground water protection.

Other Federal Agency Funds. These are often used to either supplement EPA funds or to support specific pieces of a non-regulatory approach or initiative. In some instances land management agencies have large budgets devoted to mining related programs. These can be significantly greater than the EPA funds discusses above.

State/Local Partnerships. Although usually smaller in size than federal monies, support from state and local stakeholders can often fill financial holes in geographic based approaches.

Voluntary efforts. Good Samaritan work by private parties can contribute a significant amount towards cleanup of inactive and abandoned mines.

11.11.1.2 Institutional

Institutional support is critical for non-regulatory tools to be successful. These include the following.

Interagency Agreements. MOUs, MOAs, and IAGs are all tools that can be used to deal with the large number of agencies that regulate mining. When used effectively, they can help clarify roles and streamline the overall regulatory process. For example, as part of the Coeur d'Alene Restoration Project a MOA between EPA, the State of Idaho and the Coeur d'Alene Tribe was instrumental in helping reduce differences among the parties and focusing efforts on restoration goals.

External/Internal teamwork. At a less formal level, interagency groups are often an effective means of focusing attention on certain projects or issues. They provide a way for individuals with expertise to interact. These coalitions are also and important first step in breaking regulatory impasses. The WGA Mine Waste Task Force is such an example. Within a Region, internal EPA teams also help focus efforts on mining issues, such as in Regions 8, 9, and 10, where most of the staff participation on mining teams is voluntary.

Regional and National Initiatives. These are also a useful way of improving communications and focusing efforts on addressing mining problems. The site specific approaches described in more detail in Appendix C of EPA's National Hardrock Mining Framework are all examples of such initiatives at the regional level.

Outreach. This ranges from detailed outreach to a local community to simply providing on-site staffing at critical junctures during a remediation. One type of outreach, involving community based environmental indicators, can provide an important link with strategically significant technical tool, watershed planning.

11.11.1.3 Technical

Technical assistance. This would include the dedication of either Agency staff or contractor hours to providing direct help to a stakeholder. This is often an effective tool in working with other agencies and states.

Analytic methodologies. These can range from predictive tools to well developed monitoring and testing standards that help make data analysis consistent. Examples include: resource assessment and goal setting methods, alternatives development, and cost effectiveness methodologies. One specific example of this is the State of Montana, which has developed an HRS type system used for priority setting.

Technical demonstration. Technology demonstration efforts have had a couple of roles in non-regulatory efforts. One is a traditional means of identifying new and effective treatment technologies. Another is that non-regulatory approaches themselves have been able to attempt less proven methods than more regulatory, Superfund type approaches to remediation.

Education and Training. Because of the multimedia nature of mining issues, training is often necessary to bring key players up to speed on technical or regulatory issues. Education efforts on a more broader scale have been used to highlight and respond to community concerns regarding the impacts of mining and regulatory activities.

Standardization Analysis and Monitoring Methods. Different agencies use different methods for measurement ranging from simple location data to kinetic testing methodologies. Efforts to standardize this information make priority setting and monitoring significantly easier.

11.11.2 Other Characteristics

Enforcement Discretion. Where there is a significant enforcement history in connection with non-regulatory initiative, enforcement discretion is often a factor in helping to build a working coalition amongst a variety of players.

Institutional Controls. These include a variety of approaches, such as deed restrictions and other local regulations, that can be useful as part of an overall strategy.

11.11.3 Limits

There are limits to what can be accomplished with non-regulatory tools. These would include the following.

Staff resources. One of the main drawbacks on non-regulatory tools are the large amount of staff time needed to make them successful. To some extent, though, this may be a matter of perception only. Although these approaches can require significant staff resources, they can avoid a much higher resource cost in the future if properly focused.

Enforcement related issues. As a result of the regulatory backdrop for many of these examples, enforcement and liability can obstruct or delay non-regulatory, cooperative or Good Samaritan efforts.

Liability concerns. Sometimes private parties are reluctant to take action under a non-regulatory framework as such effort often do not address potential liability concerns. Efforts are underway to address these concerns through amendments to the CWA and CERCLA.

NOTICE