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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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Table of Contents

Chapter 5 Community Involvement at Mining Waste Sites

Chapter 6 Scoping Studies of Mining and Mineral Processing Impact Areas

Chapter 7 Sampling & Analysis of Impacted Areas

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

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

Chapter 9 Site Management Strategies

Chapter 10 Remediation and Cleanup Options

Chapter 11 The Regulatory "Toolbox"

APPENDICES

Disclaimer

Mention of trade names or company products does not constitute endorsement or recommendation for use by the U.S. Government or by the Environmental Protection Agency.

Chapter 1
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

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 3-5**
> **The Summitville Mine**
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> 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 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

> **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.

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.

[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.

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.

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.

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.

[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

[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 land-scape.

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, and 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.

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

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.

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/sedimentationcontrols 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.
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> **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. Setion 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. Setion 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

This document provides a reference resource to EPA and other staff addressing 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.

APPENDIX A

ACRONYM LIST and

GLOSSARY OF MINING TERMS

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NPS	National Park Service
OSC	On-Scene Coordinator
OPPTS	Office of Prevention Pesticides and Toxic Substances
ORD	Office of Research and Development
O&M	Operating and maintenance
OSM	Office of Surface Mining
OSHA	Occupational Safety and Health Act
OSW	Office of Solid Waste
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Units
OW	Office of Water
PAHs	Poly Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenols
PRG	Preliminary Remediation Goals
PRP	Potentially Responsible Party
QAPP	Quality Assurance Project Plan
RAGS	Risk Assessment Guidance for Superfund
RAOs	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation and Feasibility Study
RFS	RCRA Facility Assessment
RPMs	Remedial Project Managers
ROD	Record of Decision
SACM	Superfund Accelerated Cleanup Model
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SITE	Superfund Innovative Technology Evaluation
SDWA	Safe Drinking Water Act
SPLC	Synthetic Precipitation Leaching Procedure
SVOCs	Semi-Volatile Organic Compounds
TAG	Technical Assistance Grant
TCE	Trichloroethylene
TCLP	Toxicity Characteristic Leaching Procedure
TOSC	Technical Outreach Services for Communities
TSCA	Toxic Substances Control Act
TMDL	Total Maximum Daily Load
TRW	Technical Review Workgroup
USFS	US Forest Service
USGS	U.S. Geological Survey
USCG	U.S. Coast Guard
WET	California's Waste Extraction Test
XRF	X-ray Fluorescence analytical method
VOCs	Volatile Organic Compounds
WGA	Western Governors' Association

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

Active treatment systems: Systems that require periodic or continual maintenance or upkeep to maintain system effectiveness. Examples include treatment plants and alkaline chemical addition.

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

Aerobic: In the presence of oxygen. Aerobic wetlands are those in which oxidizing processes dominate.

Alkalinity: The capacity of water to accept protons (acidity). Alkalinity is imparted to natural waters by bicarbonate, carbonate, or hydroxide anions.

Alkalinity producing systems: A type of passive treatment system designed to produce neutral effluent with excess alkalinity. Typically these alkalinity producing systems combine anoxic limestone drains with anaerobic wetlands.

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

Amalgamation: The use of mercury to catch native gold by sorption, forming a liquid "amalgam" from which the mercury is later removed by distillation.

AMD: Acid mine drainage, characterized by low pH, high sulfate, and high iron and other metal species.

Anaerobic: In the absence of oxygen. Anaerobic wetlands are those in which reducing processes dominate.

Anfo: A free running explosive used in mine blasting made of 94% prilled aluminum nitrate and 6% No. 3 fuel oil.

Anionic species: Ions with a negative charge.

Anode: The negative electrode.

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

Anoxic: In the absence of oxygen.

ARD: Acid Rock Drainage. See AMD

Assay: To determine the amount of metal contained in an ore.

Beneficiation: Physical treatment of crude ore to improve its quality for some specific purpose. Also called mineral processing. RCRA defines beneficiation as: restricted to the following activities: Crushing; grinding; washing; dissolution; crystallization; filtration; sorting; sizing; drying; sintering;

pelletizing; briquetting; calcining to remove water and/or carbon dioxide; roasting, autoclaving, and/or chlorination in preparation for leaching; gravity concentration; magnetic separation; electrostatic separation; flotation; ion exchange; solvent extraction; electrowinning; precipitation; amalgamation; and heap, dump, vat, tank, and *in situ* leaching. See 40 CFR 261.4 (b)7 for more information

Bioreactor: An engineered container filled with untreated waters and organic matter such as hay or manure which provides sulfate-reducing bacteria and a carbon source to sustain the bacteria.

Block Caving: Large massive ore bodies may be broken up and removed by this method with a minimum of direct handling of the ore required. Generally, these deposits are of such a size that they would be mined by open-pit methods if the overburden were not so thick. Application of this method begins with the driving of horizontal crosscuts below the bottom of the ore body, or below that portion which is to be mined at this stage. From these passages, inclined raises are driven upward to the level of the bottom of the mass which is to be broken. Then a layer is mined so as to undercut the ore mass and allow it to settle and break up. Broken ore descends through the raises and can be dropped into mine cars for transport to the surface. When waste material appears at the outlet of a raise it signifies exhaustion of the ore in that interval. If the ore extends to a greater depth, the entire process can be continued by mining out the mass which contained the previous working passage.

Cathode: The positive electrode.

Cation exchange: A reverseable exchange process, that uses a resin, mineral or other exchange medium, in which one cation is removed from solution and replaced by another cation displaced from the exchange medium without destruction of the exchange medium or disturbance of electrical neutrality. The process is accomplished by diffusion.

Cationic species: Ions with a positive charge.

Classification: Separation of particles in accordance with their rate of fall through a fluid (usually water). The hydrocyclone is the most commonly used classification machine.

Clinoptilolite: A common zeolite mineral that has sodium and potassium as the primary cations and that commonly forms by alteration of natural volcanic glass by ground water or in a saline lake environment.

Comminution: Crushing and/or grinding of ore by impact and abrasion. Usually, the word "crushing" is used for dry methods and "grinding" for wet methods. Also, "crushing" usually denotes reducing the size of coarse rock while "grinding" usually refers to the reduction of the fine sizes.

Complexing: The chemical process of forming metal complexes.

Concentrate: The concentrate is the valuable product from mineral processing, as opposed to the tailing, which contains the waste minerals. The concentrate represents a smaller volume than the original ore.

Crushing: See "Comminution".

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

Cyanidation: The process of extracting gold and silver by leaching with cyanide (CN-). Cyanide, usually added in the form of a salt (e.g., NaCN, KCN), dissolves gold by the following reaction:

$$4Au + 8CN^- + O_2 + 2H_2O = 4Au(CN)_2^- + 4OH^-$$

Cyclone (hydrocyclone): A classifying (or concentrating) separation machine into which pulp is fed so as to take a circular path. Coarser and heavier fractions of solids report at the apex of a long cone while the finer particles overflow from the vortex.

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

Eh: The redox or oxidation potential. A measure of the ability of a natural environment to bring about any oxidation or reduction process by supplying electrons to an oxidizing agent or accepting electrons from a reducing agent.

Extraction: The process of removing ore from the ground.

Extractive metallurgy: The processes of chemically separating the valuable metal from its mineral matrix (ore or concentrate) to produce the pure metal. Includes the disciplines of hydrometallurgy and pyrometallurgy.

Ferric iron: Iron present in its oxidized state, with an ionic charge of +3.

Ferrous iron: Iron present in its reduced state, with an ionic charge of +2.

Flotation: Separation of minerals based on the interfacial chemistry of the mineral particles in solution. Reagents are added to the ore slurry to render the surface of selected minerals hydrophobic. Air bubbles are introduced to which the hydrophobic minerals attach. The selected minerals are levitated to the top of the flotation machine by their attachment to the bubbles and into a froth product, called the "flotation concentrate." If this froth carries more than one mineral as a designated main constituent, it is called a "bulk float". If it is selective to one constituent of the ore, where more than one will be floated, it is a "differential" float. The remaining slurry left after flotation is called the "flotation tailing." Flotation is the dominant method of mineral concentration currently in use.

Fluvial: Of or pertaining to rivers.

Flux: A component intentionally added to high temperature processing to modify properties (e.g., melting point, viscosity, chemical properties) of the slag.

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

Grade: Percentage of a metal or mineral composition in an ore or processing product from mineral processing.

Gravity separation: Exploitation of differences in the densities of particles to achieve separation. Machines utilizing gravity separation include jigs and shaking tables.

Grinding: See "Comminution".

Hydrometallurgy: A type of extractive metallurgy utilizing aqueous solutions/solvents to extract the metal value from an ore or concentrate. Leaching is the predominant type of hydrometallurgy.

Ion: An atom, group of atoms, or molecule that has acquired a net electric charge by gaining or losing electrons from an initially electrically neutral configuration.

Iron hydroxide: A chemical compound composed of iron cation and a hydroxide (oxygen plus hydrogen) anion, with the chemical formula $Fe(OH)_3$. It is a common precipitate in acidic environments, with a yellowish, orangish or reddish coloration.

Layered base amendments: Alkaline (base) materials that are interlayered with acid generating materials in order to provide a measure of neutralizing capacity.

Liberation: Freeing, by comminution, of particles of specific mineral from their interlock with other constituents of the ore.

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

Lode: An unusually large vein or set of veins containing ore minerals.

Longwall mining: In level, tabular ore bodies it is possible to recover virtually all of the ore by using this method (in the United States, only coal is known to have been mined using longwall methods). Initially, parallel drifts are driven to the farthest boundary of the mine area. The ore between each pair of drifts is then mined along a continuous face (the longwall) connecting the two drifts. Mining proceeds back toward the shaft or entry, and only enough space for mining activities is held open by moveable steel supports. As the longwall moves, the supports are moved with it and the mined out area is allowed to collapse. Various methods can be used to break up and remove the ore. In many cases, the rock stresses that are caused by the caving of the unsupported area aids in breaking the material in the longwall face.

Magnetic separation: Use of permanent or electro-magnets to remove relatively strong ferro-magnetic particles from para- and dia-magnetic ores.

Matte: An impure metallic sulfide product obtained from the smelting of sulfide ores of metals such as copper, lead, and nickel.

Metal complexes: An ion consisting of several atoms including at least one metal cation.

Metallurgy: The science and art of extracting metals from their ores, refining them, and preparing them for use. Metallurgy consists of three major disciplines: mineral processing metallurgy, extractive metallurgy, and physical metallurgy.

Microbial mat: A naturally occurring mat of organic matter found in wetland environments, typically composed predominantly of blue-green algae.

Mill: Includes any ore mill, sampling works, concentration, and any crushing, grinding, or screening plant used at, and in connection with, an excavation or mine.

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

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

Mineral processing: Preparation of ores by physical methods. A subcategory of metallurgy. Methods of mineral processing include comminution, classification, flotation, gravity separation, etc.

Native metal: A natural deposit of a metallic element in pure metallic form, not combined as a mineral with other elements.

Open Stope: In competent rock, it is possible to remove all of a moderate sized ore body, resulting in an opening of considerable size. Such large, irregularly-shaped openings are called stopes. The mining of large inclined ore bodies often requires leaving horizontal pillars across the stope at intervals in order to prevent collapse of the walls.

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

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

Oxidizing: Increasing in oxidation number (valence charge). The process of oxidation involves a loss of electrons.

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

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

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

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

Porous reactive walls: Trenches constructed to intercept contaminated ground water and which are filled with materials such as activated charcoal that sorb or precipitate metals from solution.

Pyrometallurgy: A type of extractive metallurgy where furnace treatments at high temperature are used to separate the metal values from an ore or concentrate. The waste product is removed as slag and/or gases. Smelting and refining are common pyrometallurgical processes.

Reducing: Decreasing in oxidation number (valence charge). The process of reduction involves a gain of electrons.

Reduction-oxidation potential: The redox potential or Eh.

Refining: A high temperature process in which impure metal is reacted with flux to reduce the impurities. The metal is collected in a molten layer and the impurities in a slag layer. Refining results in the production of a marketable material.

Riparian: Pertaining to the bank of a natural watercourse.

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

Room and Pillar: This method is suitable for level deposits that are fairly uniform in thickness. It consists of excavating drifts (horizontal passages) in a rectilinear pattern so that evenly spaced pillars are left to support the overlying material. A fairly large portion of the ore (40%-50%) must be left in place. Sometimes the remaining ore is recovered by removing or shaving the pillars as the mine is vacated, allowing the overhead to collapse or making future collapse more likely.

Sedges: Any of numerous plants of the family Cyperaceae, resembling grasses but having solid rather than hollow stems.

Sequential extraction: A chemical extraction process in which chemical species are removed from solution for analysis in a sequential manner using laboratory techniques that do not affect the concentrations of the constituents remaining in solution.

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

Shrinkage Stoping: In this method, mining is carried out from the bottom of an inclined or vertical ore body upwards, as in open stoping. However, most of the broken ore is allowed to remain in the stope in order both to support the stope walls and to provide a working platform for the overhead mining operations. Ore is withdrawn from chutes in the bottom of the stope in order to maintain the correct amount of open space for working. When mining is completed in a particular stope, the remaining ore is withdrawn, and the walls are allowed to collapse.

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

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

Sorption: The process of sorbing as by adsorption or absorption.

Spoil: Debris or waste material from a mine.

Square-set Stoping: Ore bodies of irregular shape and/or that occur in weak rock can be mined by providing almost continuous support as operations progress. A square set is a rectangular, three-dimensional frame usually of timber, which is generally filled with waste rock after emplacement. In this method, a small square section of the ore body is removed, and the space created is immediately filled by a square-set. The framework provides both lateral and vertical support, especially after being filled with waste. Use of this method may result in a major local consumption of timber and/or other materials utilized for construction of the sets.

Stope: An excavation in a mine, other than development workings, made for the purpose of extracting ore.

Sublevel Caving: In this method, relatively small blocks of ore within a vertical or steeply sloping vein are undercut within a stope and allowed to settle and break up. The broken ore is then scraped into raises and dropped into mine cars. This method can be considered as an intermediate between block carving and top slicing.

Substrate: An underlayer. In passive treatment systems this refers to a layer of organic or other matter that underlies ponded acidic water.

Taconite: A chemical precipitate sedimentary rock composed of iron-bearing chert and which can serve as an ore material for iron.

Tailings: Residue from milling processes (e.g., flotation tailings, gravity tailings, leach tailings, etc.).

Top Slicing: Unlike the previously described methods in which mining begins at the bottom of an ore body and proceeds upward, this procedure involves mining the ore in a series of slices from the top downward, first removing the topmost layer of the ore and supporting the overhead with timber. Once the top layer of an area is completely removed, the supports are removed and the overlying material allowed to settle onto the new top of the ore body. The process is then repeated, so that as slices of ore are removed from the ore body, the overburden repeatedly settles. Subsequent operations produce an ever- thickening mat of timber and broken supports. This method consumes major quantities of timber.

Vein: A mineralized zone having a more or less regular development in length, width, and depth to give it a tabular form.

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

Zeolite: A group of hydrous aluminosilicate minerals containing sodium, calcium, potassium or other alkali or alkaline earth elements, which typically have an open crystal structure. These minerals are widely used in chemical processes for their cation exchange capabilities.

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APPENDIX B

ACID MINE DRAINAGE

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Appendix B
Acid Mine Drainage

Table of Contents

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Appendix B
Acid Mine Drainage

B.1 Introduction

Acid mine drainage (AMD), also called acid rock drainage (ARD), is a natural occurrence resulting from the exposure of sulfur and iron bearing materials to erosion and weather. Percolation of water through these materials results in a discharge with low pH and high metals concentration. Although AMD is naturally occurring, mining activities may greatly accelerate its production. AMD production is accelerated since mining exposes new iron and sulfide surfaces (e.g, underground mine walls, open pit walls, and overburden and mine waste piles) to oxygen. As such, AMD is one of the primary environmental threats at mining sites.

To efficiently remediate mining sites, project managers must understand the formation of AMD and those factors that influence its quality and quantity, such as the interaction of sulfide minerals, air, water, and micro-organisms. This section has been added to introduce the project manager to these issues.

B.2 Description

AMD results from the oxidation of sulfide minerals inherent in some ore bodies and the surrounding rocks. Iron sulfide minerals, especially pyrite (FeS_2) and also pyrrhotine (FeS) contribute the most to formation of AMD. Oxygen (from air or dissolved oxygen) and water (as vapor or liquid) which contact the sulfide minerals directly cause chemical oxidation reactions which result in the production of sulfuric acid. The primary reactions associated with pyrite are described below.[1]

Pyrite is initially oxidized by atmospheric oxygen producing sulfuric acid and ferrous iron (Fe^{2+}) according to the following reaction:

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

$$Fe^{2+} + 1/4\ O_2 + H^+ > Fe^{3+} + \tfrac{1}{2} H_2O \qquad (2)$$

The ferrous iron may be further oxidized by oxygen releasing more acid into the environment and precipitating ferric hydroxide.

$$Fe^{2+} + 1/4\ O_2 + 5/2\ H_2O > Fe(OH)_3 + 2H^+ \qquad (3)$$

As acid production increases and the pH drops (to less than 4), oxidation of pyrite by ferric iron (Fe^{3+}) becomes the main mechanism for acid production.

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

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[1] Singer, P.C. and W. Strumm. 1970. Acid Mine Drainage: the rate-determining step, Science 167:1121-1123.

This reaction is catalyzed by the presence of Thiobacillus ferrooxidans. This bacterium accelerates the oxidation of ferrous iron into ferric iron (reaction 2) by a factor of 106:1. The sulfuric acid produced in the above reactions increases the solubility of other sulfide minerals in the solid surfaces. Ferric iron in acidic solution can oxidize metal sulfides per the following reaction:

$$MS + 2Fe3+ > M2+ + S + 2Fe2+ \qquad (5)$$

where MS = metal sulfide (galena PbS, sphalerite, ZnS, etc.)

Metals commonly solubilized from sulfides in AMD include aluminum, copper, lead, manganese, nickel, and zinc. Metals in the form of carbonates, oxides, and silicates may also be mobilized, often aided by biological catalysts. AMD may also leach uranium, thorium, and radium from mine wastes and tailings associated with uranium mining operations. The most common metal in AMD is iron in the form of soluble ferrous ions, ferrous hydroxide (Fe(OH)2), ferrous sulfate, and ferric sulfate, as well as suspended insoluble ferric hydroxide precipitate. The iron hydroxides give AMD a red to orange color.[2]

The rates of the reactions associated with AMD have important implications, as they influence the quality (pH and metals content) and quantity of AMD produced. The rate of AMD formation depends on several factors, including the presence of microorganisms, the type of the sulfide and non-sulfide minerals present, particle size of the minerals, pH, temperature, and the amount of oxygen present.

The presence of iron-oxidizing microorganisms as catalysts affects the rate of AMD forming reactions. These bacteria are indigenous to many environments including sulfide ore bodies. As discussed above, the iron oxidizing autotrophic bacteria, T. ferrooxidans, greatly increases the oxidation of ferrous to ferric iron, which causes reaction 4 to quickly proceed. Reaction 4 produces 16 equivalents of hydrogen ions further lowering pH and causing more ferric iron to be oxidized. At low pH levels (pH 2 to 4) these bacteria thrive and multiply, further increasing reaction rates. Sulfide-oxidizing bacteria, such as T. thiooxidans may also increase AMD formation, although to what extent is less well-known.

Mineral sulfides vary in their reactivity. This is due to the physical and chemical characteristics of the various sulfide minerals. For example some metal sulfides (i.e., copper, lead, and zinc) have a tendency to form low solubility minerals which encapsulate them and prevent further oxidation. The crystal structure of the sulfide minerals is an important factor for two reasons: (1) certain crystalline structures are more stable and resist weathering (oxidation); and (2) due to the increased surface area, smaller crystals react faster.[3]

The rate of AMD formation depends upon the particle size and surface area of rocks containing the sulfide minerals. Smaller particles have increased surface area that can contact the

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[2] duMond, Mike, "New Mexico Mine Drainage Treatment," State of New Mexico Energy, Minerals and Natural Resources Department, Albuquerque, New Mexico, 1987.

[3] Steffen, Robertson, and Kirsten Inc., Acid Rock Drainage Draft Technical Guide, Volume 2 - Summary Guide, December 1989.

weathering agents. Therefore, rock tailings (very fine particles) will weather faster than large boulders. Rates of weathering and production of AMD are dramatically increased in processed materials (e.g, crushed tailings from mineral processing or leaching), due to the increased amount of surface area.

The rate of AMD formation is also dependent on pH and temperature. The chemical reaction rate is higher at low pH because the solubility of the metals increases and biological oxidation peaks at a pH of about 3.5. Therefore, it is generally true that as more sulfuric acid is released and the pH decreases, more leaching occurs. Both the chemical and biological reaction rates also increase with increased temperature. This is because of increased solubility of metal species and increased biological activity at higher temperatures.

It is apparent from the above discussion that the production of AMD is complicated. Due to the many factors that influence AMD, the short-term and long-term quality and quantity produced may be difficult to characterize or predict. Section A.4.2 of this document discusses methods for characterizing the production of AMD from waste solids (sources) associated with mining processes.

B.3 Environmental Effects

As discussed above, AMD introduces sulfuric acid and heavy metals into the environment. The environment can naturally assimilate some AMD through dilution, biological activity, and neutralization, although its capacity to treat AMD may be limited. When this treatment capacity is exceeded, drainage and surface water flowing out of mining areas can be very acidic and contain elevated concentrations of metals. The metal-laden acidic drainage and surface water can lead to ground water contamination.

The ability of the receiving environment to assimilate AMD will depend on site specific conditions such as drainage patterns and dilution, biological activity, and neutralizing capacity of the ore, waste material, tailings, and/or surrounding soils. Drainage patterns and dilution depend largely on the climate and topography of a site. Naturally occurring biological activity can attenuate the metals concentration by adsorption and precipitation of some metal species such as sulfates.

Neutralization is the consumption of acidity in which hydrogen ions are consumed according to the following reactions:

$$CaCO3 + H+ > Ca2+ + HCO3- \quad (6)$$
$$HCO3- + H+ > H2O + CO2 \quad (7)$$

The neutralization capacity of a soil depends largely on the presence of naturally occurring, acid consuming minerals. The most common mineral is calcite (CaCO3), a major constituent of limestone, and dolomite (CaMg(CO3)2). Other neutralizing minerals include other carbonates of iron and magnesium and aluminum and iron hydroxides. As neutralization occurs, metals precipitate because of decreased solubility at higher pH.

The impact of AMD can increase over time if the neutralizing capacities of the soil are depleted. This may occur if the neutralizing minerals have a tendency to form crusts of precipitated salts or gypsum which inhibits further reaction, or if the neutralizing minerals are depleted through numerous reactions with AMD. The impact of AMD can also change if the rates of AMD formation change due to the alteration of site conditions. For these reasons, there is often a time lag after mining activities begin until AMD is detected. The times can range from 1 to 10 or more years; AMD may not be detected until after surface reclamation occurs. Acid generation, once it begins, is difficult to control, often accelerates, and can persist for centuries.

AMD may be compounded by other problems caused by mining activities. Chemicals or petroleum products used in equipment and vehicle maintenance can pollute mining sites. Heap leaching technologies utilize cyanide to extract gold, and the failure of liners can introduce cyanide into the environment. In addition, mining often leads to higher erosion rates and increased dissolved salts, sediment loads, and turbidity of run-off. Radionuclides can also be leached out of the rock. All of these contaminants, as well as the heavy metals mentioned earlier can enter the surface water and the ground water. These contaminants, in addition to the acidic run-off, must all be considered when treating AMD.

If site conditions are conducive to AMD formation and the capacity to assimilate AMD has been exceeded, environmental impacts can be quite severe. Impacts depend on the nature (strength and volume) of the AMD and the proximity of aquatic resources. Impacts can include lowering of water quality, alteration of aquatic and terrestrial ecosystems, potential destruction of aquatic habitats, and, if the site is near human residences, contamination of drinking water supplies. Impacts are far reaching, are of concern to regulatory decisionmakers, and must be addressed during cleanup actions.

B.4 Contacts and References

Appendix B of this Manual is an annotated bibliography of passive acid mine drainage treatment technologies. EPA regional and other Federal Land Management Agency contacts with expertise in acid mine drainage prediction, analysis, and remediation, can be found in Appendix L. The remainder of this document is an annotated bibliography of acid mine drainage references.

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Bowders, J. and E. Chiado, 1990, " Engineering Evaluation of Waste Phosphatic Clay for Producing Low Permeability Barriers," in Proceedings 1990 Mining and Reclamation Conference and Exhibition, Volume 1, 11-18pp, West Virginia University.

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Brady, K. B., M. Smith, R. Beam and C. Cravotta III, 1990, "Effectiveness of Addition of Alkaline Materials at Surface Coal Mines in Preventing and Abating Acid Mine Drainage: Part 2 Mine Site Case Studies," in Proceedings of the 1990 Mining and Reclamation Conference and Exhibition, Volume 1, 227-242pp, West Virginia University.

Reference not available.

Brady K.B., J.R. Shaulis and V.W. Sekma, 1988, "A Study of Mine Drainage Quality and Prediction Using Overburden Analysis and Paleoenvironmental Reconstructions, Fayette County, Pennsylvania," in Conference Proceedings, Mine Drainage and Surface Mine Reclamation, U.S. Bureau of Mines Information Circular 9183, 33-44pp.

Reference not available.

Brodie, G., et al. “Passive Anoxic Limestone Drains to Increase Effectiveness of Wetlands Acid Drainage Treatment Systems,” Proceedings: 12th Annual NAAMLP Conference, Returning Mined Land to Beneficial Use, Breckinridge, Colorado, September 16-20, 1990.

Reference not available.

Brodie, G.A., 1993. Staged, aerobic constructed wetlands to treat acid drainage: Case history of Fabius impoundment 1 and overview of the Tennessee Valley Authority’s program, *in* Moshiri, Gerald A., ed., *Constructed Wetlands for Water Quality Improvement,* Lewis Publishers, Boca Raton, p. 157-165.

Reviews the success of 12 wetland systems operated by TVA and discusses the quality of effluent from impoundment 1, which has been in operation since 1985.

Brodie, G.A., Britt, C.R., Tomaszewski, T.M., and Taylor, H.N., 1993. Anoxic limestone drains to enhance performance of aerobic acid drainage wetlands: Experiences of the Tennessee Valley Authority, *in* Moshiri, Gerald A., ed., *Constructed Wetlands for Water Quality Improvement,* Lewis Publishers, Boca Raton, p. 129-138.

Reviews the effectiveness of anoxic limestone drains in increasing alkalinity to prevent pH decreases due to Fe hydrolysis.

Brodie, Gregory A., Hammer, Donald A., and Tomljanovich, David A., 1989. Treatment of acid drainage with a constructed wetland at the Tennessee Valley Authority 950 Coal Mine, *in* Hammer, Donald A., ed., *Constructed Wetlands for Wastewater Treatment,* Lewis Publishers, Ann Arbor, MI, p. 201-209.

Reviews the design, construction, and success of a constructed wetland to treat acidic drainage from impoundment 3 at the 950 coal mine in AL.

Brodie, Gregory A., Hammer, Donald A., and Tomljanovich, David A., 1988. An evaluation of substrate types in constructed wetlands acid drainage treatment systems, *in* U.S. Bureau of Mines, *Mine Drainage and Surface Mine Reclamation, Volume I: Mine Water and Mine Waste,* U.S. Bureau of Mines Information Circular 9183, p. 389-398.

Experimentally investigated the effectiveness of 5 substrate types (natural wetland, acidic wetland, clay, mine spoil, and river pea gravel) in mitigating acidic drainage from the Fabius coal mine (AL). Study showed that substrate type is less important than the plant-soil-microbe complex that developed in each cell.

Brookhaven National Laboratory, Dept. of Applied Science. "Treatment of Acid Mine Drainage by Ozone Oxidation." Washington: EPA Water Quality Office; for sale by the Superintendent of Documents, U.S. Government Printing Office, 1970.

Reference not available.

Brooks 1992. Reclamation of the Timberline Heap Leach: Tooele County, Utah, USDI Bureau of Land Management, Technical Note #386, by Steven J. Brooks, 1992.

Reference not available.

Burnett, MacKenzie and Skousen, Jeffrey G., 1995. Injection of limestone into underground mines for AMD control, *in* Skousen, Jeffrey and Ziemkiewicz, Paul, eds., *Acid Mine Drainage: Control & Treatment, 2nd edition,* National Mine Land Reclamation Center, p. 357-362.

Describes a project in which a coal mine portal was sealed and backfilled with limestone. Initially, the seal reduced water flow, increased pH of the remaining effluent, and created net alkaline effluent with reduced Fe and Al concentrations. Subsequent high flows changed flow paths so that water no longer contacts the limestone and escapes untreated.

Cambridge, M., 1995. Use of passive systems for the treatment and remediation of mine outflows and seepages, *Minerals Industry International,* No. 1024, p. 35-42.

A review of the potential uses of the passive systems available and of their effectiveness in preventing long-term environmental damage. Cites case studies of the treatment systems used at the Wheal Jane and Consolidated copper-tin mines (Cornwall, England). Includes a discussion of general principles that may affect the long-term development of acidity.

Camp, Dresser & McKee, Inc., 1991. *Clear Creek Phase II Feasibility Study Report,* prepared for the Colorado Department of Health, Hazardous Materials and Waste Management Division, Denver, CO, vol. 1, p. 3-77 to 3-179.

Contains sections on passive treatment and combined passive and active systems for treating metal-laden AMD from precious metal mines in the Clear Creek drainage of Colorado. Passive treatment technologies include cascade aeration to promote precipitation of iron compounds and wetland treatment in aerobic and anaerobic environments to reduce metal and sulfur contents. Passive treatment designs are discussed for the Argo Tunnel, Big Five Tunnel, National Tunnel, Burleigh Tunnel, Rockford Tunnel, Gregory Incline, Quartz Hill Tunnel, and McClelland Tunnel. Discusses designs that incorporate disposal of precipitated metals in accordance with RCRA guidelines and for *in situ* fixation of precipitated metals. Active treatment includes chemical precipitation of metals. Considers treatment of surface and ground waters.

Caruccio F. T. and G. Gediel, 1989, "Water Management Strategies in Abating Acid Mine Drainage - Is Water Diversion Really Beneficial?," in Proceedings 1989 Multinational Conference on Mine Planning and Design, University of Kentucky, Lexington, Kentucky.

Reference not available.

Catalytic, Inc. "Neutradesulfating Treatment Process for Acid Mine Drainage," prepared for the U.S. Environmental Protection Agency; for sale by the Superintendent of Documents, U.S. Government Printing Office, 1971.

Reference not available.

Chapman, B.M, Jones, D.R., and Jung, R.F., 1983. Processes controlling metal ion attenuation in acid mine drainage streams, *Geochimica et Cosmochimica Acta,* v. 47, p. 1957-1973.

Presents detailed analyses of two acid mine drainage streams in Australia to determine the dominant processes that control heavy metal transport and attenuation under conditions of chronic high-level pollution. Streams receive AMD input from sulfide-rich base and precious metals deposits. Results show that natural processes cause precipitation of metal hydroxides that lower Fe, Cu, and Al in stream waters as pH rises due to the inflow of higher pH tributary waters. Concentrations of Cd, Zn, and Mn apparently diminished only by dilution. Presents a graphical method to delineate the point along a stream channel where chemical removal mechanisms become effective for each element.

Cliff, John, Sterner, Pat, Skousen, Jeff, and Sexstone, Alan, 1995. Treatment of acid mine drainage with a combined wetland/anoxic limestone drain: A comparison of laboratory versus field results, *in* Skousen, Jeffrey and Ziemkiewicz, Paul, eds., *Acid Mine Drainage: Control & Treatment, 2nd edition,* National Mine Land Reclamation Center, p. 311-330.

Compares results from the Douglas Highwall project (WV) and greenhouse experiments conducted at West Virginia University, both of which utilized similar designs. Found that slight differences in influent flow rate and the hydraulic conductivity of organic substrates used in anoxic limestone drains greatly affected the ability of the system to reduce and remove Fe, increase Eh, and neutralize acid.

Cohen, R.H., 1996. The technology and operation of passive mine drainage treatment systems, *in Managing Environmental Problems at Inactive and Abandoned Metals Mine Sites,* U.S. Environmental Protection Agency Seminar Publication No. EPA/625/R-95/007, p. 18-29.

Reference not available.

Colorado Department of Public Health and Environment, Wetlands-based treatment, http://www.gnet.org/gnet/tech/techdb/site/demongng/colodepa.htm.

Describes the technology in use and status of studies at metal mines in Colorado.

Concurrent Technologies Corporation, “Recovering Metal Values from Acid Mine Drainage: Market and Technology Analyses,” Summary Report to Southern Alleghenies Conservancy, March 29, 1996.

Reference not available.

Dames and Moore, 1981, "Outcrop Barrier Design Guidelines For Appalachian Coal Mines," prepared for the U.S. Bureau of Mines, Contract J0395069, Bureau of Mines Open File Report 134-81.

Reference not available.

Dames and Moore, 1981, “Outcrop Barrier Design Guidelines For Appalachian Coal Mines,” prepared for the U.S. Bureau of Mines, Contract J0395069, Bureau of Mines Open File Report 134-81.

Reference not available.

Davison, J., 1993. Successful acid mine drainage and heavy metal site bioremediation, *in* Moshiri, Gerald A., ed., *Constructed Wetlands for Water Quality Improvement,* Lewis Publishers, Boca Raton, p. 167-178.

Discusses the Lambda Bio-Carb Process (patent pending) for *in situ* bioremediation. The process uses site-indigenous cultures in microecological balance to construct a self-sustaining system that self-adjusts to variations in influent composition.

Desborough, George A., 1992. *Ion exchange capture of copper, lead, and zinc in acid-rock drainages of Colorado using natural clinoptilolite--Preliminary field studies,* U.S. Geological Survey Open-File Report 92-614, 16 pp.

Study evaluated efficiency of clinoptilolite-rich rock in reducing heavy metal concentrations in 9 stream sites contaminated by acid mine drainage (pH=2-5) in central CO. Fe and As deposited as fine particles on zeolite surface, whereas Cu, Pb, and Zn were ion exchangeable using ammonium chloride solution. Dominant factors influencing ion exchange rates were dissolved metal concentration, water flow rate, zeolite fragment size, and water temperature.

Dietz, Jonathan M., Watts, Robert G, and Stidinger, Dennis M., 1994., Evaluation of acidic mine drainage treatment in constructed wetlands systems, *in International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage,* U.S. Bureau of Mines Special Publication, SP 06A-94, vol. 1, p. 71-79.

Conducted and evaluated field tests of 6 constructed wetland treatment systems for a 2 year period. Tests monitored acid and metals removal from stream sites receiving AMD in central PA.

Donlan, Ron, "Constructed Wetlands for the Treatment of Acid Mine Drainage," Water Pollution Control Association of Pennsylvania, March-April 1989.

Reference not available.

Donovan, Joseph J. and Ziemkiewicz, Paul F., 1994. Early weathering of pyritic coal spoil piles interstratified with chemical amendments, *in International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage,* U.S. Bureau of Mines Special Publication, SP 06A-94, vol. 1, p. 119-128.

Monitored acidity from eleven 400-ton constructed piles in WV during 1982. Piles had 1) no treatment, 2) layered base amendments (limestone, lime, rock phosphate), and 3) sodium lauryl phosphate amendment. Acid conditions ensued for all nontreated piles and amended piles with NP/MPA <1. Acid conditions developed in some amended piles with NP/MPA up to 2.3. Layered amendments were judged to be less effective than piles in which basic materials were evenly dispersed.

Doyle 1990. *Mining and Mineral Processing Wastes,* proceedings of the Western Regional Symposium on Mining and Mineral Processing Wastes, Berkeley, California, May 30-June 1, 1990, Society for Mining, Metallurgy, and Exploration, Inc., Doyle, F.M., editor, 1990.

Reference not available.

DuMond, Mike, 1988. New Mexico mine drainage treatment, *in Proceedings of the U.S. EPA's Forum on Remediation of CERCLA Mining Waste Sites, April 25, 1989, Ward, Colorado,* p. 65-94.

Describes a variety of techniques presently being used to treat AMD at coal, metal, and uranium mines in New Mexico. Both active and passive treatment techniques are discussed.

Durkin, T.V. and Hermann, J.G., 1996. Focusing on the problem of mining wastes: An introduction to acid mine drainage, *in Managing Environmental Problems at Inactive and Abandoned Metals Mine Sites,* U.S. Environmental Protection Agency Seminar Publication No. EPA/625/R-95/007, p. 1-3.

Reference not available.

Eger, Paul and Lapakko, Kim, 1989. Use of wetlands to remove nickel and copper from mine drainage, *in* Hammer, Donald A., ed., *Constructed Wetlands for Wastewater Treatment,* Lewis Publishers, Chelsea, MI, p. 780-787.
Describes the use of natural wetlands to treat drainage from taconite mines in MN contaminated with Ni, Cu, Co, and Zn. Also discusses the siting and design of test cells within existing wetlands.

Eger, P. and Lapakko, K., 1988. Nickel and copper removal from mine drainage by a natural wetland, *Mine Drainage and Surface Mine Reclamation, Volume I: Mine Water and Mine Waste,* U.S. Bureau of Mines Information Circular 9183, p. 301-309.
Reports results of a study of metal removal from neutral drainage (pH=7.2) generated from an open-pit taconite mine in MN. The natural white cedar peatland removed significant amounts of nickel and copper, most taken up by the peat.

Ellison, R.D. & Hutchison, I.P.G., Mine Waste Management: A Resource for Mining Industry Professionals, Regulators and Consulting Engineers, Lewis Publishing, INC.,Chelsea, MI, 1992, pgs.127-184.
Reference not available.

Emerick, J.C., Huskie, W.W., and Cooper, D.J., 1988. Treatment of discharge from a high elevation metal mine in the Colorado Rockies using an existing wetland, *in Mine Drainage and Surface Mine Reclamation, Volume I: Mine Water and Mine Waste,* U.S. Bureau of Mines Information Circular 9183, p. 345-351.
Reports inconclusive results of a study in which acidic mine drainage (pH=3.6) was diverted into a natural wetland. Study found that significant accumulations of metals existed in the wetland prior to the introduction of mine drainage and that the low hydraulic conductivity of the peat precluded significant flow of mine drainage through wetland sediments. Study did confirm that the plant species present had a high tolerance to metals and low pH and could be used in constructed wetlands throughout the region.

Emerick, John C., Wildeman, Thomas R., Cohen, Ronald R., and Klusman, Ronald W., 1994. Constructed wetland treatment of acid mine discharge at Idaho Springs, Colorado, *in* K.C. Stewart and R.C. Severson, eds., *Guidebook on the Geology, History, and Surface-Water Contamination and Remediation in the Area from Denver to Idaho Springs, Colorado,* U.S. Geological Survey Circular 1097, p. 49-55.
Investigates factors influencing the effectiveness of wetlands constructed to treat acid mine drainage from the Big Five Tunnel over a three year period. Discusses biochemical processes that lead to effective treatment. Results show that Cu and Zn are effectively removed, Fe less effectively removed, and pH buffered to 5.5 or higher for the long term. Concludes that treatment systems incorporating forced vertical flow are more effective than those relying on lateral flow and that low flow rates permit more metal removal than high flow rates.

Environmental Research and Applications, Inc. "Concentrated Mine Drainage Disposal Into Sewage Treatment Systems; the Disposal of Acid Brines from Acid Mine Drainage in Municipal Wastewater Treatment." Washington: EPA Research and Monitoring, 1971.
Reference not available.

Erickson, B.M., Briggs, P.H., and Peacock, T.R., 1996. Metal concentrations in sedges in a wetland receiving acid mine drainage from St. Kevin Gulch, Leadville, Colorado, *in* Morganwalp, David W. and Aronson, David A., eds., *U.S. Geological Survey Toxic Substances Hydrology Program--Proceedings of the Technical Meeting, Colorado Springs, CO, September 20-24, 1993,* U.S. Geological Survey Water Resources Investigation Report 94-4015, p. 797-804.

Characterizes the concentrations of Cd, Cu, Fe, Pb, Mn, and Zn in apparently healthy sedges from a natural wetland receiving AMD. Finds that baseline concentrations are elevated above the geometric mean for noncontaminated areas and that Cd, Pb, and Zn locally exceed recommended dietary levels for cattle.

Erickson, B.M., Briggs, P.H., and Peacock, T.R., 1994. Metal composition of sedges collected on the wetland receiving acid mine drainage from St. Kevin Gulch, Leadville, Colorado, *U.S.G.S. Research on Mineral Resources - 1994,* U.S. Geological Survey Circular 1103-A, p. 33-34.

Characterizes the content of Cd, Cu, Fe, Pb, Mn, and Zn in sedges from a wetland receiving acid mine drainage, in order to determine background values and the amount of material removed from AMD influent.

Erickson, L.J., and J.H. Deniseger, 1987. "Impact Assessment of Acid Drainage from an Abandoned Copper Mine on Mt. Washington", in an unpublished report of the British Columbia Ministry of Environment and Parks, Waste Management Program, Nanaimo.

Reference not available.

Evangelou, V., U. Sainju and E. Portig, 1991, "Some Considerations When Applying Limestone/Rock Phosphate Materials on to Acid Pyritic Spoils," in Proceedings Twelfth Annual West Virginia Surface Mine Drainage Task Force Symposium , April 3-4, 1991, Morgantown, West Virginia.

Reference not available.

Faulkner, Ben B. and Skousen, Jeff G., 1995. Treatment of acid mine drainage by passive treatment systems, *in* Skousen, Jeffrey and Ziemkiewicz, Paul, eds., *Acid Mine Drainage: Control & Treatment, 2nd edition,* National Mine Land Reclamation Center, p. 267-274.

Reviews the effectiveness of wetlands and anoxic limestone drains in treating AMD from coal mines in WV. Studied sites include the Keister, S. Kelly, Pierce, and Z&F wetlands and the Greendale, Kodiak, Lillybrook, Preston, Lobo Capital, and Benham anoxic limestone drains. Finds that limestone in wetland substrates does not appear to improve metal removal efficiency, that hay added to anoxic limestone drains diminishes the ability of limestone to neutralize acidity, and that maintaining water flow through the drain is critical to the drain's success.

Faulkner, Ben B. and Skousen, Jeff G., 1993. Monitoring of passive treatment systems: An update, *in Proceedings Fourteenth Annual West Virginia Surface Mine Drainage Task Force Symposium,* Morgantown, West Virginia, April 27-28, 1993.

Reports updated monitoring results on the Keister, S. Kelly, Pierce, and Z&F wetlands and the Benham, Lobo Capital, Kodiak, Lillybrook, and Preston anoxic limestone drains, all of which are associated with eastern coal mines.

Faulkner, B. (ed.), 1991, "Handbook for Use of Ammonia in Treating Mine Waters," West Virginia Mining and Reclamation Association, Charleston, West Virginia.

Reference not available.

Filipek, Lorraine H., 1986. Organic-metal interaction in a stream contaminated by acid mine drainage, *in* Donald Carlisle, Wade L. Berry, Isaac R. Kaplan, and John R. Watterson (eds)., *Mineral Exploration: Biological Systems and Organic Matter, Rubey Volume V,* Prentice-Hall, Englewood Cliffs, NJ, p. 206.

Abstract reporting results of a study to examine the effect of pH on the metal scavenging ability of algae. Concludes that cationic species are less effectively scavanged at low pH, whereas anionic metal species (e.g., As) are completely removed from solution within a short distance from the source.

Frostman, T.M., 1993. A peat/wetland treatment approach to acidic mine drainage abatement, *in* Moshiri, Gerald A., ed., *Constructed Wetlands for Water Quality Improvement,* Lewis Publishers, Boca Raton, p. 197-200.

Reviews the design and operation of a peat/wetland system that could be installed to treat AMD from an iron mine in MN (pH of 5-6, low metal content).

Fyson, Andrew, Kalin, Margarete, and Adrian, Les, W., 1994. Arsenic and nickel removal by wetland sediments, *in International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage,* U.S. Bureau of Mines Special Publication, SP 06A-94, vol. 1, p. 109-118.

Laboratory experiments to test the capacity of muskeg sediments to treat mildly acidic (pH=4), metal-bearing drainage. Alfalfa, potato waste and hydroseed mulch used to simulate muskeg sediments. Experiments show this treatment can be effective in removing metals and raising pH, especially if reducing conditions can be maintained.

Ganse, Margaret A., 1993. *Geotechnical Design of a Four-stage Constructed Wetland for the Remediation of Acid Mine Drainage,* Unpubl. M.S. Thesis, Colorado School of Mines, Golden, CO, 133 pp.

Develops guidelines for creating effective conceptual designs that utilize knowledge of wetland chemistry, hydraulic capacity, and structural integrity of treatment components. Applies guidelines to the redesign of the passive treatment system from the Marshall No. 5 coal mine near Boulder, CO. System components include an anoxic limestone drain to add alkalinity, a settling basin to promote aeration of the AMD, a wetland with aerobic and anaerobic function to raise pH, and a polishing cell for final aerobic treatment. Preliminary results show pH increasing from 4.5 to 6.4 and alkalinity increasing from 8 mg/l to 79 mg/l.

Garbutt, K., Kittle, D.L., and McGraw, J.B., 1994. The tolerance of wetland plant species to acid mine drainage: A method of selecting plant species for use in constructed wetlands receiving mine drainage, *in International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage,* U.S. Bureau of Mines Special Publication, SP 06A-94, vol. 2, p. 413.

Study exposed five common wetland species to AMD with a range of pH values to test individual species tolerance. Recommended species are suggested for various pH levels.

Girts, M.A. and Kleinmann, R.L.P., 1986. Constructed wetlands for treatment of mine water, *in American Institute of Mining Engineers Fall Meeting, St. Louis, MO.*

Reference not available.

Gormely, L., Higgs, T.W., Kistritz, R.U., and Sobolewski, A., 1990. Assessment of wetlands for gold mill effluent treatment, report prepared for the Mine Pollution Control Branch of Saskatchewan Environment and Public Safety, Saskatoon, SK, Canada, 63 pp.

Reference not available.

Gross, M.A., Formica, S.J., Gandy, L.C., and Hestir, J., 1993. A comparison of local waste materials for sulfate-reducing wetlands substrate, *in* Moshiri, Gerald A., ed., *Constructed Wetlands for Water Quality Improvement,* Lewis Publishers, Boca Raton, p. 179-185.

Investigates the suitability of locally derived organic materials for their use in sulfate-reducing constructed wetlands at a clay mine in AR and presents the results of lab tests.

Groupe de Recherche en Geologie de L'ingenieur, 1992. *Acid Mine Drainage Generation from a Waste Rock Dump and Evaluation of Dry Covers using Natural Materials: La Mine Doyon Case Study, Quebec,* Final Report to Service de la Technologie Miniere Centre de Recherches Minerales, 22 pp.

Objectives were to characterize the problem of AMD generation in the south mine dump of the La Mine Doyon and to study the feasibility of using natural materials to construct dry covers to control air and water circulation in the dump.

Guertin, deForest, Emerick, J.C., and Howard, E.A., 1985. Passive mine drainage treatment systems: a theoretical assessment and experimental evaluation, Colorado Mined Land Reclamation Division, Unpubl. Manuscript, 71 pp.

Describes utility of passive AMD systems with application to the Marshall No. 5 coal mine.

Hammer, D.A., ed., 1989. *Constructed Wetlands for Wastewater Treatment,* Lewis Publishers, Ann Arbor, MI.

Contains numerous papers on passive treatment systems at metal mines and coal mines, most of which are annotated herein.

Healey, P.M. and Robertson, A.M., 1989. A case history of an acid generation abatement program for an abandoned copper mine, *in* Vancouver Geotechnical Society, *Geotechnical Aspects of Tailings Disposal and Acid Mine Drainage,* May 26, 1989.

Describes rationale for the implementation of an AMD abatement program at an open-pit copper mine and aspects of the design. The method selected to control AMD consisted of a low permeability till cover over waste material to reduce oxygen and water infiltration to sulfide-bearing materials, collection and diversion ditches and a limestone-lined channel.

Hedin, Robert S., Hammack, Richard, and Hyman, David, 1989. Potential importance of sulfate reduction processes in wetlands constructed to treat mine drainage, *in* Hammer, Donald A., ed., *Constructed Wetlands for Wastewater Treatment,* Lewis Publishers, Chelsea, MI, p. 508-514.

Discusses the processes by which sulfides are formed and destroyed in wetlands and the importance of maintaining a sulfide-forming (reducing) environment. Presents characteristics of an ideal treatment system and discusses it operation.

Hedin, R.S. and Nairn, R.W., 1993. Contaminant removal capabilities of wetlands constructed to treat coal mine drainage, *in* Moshiri, Gerald A., ed., *Constructed Wetlands for Water Quality Improvement,* Lewis Publishers, Boca Raton, p. 187-195.

Reports measurements of contaminant removal at 11 constructed wetlands in western PA. Concludes that contaminant removal occurs in a manner consistent with well-known chemical and biological processes.

Hedin, R.S. and Nairn, R.W., 1990. Sizing and performance of constructed wetlands: Case studies, *in Proceedings of the 1990 Mining and Reclamation Conference and Exhibition,* Charleston, WV, vol. 2, p. 385-392.

Reference not available.

Hedin, Robert S., Nairn, Robert W., and Kleinmann, Robert L.P., 1994. *Passive Treatment of Coal Mine Drainage,* U. S. Bureau of Mines, Information Circular 9389, 35 pp.

Reviews the construction and operation of passive treatment systems, including chemical and biological processes, contaminant removal, and system design and sizing. Considers three types of passive technologies: aerobic wetlands, organic substrate wetlands, and anoxic limestone drains. Presents a model for design and sizing of passive treatment systems.

Hedin, Robert S. and Watzlaf, George R., 1994. The effects of anoxic limestone drains on mine water chemistry, *in International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage,* U.S. Bureau of Mines Special Publication, SP 06A-94, vol. 1, p. 185-194.

Studied construction and water quality characteristics of 21 anoxic limestone drains in Appalachia to identify and evaluate factors responsible for the variable performance of these systems. Large changes in acidity were primarily associated with retention of ferric iron and aluminum. Presents a technique to determine drain size.

Hedin, Robert S. and Robert W. Nairn. "Designing and Sizing Passive Mine Drainage Treatment Systems," 13th Annual West Virginia Surface Mine Drainage Task Force Symposium, April 8-9, 1992.

Reference not available.

Hedin, R.S., et al., "Constructing Wetlands to Treat Acid Mine Drainage," Course Notes, 13th Annual West Virginia Surface Mine Drainage Task Force Symposium, April 8-9, 1992.

Reference not available.

Hedin, R.S., "Passive Anoxic Limestone Drains: A Preliminary Summary," 1990.

Reference not available.

Hedin, R.S. and R.W. Nairn, "Sizing and Performance of Constructed Wetland: Case Studies," Mine and Reclamation Conference and Exhibition, Charleston, WV, April 23-26, 1990.

Reference not available.

Hedin, R.S., "Treatment of Coal Mine Drainage with Constructed Wetlands," Wetlands, Ecology and Conservation: Emphasis in Pennsylvania, Pennsylvania Academy of Science, 1989. (Chapter 28)

Reference not available.

Heil, Michael T. and Kerins, Jr., Francis J., 1988. The Tracy wetlands: A case study of two passive mine drainage treatment systems in Montana, *in* U.S. Bureau of Mines, *Mine Drainage and Surface Mine Reclamation, Volume I: Mine Water and Mine Waste,* U.S. Bureau of Mines Information Circular 9183, p. 352-358.

Reports results for two constructed wetlands receiving acidic (pH=2.7) coal mine drainage. Low system retention times and minimal contact time between the peat and mine drainage precluded effective treatment by these wetlands.

Hellier, William W., Giovannitti, Ernest F., and Slack, Peter T., 1994. Best professional judgment analysis for constructed wetlands as a best available technology for the treatment of post-mining groundwater seeps, *in International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage,* U.S. Bureau of Mines Special Publication, SP 06A-94, vol. 1, p. 60-69.

Results of an analysis of 73 constructed wetlands to assess removal of acidity, Fe and Mn from surface coal mines. Develops sizing guidelines and costs to treat seeps for 25 years with and without anoxic limestone drain pretreatment.

Henrot, Jacqueline, Wieder, R. Kelman, Heston, Katherine P., and Nardi, Marianne P., 1989. Wetland treatment of coal mine drainage: Controlled studies of iron retention in model wetland systems, *in* Hammer, Donald A., ed., *Constructed Wetlands for Wastewater Treatment,* Lewis Publishers, Chelsea, MI, p. 793-800.

Results of a pilot lab study to evaluate the effects of Fe concentration in influent waters on Fe retention in wetlands. Concludes that the formation of iron oxides is key control on iron retention and the effective lifetime of a constructed wetland.

Holm, J. David and Bishop, Michael B., 1985. Passive mine drainage treatment, *in* Randol International, Ltd., *Water Management and Treatment for Mining and Metallurgical Operations,* vol. 3, p. 1593-1602.

Describes natural processes that can be used to passively treat acidic mine drainage. Includes a description of wetlands constructed to treat AMD from the Delaware Mine, a silver mine in the Peru Creek, CO drainage and the Schuster Mine and Marshall No. 5 Mine, both of which are coal mines.

Holm, J.D. and Elmore, T., 1986. Passive mine drainage treatment using artificial and natural wetlands, *in Proceedings of the High Altitude Revegetation Workshop,* no. 7, p. 41-48.

Reference not available.

Holm, Bishop, and Tempo, 1985. Incomplete reference included in Randol International, Ltd., *Water Management and Treatment for Mining and Metallurgical Operations,* vol. 3, p. 1651-1670.

Briefly describes passive treatment systems in use at the Marshall No. 5 Coal Mine (CO), U.S. Bureau of Mines Bruceton Research Station, AMAX Buick lead and zinc mill (MO), New Lead Belt region (MO), and the Pierrepont (NY) lead-zinc mine.

Holm, J.D., 1983. Passive mine drainage treatment: Selected case studies, *in* Medine A. and Anderson, M., eds., *Proceedings, 1983 National Conference on Environmental Engineering,* American Society of Civil Engineers.

Provides descriptions of case studies of wetlands constructed to treat AMD from non-coal mines in Colorado. Reference not available.

Holm, J. David, and Guertin, deForest, 1985. Theoretical assessment and design considerations for passive mine drainage treatment systems, *in* Randol International, Ltd., *Water Management and Treatment for Mining and Metallurgical Operations,* vol. 3, p. 1603-1650.

Briefly describes passive treatment mechanisms including pH modulation, cation exchange, sorption and coprecipitation, complexing, biological extraction, and dilution. Discusses the design of passive treatment systems and evaluation of appropriate sites for their installation.

Howard, Edward A., Emerick, John C., and Wildeman, Thomas R., 1989. Design and construction of a research site for passive mine drainage treatment in Idaho Springs, Colorado, *in* Hammer, Donald A., ed., *Constructed Wetlands for Wastewater Treatment,* Lewis Publishers, Chelsea, MI, p. 761-764.

Describes the design and construction of a wetland in a high mountain climate to treat AMD from the Big Five Tunnel. Provides information on liner types, drain spacing and size, organic substrate materials, and vegetation.

Howard, Edward A., Emerick, John C., and Wildeman, Thomas R., 1988. The design, construction and initial operation of a research site for passive mine drainage treatment in Idaho Springs, CO, *in Proceedings of the U.S. EPA's Forum on Remediation of CERCLA Mining Waste Sites, April 25, 1989, Ward, Colorado,* p. 122-133.

Describes the design and construction of an artificial wetland to treat AMD from the Big Five Tunnel precious metal mine. Included are sections that discuss the preparation of plants and substrate materials and procedures for sample collection.

Howard, Edward A., Hestmark, Martin C., and Margulies, Todd D., 1989. Determining feasibility of using forest products or on-site materials in the treatment of acid mine drainage in Colorado, *in* Hammer, Donald A., ed., *Constructed Wetlands for Wastewater Treatment,* Lewis Publishers, Chelsea, MI, p. 774-779.

Characterizes the cation exchange capacities and metal removal efficiencies of humus and forest litter from ponderosa pine, lodgepole pine, spruce-fir, and aspen forests. Concludes that ponderosa and aspen litters have the highest ion exchange capacities but that aspen and spruce-fir materials were the most efficient at removing metals from AMD. These materials are suitable for passive treatment systems.

Huskie, William W., 1987. Pennsylvania mine drainage diversion study: Site survey and water quality assessment, *in* Emerick, John C., Cooper, David J., Huskie, William W., and Lewis, W. Stephen, eds., *Documentation and Analysis of the Effects of Diverted Mine Water on a Wetland Ecosystem, and Construction of a Computerized Data Base on Acid Mine Drainage in Colorado,* Final Report to the Mined Land Reclamation Division, Department of Natural Resources, Colorado, p. 13-50.

Evaluated the effects of rerouting AMD from a base and precious metals mine into a wetland ecosystem. Results showed that only Fe was significantly removed, with little effect on Al, Mn, or Zn levels. Surface water quality below the wetland was not improved significantly. The natural wetland was found to have a significant metal content prior to diversion that may have precluded additional metal uptake during the experiment.

Huskie, William W., 1987. *The Pennsylvania Mine Diversion Drainage Study: Evaluation of an Existing High Mountain Wetland for Passive Treatment of Metal-Laden Acid Mine Drainage in Colorado,* Unpubl. M.S. Thesis, Colorado School of Mines, Golden, CO.

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Hutchison, Ian P.G., Leonard, Sr., Michael L., and Cameron, David P., 1995. Remedial alternatives identification and evaluation, *in* Posey, Harry H., Pendleton, James A., and Van Zyl, Dirk, eds., *Proceedings: Summitville Forum '95,* Colorado Geological Society Special Publication 38, p. 109-120. This paper describes how treatment strategies (active and passive) are being developed for the Summitville (CO) Mine. It provides a brief summary of the AMD issues at Summitville Mine, identifies the types of remedial technologies and process operations that could be applied at the site, discusses the basis for evaluating alternative remedial measures, and describes selected remedial measures and their implementation.

Hyman, D.M. and G.R. Watzlaf, "Mine Drainage Characterization for the Successful Design and Evaluation of Passive Treatment Systems," presented at the 17th Annual National Association of Abandoned Mine Lands Conference. Undated.
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Inventory Guiding Principles Group, 1996. *Guiding Principles for Inventorying Inactive and Abandoned Hardrock Mining Sites,* The Inventory Guiding Principles Group, Western Governor's Association and U.S. Bureau of Mines.
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Jones, D.R. and Chapman, B.M., 1995. Wetlands to treat AMD - Facts and fallacies, *in* Grundon, N.J. and Bell, L.C., eds., *Proceedings of the Second Annual Mine Drainage Workshop,* Queensland, Australia, p. 127-145.
Reference not available.

Kelly, Martyn, 1988, Mining and the Freshwater Environment, Elsevier Science Publishing Co., London, pgs. 16-42
Reference not available.

Kepler, D.A., 1988. Overview of the role of algae in the treatment of acid mine drainage, *in* U.S. Bureau of Mines, *Mine Drainage and Surface Mine Reclamation, Volume I: Mine Water and Mine Waste,* U.S. Bureau of Mines Information Circular 9183, p. 286-290.
Reports preliminary results from a wetland system constructed to treat coal mine drainage in PA (pH=5.0), which show that algae effectively bioaccumulate metals including Mn and Fe.

Kepler, Douglas A. and McCleary, Eric C., 1994. Successive alkalinity-producing systems (SAPS) for the treatment of acid mine drainage, *in International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage,* U.S. Bureau of Mines Special Publication, SP 06A-94, vol. 1, p. 195-204.
Study focuses on the ability to create effective anoxic limestone dissolution treatment components for AMD abatement in open atmospheres. Studies 3 SAPS in PA that utilize wetlands with mixed substrates of organic compost and limestone gravel. This wetland configuration promotes anoxic conditions, generates alkalinity in excess of acidity regardless of acidity concentrations, produces quasi-neutral water and decreases treatment area requirements.

Kim, A., B. Heisey, R. L. P. Kleinmann and M. Duel, 1982, "Acid Mine Drainage: Control and Abatement Research," U.S. Bureau of Mines Information Circular 8905.
Reference not available.

Kimball, Briant A., 1996. Past and present research on metal transport in St. Kevin Gulch, Colorado, *in* Morganwalp, David W. and Aronson, David A., eds., *U.S. Geological Survey Toxic Substances Hydrology Program--Proceedings of the Technical Meeting, Colorado Springs, CO, September 20-24, 1993,* U.S. Geological Survey Water Resources Investigation Report 94-4015, p. 753-758.
Describes the chemical reactions that affect metal transport in AMD in surface waters of the St. Kevin Gulch drainage near Leadville, CO in the context of hydrologic setting. Results can be used to design effective remediation measures.

Kleinmann, Robert L.P., 1985. Treatment of acid mine waters by wetlands, *in* U.S. Bureau of Mines, *Control of Acid Mine Drainage: Proceedings of a Technology Transfer Seminar,* U.S. Bureau of Mines Information Circular 9027, p. 48-52.

Discusses general aspects of passive AMD treatment and provides an update on pilot-scale and full-scale field evaluations being conducted by the Bureau of Mines.

Kleinmann, R.L.P. and Hedin, R.S., 1993. Treat minewater using passive methods, *Pollution Engineering,* vol. 25, no. 13, p. 20-22.

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Kleinmann R.L.P., D.A. Crerar and R.R. Pacelli, 1981, "Biogeochemistry of Acid Mine Drainage and a Method to Control Acid Formation," Mining Engineering, March 1981.

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Kleinmann, R.L.P. and R. Hedin, "Biological Treatment of Mine Water: an Update", in Chalkley, M.E., B.R. Conrad, V.I. Lakshmanan, and K.G. Wheeland, 1989, Tailings and Effluent Management, Pergamon Press, New York, pgs 173-179.

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Klusman, R.W. and Machemer, S.D., 1991. Natural processes of acidity reduction and metal removal from acid mine drainage, *in* Peters, D.C., ed., *Geology in the Coal Resource Utilization,* Tech Books, Fairfax, VA, p. 513-540.

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Knight Piesold, Ltd., 1996. Wheal Jane minewater project: The development of a treatment strategy for the acid mine drainage, *in Minerals, Metals, and Mining,* Institution of Mining and Metallurgy.

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Kolbash, Ronald L. and Romanoski, Thomas L., 1989. Windsor Coal Company wetland: An overview, *in* Hammer, Donald A., ed., *Constructed Wetlands for Wastewater Treatment,* Lewis Publishers, Chelsea, MI, p. 788-792.

Describes the design, construction, and effectiveness of a wetland treatment system at a coal mine in WV.

Kuyucak, N. and St-Germain, P., 1994. Possible options for *in situ* treatment of acid mine seepages, *in International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage,* U.S. Bureau of Mines Special Publication, SP 06B-94, vol. 2, p. 311-318.

Presents results of bench-scale evaluation tests of passive treatment of base metal acid mine drainage seepages. Assessed methods including: 1) anoxic lime drains (limestone kept under anoxic conditions); 2) limestone-organic mixture utilizing sulfate-reducing bacteria; 3) biosorbency in which metals are taken up by wood waste, and 4) a biotrench that utilizes different nutrients than the limestone-organic mixture. Concludes that a combination of 1 and 2 above is best for treating AMD.

Kwong, Y.T.J., 1992. Generation, attenuation, and abatement of acidic drainages in an abandoned minesite on Vancouver, Island, Canada, *in* Singhal, Raj K., Mehrotra, Anil K., Fytas, Kostas, and Collins, Jean-Luc, eds., *Environmental Issues and Management of Waste in Energy and Mineral Production,* A.A. Balkema, Rotterdam, p. 757-762.

Discusses the potential utility of passive wetlands treatment of AMD from the abandoned Mount Washington porphyry copper mine. Describes successes and failures of reclamation activities conducted to date.

Ladwig, K., P. Erickson and R. Kleinmann, 1985, Alkaline Injection: An Overview of Recent Work," in Control of Acid Mine Drainage, Proceedings of a Technology Transfer Seminar, U.S. Bureau of Mines Information Circular 9027.

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Ladwig, K., P. Erickson and R. Kleinmann, 1985, Alkaline Injection: An Overview of Recent Work," in Control of Acid Mine Drainage, Proceedings of a Technology Transfer Seminar, U.S. Bureau of Mines Information Circular 9027.

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LaRosa, et al., Black, Sivalls, and Bryson, Inc. "Evaluation of a New Acid Mine Drainage Treatment Process," prepared for the U.S. Environmental Protection Agency; for sale by the Superintendent of Documents, U.S. Government Printing Office, 1971.

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Logsdon, Mark and Mudder, Terry, 1995. Geochemistry of spent ore and water treatment issues *in* Posey, Harry H., Pendleton, James A., and Van Zyl, Dirk, eds., *Proceedings: Summitville Forum '95,* Colorado Geological Society Special Publication 38, p. 99-108.

Describes the design and operation of the cyanide heap leach pad at the Summitville precious metals mine, a program for decommissioning the leach pad, and a geochemical evaluation of potential environmental impacts from the pad. Includes brief sections on active and passive treatment of acid drainage from the leach pad. Passive treatment alternatives under consideration include wetlands, engineered anoxic systems, and direct land application; does not include information on design and feasibility of passive systems.

Madel, Robin E., 1992. *Treatment of Acid Mine Drainage in Sulfate Reducing Bioreactors: Effect of Hydraulic Residence Time and Metals Loading Rates,* Unpubl. M.S. Thesis, Colorado School of Mines, Golden, CO.

Study investigated the ability of sulfate-reducing bacteria to treat AMD at lower residence times by using multiple stage systems in parallel and series. The test results determined using samples of AMD from the Eagle Mine have implications for the design of passive treatment systems.

Meek A., 1991, "Assessment of Acid Preventative Techniques at the Island Creek Mining Co. Tenmile Site," in Proceedings Twelfth Annual West Virginia Surface Mine Drainage Task Force Symposium , April 3-4, 1991, Morgantown, West Virginia.

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MEND, "Acid Mine Drainage - Status of Chemical Treatment and Sludge Management Practices," MEND Report 3.32.1, June 1994.

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MEND, 1993. *Treatment of Acidic Seepages Using Wetland Ecology and Microbiology: Overall Program Assessment,* MEND Report 3.11.1, Natural Resources Canada.
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MEND, "Study on Metals Recovery/Recycling from Acid Mine Drainage," MEND Project 3.21.1(a), July 1991.
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MEND, 1990. *Assessment of Existing Natural Wetlands Affected by Low pH, Metal Contaminated Seepages (Acid Mine Drainage),* MEND Report 3.12.1a, Natural Resources Canada.
Reference not available.

MEND, MEND Reports Available, Mine Environment Neutral Drainage Program http://www.NRCan.gc.ca/mets/mend/report-t.htm
Listing of reports available for purchase.

Mills, Chris, An Introduction to Acid Rock Drainage. http://www.enviromine.com/ard/Eduardpage/ARD.htm
Brief description of the chemistry of acid mine drainage generation and neutralization and the kinetics of the chemical reactions. Includes links to pages concerning the role of micro-organisms in AMD.

Morin, Kevin A., 1990. *Acid Drainage from Mine Walls: The Main Zone Pit at Equity Silver Mines,* British Columbia Acid Mine Drainage Task Force, 109 pp.
Provides an overview of the generation and migration of acid mine drainage at open-pit mines, with emphasis on the Equity silver mine in British Columbia. Presents a predictive model for acid drainage from pit walls that could be used to design treatment systems.

Mueller, R.F., Sinkbeil, D.E., Pantano, J., Drury, W., Diebold, F., Chatham, W., Jonas, J., Pawluk, D., and Figueira, J., 1996. Treatment of metal contaminated groundwater in passive systems: A demonstration study, *in Proceedings of the 1996 National Meeting of the American Society for Surface Mining and Reclamation, Knoxville, TN, May 19-25, 1996,* p. 590-598.
Reference not available.

Noller, B.N., Woods, P.H., and Ross, B.J., 1994. Case studies of wetland filtration of mine waste water in constructed and naturally occurring systems in northern Australia, *Water Science and Technology*, vol. 29, p. 257-266.
Reference not available.

Norecol Environmental Consultants, 1989. Wetland treatment, *in* British Columbia Acid Mine Drainage Task Force, *Draft Acid Rock Drainage Technical Guide, Volume 1* ,p. 8-47 to 8-52.
Provides a general overview of wetlands treatment of AMD, including a discussion of the advantages and disadvantages of wetland treatment systems.

Novotny, Vladimir and Olem, Harvey, 1994. *Water Quality: Prevention, Identification and Management of Diffuse Pollution,* Van Nostrand, New York, 1054 pp.

Contains sections that review the retention of sulfur in wetland environments, the types of constructed wetlands, design considerations and parameters for constructed wetlands, constituent loadings in wetlands, and metals and toxic chemicals in wetland environments.

Parisi, Dan, Horneman, Jeffrey, and Rastogi, Vijay, 1994. Use of bactericides to control acid mine drainage from surface operations, *International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage,* U.S. Bureau of Mines Special Publication, SP 06B-94, vol. 2, p. 319-325.

Describes three applications of bacterial inhibitors: 1) surface coal mine with highly pyritic shale overburden in central PA, 2) refuse disposal area in central PA, 3) silver mine in Idaho where waste rock is used as pit backfill. All studies were successful field tests indicating that bacterial inhibitors control acid generation and achieve long-term control through controlled release systems.

Paschke, Suzanne S. and Harrison, Wendy J., 1995. Metal transport between an alluvial aquifer and a natural wetland impacted by acid mine drainage, Tennessee Park, Leadville, Colorado, *in Tailings and Mine Waste '95,* A.A. Balkema, Rotterdam, p. 43-54.

Describes the effects of percolating AMD carried in a surface stream (St. Kevin Gulch) on regional ground water quality. Discusses the fate of AMD generated from metal mining in ground water where both oxidizing and reducing conditions are present.

Pfahl, J.C., 1996. Innovative approaches to addressing environmental problems for the upper Blackfoot mining complex: Voluntary remedial actions, *in Managing Environmental Problems at Inactive and Abandoned Metals Mine Sites,* U.S. Environmental Protection Agency Seminar Publication No. EPA/625/R-95/007, p. 75-80.

Reference not available.

Phillips, Peter, Bender, Judith, Simms, Rachael, Rodriguez-Eaton, Susana, and Britt, Cynthia, 1994. Manganese and iron removal from coal mine drainage by use of a green algae-microbial mat consortium, *in International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage,* U.S. Bureau of Mines Special Publication, SP 06A-94, vol. 1, p. 99-108.

Results of a field test of three constructed wetlands using native blue-green algae and limestone or pea gravel substrates at the Fabius Coal Mine, AL. AMD was pre-treated in an oxidation pond prior to flow into the wetland. Study evaluated feasibility of microbial mat treatment and assessed mat performance under environmental conditions (seasonal variation, day-night conditions, etc.).

Plumlee, G., Smith, K.S., Erdman, J., Flohr, M., Mosier, E., and Montour, M., 1994. Geologic and geochemical controls on metal mobility from the Summitville mine and its downstream environmental effects, *in Abstracts with Programs,* Geological Society of America Annual Meeting, vol. 26, p. A-434 to A-435.

Abstract describes the geochemisty of metal-rich AMD generated from the Summitville gold mine (CO) and its downstream distribution in the Alamosa River system.

Posey, Harry H., Pendleton, James A., and Van Zyl, Dirk, 1995. *Proceedings: Summitville Forum '95,* Colorado Geological Survey Special Publication 38, 375 pp.

Contains numerous articles that describe the geochemistry of AMD from the Summitville gold mine and its downstream effects on the Alamosa River, Terrace Reservoir, and natural wetlands.

Powers, Thomas J. "Use of Sulfate Reducing Bacteria in Acid Mine Drainage Treatment." U.S. EPA Risk Reduction Engineering Laboratory. Undated.
Reference not available.

Ptacek, C.J., Inorganic Contaminants in Groundwater and Acid Mine Drainage. http://gwrp.cciw.ca/gwrp/studies/ptacek/ptacek.html
Describes the mechanisms controlling the transport of metals in tailings impoundments and underlying aquifers. Contains a reference to *In-situ remediation of metal contaminated groundwater*, which describes the use of porous reactive walls to passively treat metals contaminated groundwater. Lists numerous AMD abstracts published by the author.

Renton, J., A. H. Stiller and T. E. Rymer, 1988, "The Use of Phosphate Materials as Ameliorants for Acid Mine Drainage," in Conference Proceedings Mine Drainage and Surface Mine Reclamation, U.S. Bureau of Mines Information Circular 9183, 67-75pp.
Reference not available.

Renton, J., A.H. Stiller, and T.E. Rymer, 1988, "The Use of Phosphate Materials as Ameliorants for Acid Mine Drainage," in Conference Proceeding Mine Drainage and Surface Mine Reclamation, U.S. Bureau of Mines Information Circular 9183, pp. 67-75.
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Rex Chainbelt, Inc. Technical Center. "Treatment of Acid Mine Drainage by Reverse Osmosis," prepared for the Commonwealth of Pennsylvania, Dept. of Mines and Mineral Industries and the Federal Water Quality Administration, U.S. Dept. of the Interior; Washington: for sale by the Superintendent of Documents, U.S. Government Printing Office, 1970.
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Robertson, A.M., Blowes, D.W., and Medine, A.J., 1992. *Prediction, Prevention, and Control of Acid Mine Drainage in the West,* Workshop, Breckenridge, CO.
Notes, references, papers and presentations from a workshop on AMD.

Robertson, Emily, 1990. *Monitoring Acid Mine Drainage,* British Columbia Acid Mine Drainage Task Force, 72 pp.
Examines current monitoring methods at mines with AMD, reviews statistics as they are applied to water quality data and emphasizes the importance of flow data, uses a set of data collected daily to elucidate the range of fluctuations that naturally occur, and presents general guidelines for monitoring untreated water and the receiving environment.

Rowley, Michael V., Warkentin, Douglas D., Yan, Vita T., and Piroshco, Beverly M., 1994. The biosulfide process: Integrated biological/chemical acid mine drainage treatment - results of laboratory piloting, *in International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage,* U.S. Bureau of Mines Special Publication, SP 06A-94, vol. 1, p. 205-213.
Biosulfide treatment separates chemical precipitation of sulfides from biological conversion of sulfate to sulfide to produce saleable products. Objective of study was to operate and evaluate a continuous, integrated system that depended solely on microbially generated products for treatment of strongly acid water (pH=2.45). Process was demonstrated to be effective, reliable, and easy to operate through more than 1 year of operation.

Russell, Charles W., 1994. Acid rock drainage associated with large storm events at the Zortman and Landusky mines, Phillips County, Montana, *in Abstracts with Programs, Geological Society of America,* vol. 26, no. 7, p. A-34.

Describes use of a reclamation cover to control acid-generating reactions, prevent flushing of reaction products, and establish lower oxidation states to allow implementation of effective passive treatment systems.

Schultze, Larry E., Zamzow, Monica J., and Bremner, Paul R., 1994. AMD cleanup using natural zeolites, *in International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage,* U.S. Bureau of Mines Special Publication, SP 06B-94, vol. 2, p. 341-347.

Experiments using 3 samples of clinoptilolite with varying Na content and an AMD sample from the Rio Tinto copper mine in northeastern Nevada. Zeolites had differing cation exchange capacities but all were able to remove metals to drinking water standards. Zeolites could be regenerated using NaCl solution.

SCRIP Acid Mine Drainage Remediation Project, Passive Treatment Technologies, http://ctcnet.net/scrip/passive.htm

Contains an online bibliography of papers related to acid mine drainage remediation and a discussion of passive treatment technologies including oxidizing and reducing wetlands.

Sellstone, Christopher M., 1990. *Sequential Extraction of Fe, Mn, Zn, and Cu from Wetland Substrate Receiving Acid Mine Drainage,* Unpubl. M.S. Thesis, Colorado School of Mines, Golden, CO, 88 pp.

The study attempts to determine the geochemical phases into which Fe, Mn, Cu, and Zn are partitioned in a pilot-scale constructed wetland receiving AMD from the Big Five Tunnel in Idaho Springs, CO by using a geochemical technique known as sequential extraction.

Sencindiver, J.C. and Bhumbla, D.K., 1988. Effects of cattails (Typha) on metal removal from mine drainage, *in Mine Drainage and Surface Mine Reclamation,* U.S. Bureau of Mines Information Circular 9183, p. 359-368.

Reference not available.

Shelp, Gene, Chesworth, Ward, Spiers, Graeme, and Liu, Liangxue, 1994. A demonstration of the feasibility of treating acid mine drainage by an in situ electrochemical method, *International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage,* U.S. Bureau of Mines Special Publication, SP 06B-94, vol. 2, p. 348-355.

Experimentally proved technical feasibility of electrochemical treatment using a block of massive sulfide-graphite rock as cathode, scrap iron as anode, and AMD from an open-pit iron mine in Canada as the electrolyte. Electrolyte pH was raised to a maintained level of 5.5, reduction-oxidation potential was decreased, and iron sulfate precipitate removed Al, Ca, and Mg from solution.

Sherlock, E.J., Lawrence, R.W., and Poulin, R., 1995. On the neutralization of acid rock drainage by carbonate and silicate minerals, *Environmental Geology,* vol. 25, p. 43-54.

Provides a detailed discussion of the dissolution and neutralizing capacity of carbonate and silicate minerals related to equilibrium conditions, dissolution mechanism, and kinetics. Illustrates that differences in reaction mechanisms and kinetics have important implications for the prediction, control, and remediation of AMD.

Silver, Marvin, 1989. Biology and chemistry of generation, prevention, and abatement of acid mine drainage, *in* Hammer, Donald A., ed., *Constructed Wetlands for Wastewater Treatment,* Lewis Publishers, Chelsea, MI, p. 753-760.

Reviews the processes that lead to the formation of acid from sulfide and sulfate minerals, mechanisms by which acid generation can be prevented, and options for abating AMD.

Singer, P.C. and W. Stumm, 1970, "Acid Mine Drainage: The Rate Determining Step," Science 167;pps 1121-1123.

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Siwik, R., S. Payant, and K. Wheeland, "Control of Acid Generation from Reactive Waste Rock with the Use of Chemicals", in Chalkley, M.E., B.R. Conrad, V.I. Lakshmanan, and K.G. Wheeland, 1989, Tailings and Effluent Management, Pergamon Press, New York, pgs. 181-193.

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Skousen, J.G., et al., 1990, "Acid Mine Drainage Treatment Systems: Chemicals and Costs," in Green Lands, Vol. 20, No. 4, pp. 31-37, Fall 1990, West Virginia Mining and Reclamation Association, Charleston, West Virginia.

Reference not available.

Skousen, J. G., J. C. Sencindiver and R. M. Smith, 1987, "A Review of procedures For Surface Mining and Reclamation in Areas with Acid-producing Materials," in cooperation with The West Virginia Surface Mine drainage Task Force, the West Virginia University Energy and Water Research Center and the West Virginia Mining and Reclamation Association, 39pp, West Virginia University Energy and Water Research Center.

Reference not available.

Skousen, Jeffrey, and Paul Ziemkiwicz, ed. "Acid Mine Drainage: Control & Treatment," National Mine Land Reclamation Center. Undated.

(available from the National Mine Land Reclamation Center for $15: (304) 293-2867 ext. 444)

Reference not available.

Skousen, Jeff, 1995. Anoxic limestone drains for acid mine drainage treatment, *in* Skousen, Jeffrey and Ziemkiewicz, Paul, eds., *Acid Mine Drainage: Control & Treatment, 2nd edition,* National Mine Land Reclamation Center, p. 261-266.

A general review of the operation and effectiveness of anoxic limestone drains in the treatment of AMD. Includes steps for building an anoxic limestone drain and discusses important parameters in design and sizing.

Skousen, Jeff G., 1995. Douglas abandoned mine project: Description of an innovative acid mine drainage treatment system, *in* Skousen, Jeffrey and Ziemkiewicz, Paul, eds., *Acid Mine Drainage: Control & Treatment, 2nd edition,* National Mine Land Reclamation Center, p. 299-310.

Reviews the historical development of passive treatment strategies including wetlands, anoxic limestone drains, and alkalinity producing systems. Describes the design and construction of a two-phase treatment system employed at the Douglas Highwall mine (WV) that uses two trenches with varying ratios of organic material and limestone. Preliminary results show that the system raises pH by 3 log units, increases alkalinity from 0 to 200 mg/l, and effectively removes dissolved Al, Fe, and Mn from acidified waters.

Skousen, Jeff, Faulkner, Ben, and Sterner, Pat, 1995. Passive treatment systems and improvement of water quality, *in* Skousen, Jeffrey and Ziemkiewicz, Paul, eds., *Acid Mine Drainage: Control & Treatment, 2nd edition,* National Mine Land Reclamation Center, p. 331-344.

Reviews the function of different passive treatment technologies including aerobic and anaerobic wetlands, anoxic limestone drains, alkalinity producing systems, open limestone channels, limestone ponds, and reverse alkalinity producing systems and the processes by which they improve water quality. Discusses the effectiveness of backfilling and revegetating surface mines in reducing acid loads and improving water quality.

Skousen, J., Sexstone, K., Garbutt, K., and Sencindiver, J., 1995. Wetlands for treating acid mine drainage, *in* Skousen, Jeffrey and Ziemkiewicz, Paul, eds., *Acid Mine Drainage: Control & Treatment, 2nd edition,* National Mine Land Reclamation Center, p. 249-260.

A general overview passive wetlands treatment, including important wetlands processes, alkalinity generation and anoxic limestone drains, design and sizing parameters, and plant selection for optimum wetlands effectiveness.

Skousen, J., Sexstone, K., Garbutt, K., and Sencindiver, J., 1994. Acid mine drainage treatment with wetlands and anoxic limestone drains, *in* Kent, D.M., ed., *Applied Wetlands Science and Technology,* Lewis Publishers, Boca Raton, p. 263-281.

Reference not available.

Skousen, Jeffrey and Ziemkiewicz, Paul, 1995. *Acid Mine Drainage: Control & Treatment, 2nd edition,* National Mine Land Reclamation Center, 362 pp.

Contains 10 papers that deal with aspects of the design, treatment, and effectiveness of passive treatment systems, most dealing with coal mine AMD, in addition to multiple papers on active treatment systems and AMD prevention.

Smith, K.S., 1991. *Factors Influencing Metal Sorption onto Iron-rich Sediment in Acid-Mine Drainage,* Unpubl. Ph. D. Dissertation, Colorado School of Mines, Golden, CO.

Reference not available.

Smith, Kathleen S., Plumlee, Geoffrey S., and Ficklin, Walter H., 1994. *Predicting Water Contamination from Metal Mines and Mining Wastes,* U.S. Geological Survey Open-File Report 94-264.

Notes from a workshop presented at the International Land Reclamation and Mine Drainage Conference and the Third International Conference on the Abatement of Acidic Drainage in Pittsburgh, PA.

Smith, Teri R., Wilson, Timothy P., and Ineman, Fredrick N., 1991. The relationship of iron bacteria geochemistry to trace metal distribution in an acid mine drainage system, NE Ohio, *Geological Society of America Abstracts with Programs,* v. 23, no. 3, p. 61.

Investigates the relationship between iron bacteria type, abundance, stream environment, and water/sediment chemistry in acid drainage from a coal strip mine. Concludes that bacteria exert significant control over the precipitation of Fe-Mn oxyhydroxides, which affect the distribution of trace metals in effluent.

Sobolewski, A., 1996. Metal species indicate the potential of constructed wetlands for long-term treatment of mine drainage, *Journal of Ecological Engineering,* vol. 6, p. 259-271.

Reference not available.

Sobolewski, A., 1995. Development of a wetland treatment system at United Keno Hill Mines, Elsa, Yukon Territory, *Proceedings of the Twentieth Annual British Columbia Mine Reclamation Symposium,* Kamloops, British Columbia, p. 64-73.
Reference not available.

Sobolewski, Andre, Wetlands for Treatment of Mine Drainage. http://www.enviromine.com/wetlands/Welcome.htm
Contains links to numerous internet sources on acid mine drainage including constructed wetlands at base and precious metals mines (/wetlands/metal.htm) and examples of natural and constructed wetlands that are remediating AMD. Also includes a link to a web page that briefly describes the UK effort to remediate acid mine drainage from Cornish tin mines (http://www.intr.net/esw/494/uk.htm).

Staub, Margaret W., 1994. *Passive Mine Drainage Treatment in a Bioreactor: The Significance of Flow, Area, and Residence Time,* Unpubl. M.S. Thesis, Colorado School of Mines, Golden, CO.
Demonstrated the effectiveness of microbiological treatment on acidic mine drainage water with high metals concentration. Experiments used pilot scale bioreactors constructed underground at the Eagle Mine Superfund site in Colorado. The systems removed 95 to 100 percent of the metals.

Steffen, Robertson, and Kirsten, Inc., 1989. *Draft Acid Rock Drainage Technical Guide, Volumes 1 & 2,* prepared for the British Columbia Acid Mine Drainage Task Force, BiTech Publishers, Richmond, British Columbia.
Reference not available.

Stilwell, C.T., 1995. Stream restoration and mine waste management along the upper Clark Fork River, *in Tailings and Mine Waste '95,* A.A. Balkema, Rotterdam, p. 105-107.
Describes an attempt to attenuate AMD from metal mines in a riparian corridor in Montana. AMD is generated from tailings that were eroded and fluvially redeposited during flood events. One design uses *in situ* lime treatment, in which lime is admixed with tailings, then recontoured and vegetated.

Tarutis, W.J., Jr., Unz, R.F., and Brooks, R.P., 1992. Behavior of sedimentary Fe and Mn in a natural wetland receiving acidic mine drainage, Pennsylvania, U.S.A., *Applied Geochemistry,* vol. 7, p. 77-85.
Reference not available.

Taufen, Paul M., 1995. *A Geochemical Study of Groundwaters and Stream Waters at Two Mineralized Sites in the Noranda District, Quebec - Application to Mineral Prospecting, Mine Development, and Environmental Remediation,* Unpubl. M.S. Thesis, Colorado School of Mines, Golden, CO.
Study examines the controls on metal mobility and transport in subsurface and stream waters. A conceptual hydrogeochemical model for the production of AMD is provided for the base-metal-sulfide deposits at the abandoned Waite and Amulet mines.

Taylor, H.N., Choate, K.D., and Brodie, G.A., 1993. Storm event effects on constructed wetlands discharges, *in* Moshiri, Gerald A., ed., *Constructed Wetlands for Water Quality Improvement,* Lewis Publishers, Boca Raton, p. 139-145.
Examines the effects of storm water drainage through two constructed wetlands by evaluating effluent water quality (total Fe, total Mn, TSS, pH).

Tetcher, J.J., T.T. Phipps, and J.G. Skousen, "Cost Analysis for Treating Acid Mine Drainage from Coal Mines in the U.S.," in Proceedings Second International Conference on the Abatement of Acidic Drainage, September 16-18, 1991, Montreal , Canada, Volume 1, pp. 561-574.

Reference not available.

Titchenell, Troy and Skousen, Jeff, 1995. Acid mine drainage treatment in Greens Run by an anoxic limestone drain, *in* Skousen, Jeffrey and Ziemkiewicz, Paul, eds., *Acid Mine Drainage: Control & Treatment, 2nd edition,* National Mine Land Reclamation Center, p. 345-356.

Describes the use of anoxic limestone drains to treat three point sources of AMD from coal mines in WV. Preliminary water quality analyses indicate that the drain is increasing pH, adding alkalinity, and removing Fe and Al.

Turner, D. and D. McCoy, "Anoxic Alkaline Drain Treatment System, a Low Cost Acid Mine Drainage Treatment Alternative," National Symposium on Mining, University of Kentucky, Lexington, Kentucky, May 14-18, 1990. pp. 73-75.

Reference not available.

Tyco Laboratories. "Silicate Treatment for Acid Mine Drainage Prevention; Silicate and Alumina/Silica Gel Treatment of Coal Refuse for the Prevention of Acid Mine Drainage." Washington: EPA Water Quality Office; for sale by the Superintendent of Documents, U.S. Government Printing Office, 1971.

Reference not available.

UN/DTCD, 1991. Environmental aspects of non-ferrous mining, *in Mining and the Environment — The Berlin Guidelines,* Mining Journal Books, p. 25-52.

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U.S. Bureau of Mines, 1988. *Mine Drainage and Surface Mine Reclamation, Volume I: Mine Water and Mine Waste,* U.S. Bureau of Mines Information Circular 9183.

Proceedings of a Conference held in Pittsburgh, PA, April 19-21, 1988. Contains sections on biological mine water treatment (6 papers), wetland systems for mine water treatment: case studies (5 papers), and wetland systems for mine water treatment: process and design (5 papers).

U.S. Bureau of Mines, 1994. *International land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage,* U.S. Bureau of Mines Special Publication SP 06A-D-94, 4 volumes.

Proceedings of the conference.

U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement, "Managing Hydrologic Information: A Resource for Development of Probable Hydrologic Consequences (PHC) and Cumulative Hydrologic Impact Assessments (CHIA)," January 31, 1997.

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U.S. Environmental Protection Agency, 1996. *Managing Environmental Problems at Inactive and Abandoned Metals Mine Sites,* U.S. Environmental Protection Agency Seminar Publication No. EPA/625/R-95/007.

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U.S. Geological Survey, The Summitville Mine and its Downstream Effects: An On-line Update of Open File Report 95-23. http://helios.cr.usgs.gov/summit.web/summit.htm

An update of a previous open-file report on the environmental effects of the Summitville gold mine. Provides recent information on the impact of AMD on the Alamosa River system and wetlands in the San Luis Valley.

U.S. Geological Survey, USGS Mine Drainage Newsletter, Technical Forum, U.S. Geological Survey, http://water.wr.usgs.gov/mine/archive/forum.html

Newsletter with short technical articles pertaining to various aspects of acid mine drainage.

Updegraff, D.M., Reynolds, J.S., Smith, R.L., and Wildeman, T.R., 1992. Bioremediation of acid mine drainage by a consortium of anaerobic bacteria in a constructed wetland, *Abstracts of Papers, Part 1,* American Chemical Society, 203rd National Meeting, San Francisco, CA, April, 1992, Abstract GEOC 174.

Discusses the operation of a wetland constructed in Idaho Springs, CO to treat acid mine drainage with low pH and high concentrations of heavy metals.

Vile, Melanie A. and Weider, R. Kelman, 1993. Alkalinity generation by Fe(III) reduction versus sulfate reduction in wetlands constructed for acid mine drainage treatment. *Water, Air and Soil Pollution,* vol. 69, p. 425-441.

Study conducted to determine the extent to which ferric iron reduction occurs and the extent to which sulfate reduction versus ferric iron reduction contributes to alkalinity generation in 5 wetlands constructed with different organic substrates. Studies conducted over 18 to 22 month period in KY, using AMD from coal mines. Initial results showed that treatment was effective. However, monitoring revealed a general pattern of diminished ability to reduce concentrations of H+, soluble Fe, and SO4 during winter months, with failure to reestablish effective treatment after the second winter. Successful long-term treatment depends on the continued ability for biological alkalinity generation to balance influent acid load.

Walton, Kenneth C. and Johnson, D. Barrie, 1992. Microbiological and chemical characteristics of an acidic stream draining a disused copper mine, *Environmental Pollution,* vol. 76, p. 169-175.

Examines downstream changes in pH, metals concentrations, and iron oxidizing bacteria in AMD as a result of natural processes. Describes the relationships between stream chemistry and microbiology.

Walton-Day, Katherine, 1996. Iron and zinc budgets in surface water for a natural wetland affected by acidic mine drainage, St. Kevin Gulch, Lake County, Colorado, *in* Morganwalp, David W. and Aronson, David A., eds., *U.S. Geological Survey Toxic Substances Hydrology Program--Proceedings of the Technical Meeting, Colorado Springs, CO, September 20-24, 1993,* U.S. Geological Survey Water Resources Investigation Report 94-4015, p. 759-764.

Studies the attenuation of iron and zinc from AMD (pH=3.5-4.5) by natural processes in a wetland. Study shows that approximately 75 percent of total iron is removed by precipitation of iron hydroxides from influent but that zinc is not removed.

Weider, R. Kelman, 1994. Diel changes in iron (III)/iron (II) in effluent from constructed acid mine drainage treatment wetlands. *Journal of Environmental Quality,* vol. 23, p. 730-738.

Study documents dramatic shifts in Fe+3/Fe+2 abundances in effluent from constructed wetlands that correlates to time of day (high Fe+3 prior to sunset; high Fe+2 prior to sunrise). Discusses implications for sampling protocols for assessing Fe retention and release. Study used coal mine AMD in KY.

West Virginia University, Acid Mine Drainage Treatment, http://www.wvu.edu/~research/techbriefs/acidminetechbrief.html.

An introduction to treatment of acid mine drainage for the novice. Site is maintained by Dr. Jeff Skousen.

Western Governor's Association, 1996. *Final Report of Abandoned Mine Waste Working Group,* prepared for the Federal Advisory Committee to develop on-site innovative technologies (DOIT), Western Governor's Association, Denver, CO.

Reference not available.

Wetzel, R.G., "Constructed Wetlands: Scientific Foundations are Critical", in Moshiri, Gerald A., 1993, Constructed Wetlands for Water Quality Improvement, Lewis Publishers, Ann Arbor, pgs. 3-7.

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Whitesall, Louis B., et al. Continental Oil Company, Research and Development Dept. "Microbiological Treatment of Acid Mine Drainage Waters," prepared for the U.S. Environmental Protection Agency. Washington: EPA Reseach and Monitoring; for sale by the Superintendent of Documents, U.S. Government Printing Office, 1971.

Reference not available.

Wildeman, Thomas R., Filipek, Lorraine H., and Gusek, James, 1994. Proof-of-principle studies for passive treatment of acid rock drainage and mill tailing solutions from a gold operation in Nevada, *International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage,* U.S. Bureau of Mines Special Publication, SP 06B-94, vol. 2, p.387-394.

Samples of arsenic- and selenium-bearing AMD (pH=2.5) was treated by precipitating iron hydroxide to remove As, then passively treated in an anaerobic cell using a manure substrate to remove heavy metals, As and Se to Federal drinking water standards. Additional metals were removed in a passive aerobic polishing cell.

Wildeman, Thomas R. and Laudon, Leslie, S., 1989. Use of wetlands for treatment of environmental problems in mining: Non-coal-mining applications, , *in* Hammer, Donald A., ed., *Constructed Wetlands for Wastewater Treatment,* Lewis Publishers, Ann Arbor, MI, p. 221-231.

Reviews the chemistry of metal mine drainage, cites differences between metal mine and coal mine drainage, analyzes the geochemistry of metals removal in wetlands, and briefly summarizes the results of studies at the Big Five Tunnel (CO), Red Lake (ON), Sudbury (ON), Danka Mine (MN), and Sand Coulee (MT).

Wildeman, Thomas R. and Laudon, Leslie, S., 1988. The use of wetlands for treatment of environmental problems in mining: Non-coal mining applications, *in Proceedings of the U.S. EPA's Forum on Remediation of CERCLA Mining Waste Sites, April 25, 1989, Ward, Colorado,* p. 42-62.

Provides brief descriptions of the wetlands treatment systems presently in use at six base and precious metals mines in the U.S. and a detailed case history of the pilot treatment project at the Big Five Tunnel in Idaho Springs, CO.

Willow, Mark A., 1995. *pH and Dissolved Oxygen as Factors Controlling Treatment Efficiencies in Wet Substrate, Bio-Reactors Dominated by Sulfate-Reducing Bacteria,* Unpubl. M.S. Thesis, Colorado School of Mines, Golden, CO.

Experiments were conducted to determine if pH and dissolved oxygen of influent wastewaters limited the removal of heavy metals from AMD. Results showed that dissolved oxygen was not a limiting factor but that reduced pH did lower sulfate reduction.

Witthar, S.R., 1993. Wetland water treatment systems, *in* Moshiri, Gerald A., ed., *Constructed Wetlands for Water Quality Improvement,* Lewis Publishers, Boca Raton, p. 147-155.

Describes wetland design criteria used to construct treatment system wetlands, including physical requirements and wetland flora.

Ziemkiewicz, Paul, Skousen, Jeff, and Lovett, Ray, 1995. Open limestone channels for treating acid mine drainage: A new look at an old idea, *in* Skousen, Jeffrey and Ziemkiewicz, Paul, eds., *Acid Mine Drainage: Control & Treatment, 2nd edition,* National Mine Land Reclamation Center, p. 275-280.

Reviews the effectiveness and practical application of open channels armored with limestone for treating AMD from coal mines. Studied sites include the Brownton, Dola, Florence, Webster, and Airport channels, all located in western PA.

Ziemkiewicz, P.F., Skousen, J.G., Brant, D.L., Sterner, P.L., and Lovett, R.J., 1995. Acid mine drainage treatment with armored limestone in open limestone channels, *in* Skousen, Jeffrey and

Ziemkiewicz, Paul, eds., *Acid Mine Drainage: Control & Treatment, 2nd edition,* National Mine Land Reclamation Center, p. 281-298.

Reports the results of field and laboratory studies conducted to assess the extent to which the neutralizing capability of limestone clasts diminishes as a consequence of armoring by metal precipitates. Found that armoring reduced neutralizing capabilities by 5 to 50 percent.

Ziemkiewicz, P.J. Renton and T. Rymer, 1991, "Prediction and Control of Acid Mine Drainage: Effect of Rock Type and Amendment," in Proceedings Twelfth Annual West Virginia Surface Mine Drainage Task Force Symposium, April 3-4, 1991, Morgantown, West Virginia.

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APPENDIX C

MINING SITES ON THE NATIONAL PRIORITIES LIST

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Table of Contents

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Appendix C
Mining Sites on the National Priorities List

C.1 Purpose

This appenidix presents the mine sites and smelters listed on the National Priorities List as of May 16, 2000. It is hoped that this information will provide the user with an idea of the variety and geographic regions these sites are located in. For more information on a specific site, please contact the staff in the particular region (see Appendix I for a list of EPA Mining Contacts).

C.2 *NPL Mining Sites and Smelters as of May 16, 2000*

Site Name	City	State	Region	NPL Status
Atlas Asbestos Mine	Fresno County	CA	9	Final
Celtor Chemical Works	Humbolt County	CA	9	Final
Iron Mountain Mine	Redding	CA	9	Final
Johns-Manville Coalinga Asbestos	Fresno	CA	9	Final
Leviathan Mine	Markleeville	CA	9	Final
Lava Cap Mine	Nevada City	CA	9	Final
Sulphur Bank Mercury Mine	Lake County	CA	9	Final
Vasquez Boulevard and I-70	Denver	CO	8	Final
ASARCO, Inc. (Globe Plant)	Denver	CO	8	Proposed
Eagle Mine	Minturn/Redcliff	CO	8	Final
Central City-Clear Creek	Idaho Springs	CO	8	Final
California Gulch	Leadville	CO	8	Final
Lincoln Park	Canon City	CO	8	Final
Smuggler Mountain	Pitkin County	CO	8	Deleted
Summitville Mine	Rio Grande County	CO	8	Final
Smeltertown Site	Salida	CO	8	Proposed
Uravan Uranium	Uravan	CO	8	Final
Cedartown Industries, Inc.	Cedartown	GA	4	Final
Bunker Hill Mining & Metallurgical	Smelterville	ID	10	Final
Blackbird Mine	Lemhi County	ID	10	Proposed
Eastern Michaud Flats	Pocatello	ID	10	Final
Monsanto	Soda Springs	ID	10	Final
Circle Smelting Corp	Beckemeyer	IL	5	Proposed
DePue/New Jersey Zinc/Mobil Chem Corp	DePue	IL	5	Final
NL Industries/Taracorp Lead Smelter	Granite City	IL	5	Final
U.S. Smelter & Lead Refinery Inc.	East Chicago	IN	5	Proposed
Cherokee County	Cherokee County	KS	7	Final
National Southwire Aluminum Co.	Hawesville	KY	4	Final
NL Industries/Taracorp/Golden Auto	St. Louis Park	MN	5	Deleted
Torch Lake	Houghton County	MI	5	Final
East Helena Site	East Helena	MT	8	Final

Site Name	City	State	Region	NPL Status
Anaconda Co. Smelter	Anaconda	MT	8	Final
Basin Mining Area	Basin	MT	8	Final
Mouat Industries	Columbas	MT	8	Deleted
Upper Tenmile Creek Mining Area	Rimini/Helena	MT	8	Final
Big River Mine Tailings	St. Francois County	MO	7	Final
Oronogo-Duenweg Mining Belt	Jasper County	MO	7	Final
Carson River Mercury	Lyon & Churchill Co	NV	9	Final
Cimarron Mining Company	Carizozo	NM	6	Final
Cleveland Mill	Silver City	NM	6	Final
Homstake Mining Company	Cibola County	NM	6	Deleted
Molycorp, Inc.	Questa	NM	6	Proposed
United Nuclear Corp	McKinley County	NM	6	Final
Li Tungsten Corp.	Glen Cove	NY	2	Final
Ormet Corp.	Hannibal	OH	5	Final
National Zinc Corp.	Bartlesville	OK	6	Proposed
Tar Creek (Ottawa County)	Ottawa County	OK	6	Final
Reynolds Metal Company	Troutdale	OR	10	Final
Fremont Nat. Forest Uranium Mines	Lake County	OR	10	Final
Jacks Creek/Sitkin Smelting and Refinery	Maitland	PA	3	Final
Palmerton Zinc	Palmerton	PA	3	Final
Macalloy Corporation	North Charleston	SC	4	Final
Annie Creek Mine Tailings	Deadwood	SD	8	Deleted
Gilt Edge Mine	Lead	SD	8	Proposed
Whitewood Creek	Whitewood	SD	8	Deleted
Ross Metals Inc	Rossville	TN	4	Final
Tex-Tin Corp	Texas City	TX	6	Final
TRSR Corp.	Dallas	TX	6	Final
Jacobs Smelter	Stockton	UT	8	Final
Kennecott (North Zone)	Magna	UT	8	Proposed
Kennecott (South Zone)	Copperton	UT	8	Proposed
Midvale Slag	Midvale	UT	8	Final
International Smelting and Refining	Tooele	UT	8	Proposed
Sharon Steel Corp. (Midvale Tailings)	Midvale	UT	8	Final
Murray Smelter	Murray City	UT	8	Proposed
U.S. Titanium	Piney River	VA	3	Final
ALCOA (Vancouver Smelter)	Vancouver	WA	10	Deleted
Commencement Bay/Nearshore Tideflats	Tacoma	WA	10	Final
Silver Mountain Mine	Loomis	WA	10	Deleted
Midnite Mine	Wellpinit	WA	10	Final

Appendix D
General Discussion of
Applicable or Relevant and Appropriate Requirements
At Superfund Mining Sites

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Table of Contents

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Appendix D
General Discussion of
Applicable or Relevant and Appropriate Requirements
At Superfund Mining Sites

D.1 INTRODUCTION AND ORGANIZATION OF THE APPENDIX

Throughout any remedial action at an abandoned mining and mineral processing site, the site manager must consider compliance with applicable or relevant and appropriate requirements (ARARs in CERCLA jargon). ARARs are state, local, and federal standards that are directly applicable or may be considered relevant and appropriate to the circumstances on the site. These standards are an inherent part of the scoping process, but will affect the long-term remediation, especially in the setting of cleanup standards as well as in meeting other 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 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.

This appendix is organized in a statute-by-statute format providing information on the ARARs that have typically been selected at Superfund mining sites. It should be noted that the ARARs presented in this section may or may not apply on a site-specific basis and there may be additional laws and regulations that need to be considered on an individual site basis. Users of this handbook are strongly encouraged to refer to the pertinent CERCLA ARARs guidance documents for additional information and guidance. The structure of each section may vary according to the nature of the regulatory program under each statute, but the section will generally provide the following information:

- The nature and structure of the regulatory program and circumstances/conditions/actions that trigger the regulatory requirements;
- The potential applicability or relevance and appropriateness of a requirement for mining sites;
- A summary of the standards promulgated under the regulatory program; and
- Examples of how the statute/regulation may be an ARAR at a Superfund mining site.

Several types of ARARs are not included in this appendix because, although they may be significant at some sites, they do not appear to be issues at the majority of mine waste sites. For example, PCBs may be found at some historic mine sites, but are not a threat at most sites. In addition, EPA has published other guidance that specifically addresses these types of ARAR issues.

D.2 RESOURCE CONSERVATION AND RECOVERY ACT

Many Superfund mining site managers will be required to analyze whether the requirements of the Resource Conservation and Recovery Act (RCRA) are ARARs. RCRA ARAR determinations require knowledge of the nature of the wastes found at these sites and the types of actions that have been or will be taken at the sites (e.g., capping, removal, treatment). RCRA Subtitle D (which regulates "solid wastes" that are not hazardous wastes under RCRA - see definitions below) and Subtitle C (which regulates hazardous waste) are the RCRA requirements that are most likely to be applicable or relevant and appropriate.

D.2.1 Prerequisites for Applicability of RCRA Requirements. Either Subtitle C or Subtitle D of RCRA will be *applicable* if:

- The wastes at the site are solid wastes; and
- The wastes will be actively managed.[1]

If these two conditions are met, the wastes are subject to *at least* RCRA Subtitle D. Subtitle C (in lieu of Subtitle D) will be applicable if these solid wastes are "*hazardous* wastes" and they are actively managed. **The determination of whether a solid waste is hazardous is key to determining which RCRA requirements are applicable.** Where RCRA Subtitle D or C standards are not applicable, they may be relevant and appropriate. This determination is based on the nature of the wastes, a comparison of the objectives of the Superfund action, and the circumstances and purposes of the RCRA requirements.

Definitions of RCRA "Solid" and "Hazardous" Waste

Solid Waste

In 40 CFR 261.2 solid waste is defined as any discarded (i.e., abandoned, recycled, or inherently wastelike) material. The regulations also provide that certain materials are excluded from the definition of solid waste. The excluded materials that may be present at Superfund mining sites include: source, special nuclear, or byproduct material (as defined by the Atomic Energy Act of 1954) and materials subjected to in-situ mining techniques that are not removed from the ground as part of the extraction process (40 CFR 261.4). No RCRA regulations (i.e., those of either Subtitle C or D) will be applicable or relevant and appropriate to these excluded wastes.

The definition of solid waste includes wastes from the extraction, beneficiation, or processing of ores and minerals. These wastes will be subject to RCRA Subtitle D, unless they are subject to regulation under RCRA Subtitle C. (See Highlight D-1 for more information.)

Hazardous Waste

RCRA hazardous wastes are regulated by Subtitle C. A RCRA solid waste is hazardous if it:

- Is not excluded from regulation under Subtitle C; and
- Exhibits the characteristic of ignitability, corrosivity, reactivity, or toxicity; or
- Is listed in 40 CFR 261 Subpart D; or
- Is a mixture of a solid waste and a listed hazardous waste or a mixture of a solid waste and a characteristic waste that exhibits the characteristic;[2] or
- Is a solid waste generated during the treatment, storage, or disposal of a *listed* hazardous waste, or is derived from a characteristic waste *and* exhibits a characteristic; or
- Is a listed or characteristic waste contained in a non-solid waste matrix.

[1] "Active management" includes generation, transport, recycling, treatment, storage, and disposal. See below for more detail.

[2] EPA has proposed revisions to the "mixture" and "derived-from" rules. EPA will publish a fact sheet discussing these revisions once they are promulgated.

Several types of mining wastes are excluded from regulation as hazardous wastes under the mining waste ("Bevill") exclusion (see Highlight D-1 for details). Based on a 1986 Report to Congress, EPA determined that all solid wastes from the *extraction* or *beneficiation* of ores and minerals are covered by the exclusion, and therefore are regulated only by Subtitle D, and *never* by Subtitle C. Most mineral processing wastes were removed from the exclusion by two rulemakings (54 FR 36592 and 55 FR 2322), and these wastes are now potentially subject to Subtitle C (see Highlight D-2 for definitions of "extraction," "beneficiation," and "mineral processing"). Only 20 mineral processing wastes are now covered by the Bevill exclusion. On May 20, 1991, EPA made a final determination not to regulate these 20 wastes. These wastes are not subject to Subtitle C, but they are subject to Subtitle D.

Therefore, mineral processing wastes not included in the 20 under study are *not* covered by the Bevill exclusion and are subject to Subtitle C regulation, if they meet one of the criteria for being hazardous discussed above. The criteria most commonly found in mineral processing wastes that could lead to a determination that they are hazardous are the characteristics of toxicity and corrosivity. Mineral processing wastes will seldom, if ever, be ignitable or reactive.

One important remaining issue is whether treatment residuals from excluded mining and mineral processing wastes are themselves excluded under Bevill, or whether they are subject to Subtitle C regulation if they exhibit a characteristic. This issue has not been explicitly addressed and will require consultation with appropriate legal staff.

A mineral processing waste may also be considered hazardous if it is a listed RCRA hazardous waste. There are six listed mineral processing wastes. However, because five of these listings were remanded, only the listing for K088 (spent potliners from primary aluminum reduction) may be enforceable.[3]

Highlight D-1:
The Mining Waste ("Bevill") Exclusion

Under 40 CFR 261.4(b)(7), "solid waste from the extraction, beneficiation and processing of ores and minerals (including coal), including phosphate rock and overburden from the mining of uranium ore" is excluded from the definition of hazardous waste, and therefore is not subject to Subtitle C requirements. These wastes are excluded because implementation of Subtitle C requirements would be unnecessary, technically infeasible, or economically impracticable due to the types of waste and conditions commonly found at mining sites. These types and conditions include high volumes of waste with low toxicity and highly mobile constituents, large areas of contamination, and the arid climate in which many mining sites are located.

Although most mining wastes are still excluded from regulation as hazardous waste (e.g., all extraction and beneficiation wastes), revisions to EPA's interpretation of the Bevill exclusion have resulted in the removal of all but 20 mineral processing wastes from the exclusion. The wastes removed from the exclusion are now subject to regulation under Subtitle C. For a complete discussion of the mining waste exclusion and the wastes covered, see *Superfund Guide to RCRA Management Requirements for Mineral Processing Wastes*, 9347.3-12aFS, August 1991.

[3] The five other mineral processing wastes (K064, K065, K066, K090, and K091) were listed following their removal from the mining waste exclusion, but these listings were remanded by a July 1990 Federal Court of Appeals ruling (AMC v. EPA, 31 ERC 1935). Thus, the listings for these wastes may not be currently enforceable. These five wastes are still subject to Subtitle C requirements if they exhibit a characteristic.

Highlight D-2:
Definitions of Extraction, Beneficiation, and Mineral Processing

Extraction is the process of mining and removing ores and minerals from the ground.

Beneficiation is defined as crushing; grinding; washing; dissolution; crystallization; filtration; sorting; sizing; drying; sintering; pelletizing; briquetting; calcining to remove water and/or carbon dioxide; roasting, autoclaving, and/or chlorination in preparation for leaching (except where the roasting (and/or autoclaving and/or chlorination)/leaching sequence produces a final or intermediate product that does not undergo further beneficiation or processing); gravity concentration; magnetic separation; electrostatic separation; floatation; ion exchange; solvent extraction; electrowinning; precipitation; amalgamation; and heap, dump, vat, tank, and *in situ* leaching. (40 CFR 261.4(b)(7))

Mineral processing operations are operations that:

- Follow beneficiation of an ore or mineral (if applicable);
- Serve to remove the desired product from an ore or mineral, or enhance the characteristics of ores or minerals or beneficiated ores or minerals;
- Use mineral-value feedstocks that are comprised of less than 50 percent scrap materials;
- Produce either a final mineral product or an intermediate to the final product; *and*
- Do not combine the product with another material that is not an ore or mineral, or beneficiated ore or mineral (e.g., alloying), do not involve fabrication or other manufacturing activities, and do not involve further processing of a marketable product of mineral processing. (A listing of criteria is provided in the preamble to the September 1, 1989 rulemaking, 54 FR 36592.)

Hazardous mineral processing wastes are currently subject to all Subtitle C requirements *except* the land disposal restrictions (LDRs), because EPA has not yet set treatment standards for these wastes. Once the Agency sets treatment standards, these wastes will be subject to the LDRs.

Active Management

For RCRA regulations to be applicable requirements, a solid or hazardous waste must be actively managed. Active management includes generation, transport, recycling, treatment, storage, and disposal. Definitions of these activities are provided below and in the RCRA regulations.

Generation is defined as the act or process of producing hazardous waste or of causing a hazardous waste to become subject to regulation.

Transportation is defined as the movement of hazardous waste by air, rail, highway, or water.

Recycle is defined as the use, reuse, or reclamation of a material.

Treatment is defined as any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste, or so as to recover energy or material resources from the waste, or so as to render such waste nonhazardous, or less hazardous; safer to transport, store, or dispose of; or amenable for recovery, amenable for storage, or reduced in volume.

Storage is defined as the holding of hazardous waste for a temporary period, at the end of which the hazardous waste is treated, disposed of, or stored elsewhere.

Disposal is defined as the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including groundwaters. (40 CFR 261.10)

In addition, several requirements (e.g., the land disposal restrictions, closure requirements) are triggered by the land disposal or placement of the wastes. EPA defines placement as actions that occur when wastes are:

- Consolidated from different areas of contamination (AOCs) into a single AOC;
- Moved outside of an AOC and returned to the same or a different AOC; or
- Excavated from an AOC, placed in a separate unit, such as an incinerator or tank that is within the AOC, and redeposited into the same AOC.

Equally important, EPA has determined that placement does not occur when wastes are:

- Treated in-situ, including in-situ stabilization and in-situ land treatment (as long as the treatment is not preceded or followed by movement of wastes that constitutes placement);
- Capped in place, including grading prior to capping;
- Consolidated within the AOC; and
- Processed within the AOC (but not in a separate unit, such as a tank) to improve its structural stability for closure or for movement of equipment over the area.

RCRA Subtitle C is not automatically applicable to mining wastes that are left in place by response activities (e.g., wastes in slag piles, impoundments) and that are not managed. However, if the wastes prove to be hazardous, it often is an indication that some type of active management will be necessary as part of the remedy.

D.2.2 Relevance and Appropriateness of RCRA Requirements.

- RCRA Subtitle C requirements will generally not be relevant and appropriate for those wastes for which EPA has specifically determined that Subtitle C regulation is not warranted (i.e., wastes covered by the Bevill exclusion). As noted earlier, most mineral processing wastes are subject to RCRA Subtitle C. However, the NCP provides that if site circumstances differ significantly from those that caused EPA to decide that Subtitle C regulation is not warranted, Subtitle C may be relevant and appropriate. (See 40 CFR 300). (The circumstances that caused EPA to decide that Subtitle C regulation is not warranted for wastes covered by the Bevill exclusion include: the diversity from one mining site to another; the large quantities of waste found at individual mining sites, and the high aggregate waste quantities for all mining sites; the relatively low toxicity of mining wastes; and the high costs associated with regulating mining wastes under Subtitle C.)

- The NCP states that circumstances in which Subtitle C may be relevant and appropriate include sites containing low volumes of waste or wastes with high toxicity or highly mobile constituents, location of the site in an area of heavy precipitation (which could increase the leaching potential), or relatively small areas of contamination at the site. (See the preamble to the National Contingency Plan, 55 FR 8743 and 8763 and the *Superfund Guide to RCRA Management Requirements for Mineral Processing Wastes*, OSWER Publication No. 9347.3-12aFS, August 1991 for more information on the relevance and appropriateness of RCRA Subtitle C requirements.)

- If Subtitle D requirements are not applicable to the action, it is unlikely that they will be relevant and appropriate.

Even when not all parts of a Subtitle C requirement are ARARs, certain parts of the requirement may be evaluated to be relevant and appropriate. Where a site manager determines that RCRA requirements or parts of requirements are ARARs for a site, remedial actions must comply with these standards. RCRA closure requirements are often likely to be ARARs at mining sites. In particular, where soil cleanup is part of the remedy, movement of the soil containing RCRA hazardous waste across a unit boundary will make the closure requirements for either clean closure or closure in place applicable or relevant and appropriate to the unit into which the waste is placed. Where closure requirements are determined not to be applicable, hybrid closure (i.e., a combination of landfill and clean closure options) may be relevant and appropriate for these sites. Hybrid closure is particularly appropriate where contamination remaining at the site has low mobility and low toxicity. These conditions are often found at sites where mining waste is present.

[For a complete discussion on determining if RCRA requirements are ARARs, see the *CERCLA Compliance with Other Laws Manual, Part I and II, Interim Final*, (August 1988 and August 1989, respectively).]

D.2.3 State RCRA Requirements as ARARS. The RCRA Subtitle D program is a wholly state-managed program.[4] In most states (i.e., authorized states), the Subtitle C program is also administered by the state in lieu of federal regulation. That is, state authorities are used to issue the permits and enforce regulations for hazardous waste treatment, storage, and disposal (TSD) facilities. Until a state receives authorization, RCRA regulations are administered and enforced under federal jurisdiction. Site managers should determine if the state in which the mining site is located has an authorized RCRA program, and if state requirements are ARARs.

To be authorized under Subtitle C, state programs must be equivalent to federal programs, consistent with federal and other approved state programs, and must provide adequate enforcement of compliance with federal regulations. (See 40 CFR Part 271.) state programs may always contain elements that are more stringent than federal regulations. When federal regulations are promulgated under RCRA, there are two types of circumstances that may arise that are relevant to evaluating whether the requirements are ARARs. For regulations promulgated under authorities prior to the Hazardous and Solid Waste Amendments of 1984 (HSWA), the regulations are not enforceable as federal law in states with authorized RCRA programs until the state program adopts those regulations (a process that the state generally must do within two years, although states may do so sooner or may adopt the requirement under state law or regulations prior to official authorization).[5] Examples of these include wastes

[4] EPA has promulgated criteria for design and operation of Subtitle D landfills. Additional Subtitle D requirements may also be promulgated; however, under RCRA reauthorization, States may acquire the authority to issue their own criteria.

[5] Many States incorporate Federal RCRA changes by referencing Federal regulations in State regulations and then submitting a formal authorization request.

that were excluded originally under the Bevill exclusion, but since were studied by Reports to Congress. For regulations promulgated under HSWA authorities, EPA enforces the regulations in all states. If an authorized state adopts these regulations, the state assumes enforcement authority.

In determining if state RCRA requirements are ARARs, site managers do not need to determine if the state regulations are promulgated, enforceable, or more stringent than federal regulations (the normal criteria for evaluating whether state requirements are ARARs - see *CERCLA Compliance with Other Laws Manual*, Part II, Chapter 7). If the state has an authorized RCRA Subtitle C program, its requirements are ARARs because of the process states must go through to become authorized, which evaluates these criteria.

D.2.4 RCRA Standards. Once a site manager has determined that a site meets the conditions discussed above, the following standards should be examined as potential ARARs.

Subtitle D Standards

The Subtitle D program regulates the management of nonhazardous solid waste and is administered by the states. Under RCRA, states must develop solid waste management plans that prohibit waste disposal in open dumps and that provide for the closing or upgrading of all existing dumps. These plans must be "consistent with the minimum requirements" for approved state programs. In 40 CFR Part 257, EPA establishes criteria for determining which solid waste disposal facilities and practices pose a potential threat to human health and the environment. Currently promulgated criteria include restrictions on contamination of surface and groundwater, releases to air, and safety considerations. Criteria for municipal solid waste landfills can be found at 40 CFR Part 258. This section addresses location restrictions, operating criteria, design criteria, groundwater monitoring and corrective actions, closure and post-closure care, and financial responsibility criteria at municipal solid waste landfills receiving waste after October 9, 1991. It should be noted that most states have primacy for solid waste programs. These programs may differ and should be reviewed to determine the applicability to mine waste (e.g., Utah solid waste regulations and ground-water protection regulations as applied to mine waste).

Subtitle C Standards

The Subtitle C program regulates the generation, transportation, treatment, storage, and disposal of RCRA hazardous waste. The following are the primary types of RCRA requirements that may be ARARs for mining sites, including the basis for the requirement and specific standards that must be met.

40 CFR Part 264 Subpart F: Groundwater Protection Requirements

Where aquifers are potentially contaminated by mining sites, 40 CFR Part 264 Subpart F requirements could be ARARs. These may include:

- The Regional Administrator must set groundwater protection standards and concentration limits for Appendix VIII and IX hazardous constituents once they are detected in the groundwater at a hazardous waste disposal facility.

- Concentration limits are based on:

  -- The background level of each constituent in the groundwater at the time the limit is specified in the permit;
  -- Maximum concentration limits for 14 specified hazardous constituents if background levels are below these standards; or
  -- An "alternate concentration limit" that can be set by the Regional Administrator if it is determined that a less stringent standard will protect public health and the environment.

40 CFR Part 264 Subpart J: Tank Design and Operating Requirements

RCRA defines a tank as "a stationary device, designed to contain an accumulation of hazardous waste which is constructed primarily of non-earthen materials (e.g., wood, concrete, steel, plastic) which provide structural support." This definition can include a wide variety of structures that can be used to store mining wastes. Specific requirements for tanks include:

- The owner or operator must obtain a written assessment of the structural integrity and acceptability of existing tanks systems and designs for new tank systems, reviewed by an independent, qualified, registered professional engineer.

- All new tank systems must be enclosed in a full secondary containment system that encompasses the body of the tank and all ancillary equipment and can prevent any migration of wastes into the soil. This secondary containment system must be equipped with a leak detection system capable of detecting releases within 24 hours of release.

- Facilities with existing tank systems must install secondary containment systems within specified times based on age and waste type.

- Owners or operators may seek from the Regional Administrator both technology-based and risk-based variances from secondary containment requirements, based on either: (1) a demonstration of no migration of hazardous waste constituents beyond the zone of engineering control; or (2) a demonstration of no substantial present or potential hazard to human health and the environment.

- Annual leak tests must be conducted on non-enterable underground tanks until such time as an adequate secondary containment system could be installed. Either an annual leak test or other type of adequate inspection must also be conducted on enterable types of tanks that do not have secondary containment.

- Inspection requirements have been upgraded to include regular inspection of cathodic protection systems and daily inspection of entire tank systems for leaks, cracks, corrosion, and erosion that may lead to releases.

- The owner or operator must remove a tank from which there has been a leak, spill or which is judged unfit to use. The owner or operator must then determine the cause of the problem, remove all waste from the tank, contain visible releases, notify appropriate parties as required by other laws (i.e., CERCLA reportable quantity requirements), and certify the integrity of the tank before further use.

- Closure requirements include removing waste, residues, and contaminated liners, disposing of them as hazardous waste, and conforming with Subparts G and H (including post-closure of tank if necessary).

- The owner or operator must also comply with general operating requirements and with special requirements for ignitable, reactive, or incompatible wastes.

40 CFR Part 264 Subpart K: Surface Impoundment Design and Operating Requirements

Impoundments are a common type of unit into which mining wastes are disposed during active operations. When included as part of a Superfund site, the following requirements may be ARARs:

- Each new surface impoundment, each replacement of an existing surface impoundment unit, and each lateral expansion of an existing surface impoundment unit must have two or more liners and a leachate collection system between the liners. [The Regional Administrator may approve an alternative liner design.]

- Owners or operators must comply with groundwater monitoring requirements under 40 CFR 264 Subpart F, including corrective action, if necessary.

- Impoundments must be removed from service if the liquid level suddenly drops or the dike leaks.

- A surface impoundment may be closed by removing and decontaminating all hazardous wastes, residues, liners, and subsoils. If all hazardous wastes cannot be removed or decontaminated, the facility must be capped and post-closure care provided. An owner or operator may also close the impoundment as a disposal facility (i.e., solidify all remaining wastes, cap the facility, and comply with Part 264 post-closure requirements).

40 CFR Part 264 Subpart L: Waste Pile Design and Operating Requirements

Waste piles are a common type of unit into which mining wastes are disposed during active operations. A pile is defined as "any non-containerized accumulation of solid, nonflowing hazardous waste that is used for treatment or storage." When included as part of a Superfund site, the following requirements may be ARARs:

Waste pile owners and operators must:

- Install a liner under each pile that prevents any migration of waste out of the pile into the adjacent subsurface soil or ground or surface water at any time during the active life of the pile.
- Provide a leachate collection and removal system.
- Provide a run-on control system and a run-off management system.
- Comply with Subpart F groundwater protection requirements.
- Inspect liners during construction and inspect the wastes at least weekly thereafter.
- Close the facility by removing or decontaminating all wastes, residues, and contaminated subsoils (or comply with the closure and post-closure requirements applicable to landfills if removal or decontamination of all contaminated subsoils proves impossible).

40 CFR Part 264 Subpart M: Land Treatment Requirements

Owners or operators of facilities that dispose of hazardous waste by land application must:

- Establish a treatment program that demonstrates to the Regional Administrator's satisfaction that all hazardous constituents placed in the treatment zone will be degraded, transformed, or immobilized within that zone.

- Conduct a monitoring program to detect contaminants moving in the unsaturated zone (the subsurface above the water table).

- Continue all operations during closure and post-closure to maximize the degradation, transformation, or immobilization of hazardous constituents.

40 CFR Part 264 Subpart N: Landfills

A landfill is defined as "a disposal facility or part of a facility where hazardous waste is placed in or on land and which is not a pile, a land treatment facility, a surface impoundment, an underground injection well, a salt dome formation, a salt bed formation, an underground mine, or a cave." Landfills, which are often used at Superfund sites for hazardous waste disposal, must meet the following requirements:

- New landfills, new landfills at an existing facility, replacements of existing landfill units, and lateral expansions of existing landfill units must have two or more liners and a leachate collection system above and between the liners.

- A landfill must have run-on/run-off control systems and control wind dispersal of particulates as necessary.

- A landfill must comply with Subpart F groundwater protection requirements.

- Owners or operators of landfills must close each cell of the landfill with a final cover and institute specified post-closure monitoring and maintenance programs.

- Disposal of bulk or non-containerized liquid hazardous waste and non-hazardous liquids in a landfill is prohibited.

40 CFR Part 264 Subpart X: Standards for Miscellaneous Treatment Units

A miscellaneous unit is defined as a "hazardous waste management unit where hazardous waste is treated, stored, or disposed of and that is not a container, tank, surface impoundment, pile, land treatment unit, landfill, incinerator, boiler, industrial furnace, underground injection well with appropriate technical standards under 40 CFR part 146, containment building, corrective action management unit, or unit eligible for a research, development, and demonstration permit under §270.65." A miscellaneous unit must be located designed, constructed, operated, maintained, and closed in a manner that will ensure protection of human health and the environment. Permits for these units will contain design and operating requirements, detection and monitoring requirements, and requirements for releases of hazardous waste or hazardous constituents from the unit. Disposal units must be maintained during post-closure to ensure protection of human health and the environment.

40 CFR Part 268: Land Disposal Restrictions (LDRs)

These requirements regulate placement of hazardous waste in landfills, surface impoundments, waste piles, injection wells, land treatment facilities, salt dome formations, salt bed formations, or underground mines or caves. At this time, no mining wastes are subject to the LDRs. The LDRs will be applicable for wastes removed from the mining waste exclusion, once the Agency sets treatment standards for these wastes. For a detailed discussion of the LDRs at CERCLA sites, see *Superfund Compliance with the LDRs*, OSWER Directive No. 9347.3, the LDR Guide fact sheet series (OSWER #9347.3-01FS - 9347.3-08FS), and *Superfund Guide to RCRA Management Requirements for Mineral Processing Wastes*, OSWER #9347.3-12FS, January 1991.

40 CFR Part 264 Subpart G, 265, 270: Closure Requirements

See Highlight D-5 and *RCRA ARARs: Focus on Closure Requirements*, OSWER #9234.2-04FS, October 1989.

Highlight D-5:
RCRA as ARARs: Two Example Sites

A *former aluminum processing facility* site listed on the NPL contains areas of contamination resulting from treatment, storage, and disposal at the site, including a landfill near the aluminum reduction building. Significant waste types in the landfill include metallic wastes and spent cathode waste materials containing arsenic. Wastes containing arsenic have been found to exhibit the toxicity characteristic, and listed waste K088 (spent potliners from primary aluminum reduction) has been discovered at the site. Because these processing wastes are not covered by the mining waste exclusion, RCRA Subtitle C requirements are applicable for this site. The RCRA LDRs do not apply to these wastes, but other Subtitle C requirements (e.g., disposal in a regulated Subtitle C unit) will apply. In addition, other RCRA requirements, such as design and closure requirements, may apply to actions at this site.

At the *Celtor Chemical site* in California, where sulfide ore was processed for copper, zinc, and precious metal extraction, soil and surface water are contaminated with cadmium, heavy metals, and arsenic. RCRA landfill and surface impoundment closure requirements were considered relevant and appropriate for this site. Consolidation of wastes and capping or encapsulation with long-term groundwater monitoring may have met these requirements, but it was uncertain if interceptor trenches and subsurface drains would be able to prevent all subsurface water from entering the waste management area. Because of this uncertainty, the site manager chose clean closure (i.e., removal of the wastes to site-specific action levels that were protective of human health and the environment).

D.3 STATUTES AND REGULATIONS GOVERNING RADIOACTIVE WASTES[6]

D.3.1 Regulatory Program Structure. Radioactive wastes are regulated primarily by three agencies: EPA, the Nuclear Regulatory Commission (NRC), and the Department of Energy (DOE). When radioactive contaminants are present at a site, site managers should evaluate the standards set by the appropriate agencies as potential ARARs. **As discussed below, the requirements set by the NRC and DOE will be *applicable* only at sites within their respective jurisdictions.** (The NRC's jurisdiction includes non-DOE sites; DOE's jurisdiction includes DOE-controlled sites only.) Therefore, the requirements of these agencies may only be relevant and appropriate at most Superfund sites. EPA standards for radioactive waste will be applicable to response actions only under certain circumstances; in most cases, however, they will be only relevant and appropriate, because the standards were not intended to regulate inactive Superfund mining sites. The scope of each agency's program is described below:

- EPA's authorities to set standards for radioactive waste are based on several statutes, including the Atomic Energy Act, the Clean Air Act, the Uranium Mill Tailings Radiation Control Act, and RCRA. The requirements consist mainly of radiation standards for activities involving radioactive materials at certain types of facilities (e.g., nuclear power plants, active uranium mines, DOE facilities). The materials regulated are source, byproduct, special nuclear, and naturally occurring and accelerator-produced radioactive material (NARM), which include natural uranium and thorium, uranium and thorium mill tailings, enriched uranium, and naturally occurring radionuclides other than thorium and uranium, such as radium or wastes from mineral extraction industries. EPA's standards established under the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) regulate management of uranium and/or thorium mill tailings at certain inactive uranium processing sites and licensed commercial uranium or thorium processing sites. In addition, RCRA hazardous waste regulations may apply to hazardous wastes containing radioactive contaminants.

- NRC licenses the possession and use of source, byproduct, and special nuclear material at certain facilities. (NARM is not regulated by NRC standards.) NRC's regulatory program controls the nuclear material operations of the licensees. In addition, 29 states have entered into agreements with the NRC, under which the states adopt the NRC's regulatory authority over source, byproduct, and small quantities of special nuclear material. These state-implemented regulations are potential ARARs.

- DOE regulates radioactive wastes through internal orders that establish requirements for radiation protection and radioactive waste management. These requirements apply only to facilities within DOE's jurisdiction, such as national laboratories and certain inactive sites associated with the Formerly Utilized Sites Remedial Action Program (FUSRAP), the Uranium Mill Tailings Remedial Action Program (UMTRAP), the Grand Junction Remedial Action Program (GJAP), and the Surplus Facilities Management Program (SFMP). Because DOE orders are developed for internal DOE use, they are not promulgated regulations and are not potential ARARs for Superfund sites, unless the site is under DOE jurisdiction.

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[6] The authority for regulating radioactive wastes is derived from several statutes and regulations. This section discusses the regulatory program formed by these laws.

However, where the DOE orders are more stringent or cover areas not addressed by existing ARARs, they may be considered for Superfund actions as "to-be-considered (TBC)" information.

In determining which of the requirements listed above are potential ARARs for a mining site with radioactive contamination, site managers should consider three factors:

- The type of wastes at the site and the operations that occurred at the site to generate the waste;
- The agency that has jurisdiction over the site; and
- The regulations that establish standards that are most protective, or (if relevant and appropriate) most appropriate given site conditions.

Highlight D-6 summarizes the potential ARARs for various radioactive waste types and agency jurisdictions.

D.3.2 EPA Program. EPA regulations for radioactive wastes include those promulgated under the Clean Air Act (40 CFR Part 61), the Safe Drinking Water Act (40 CFR Part 141), the Atomic Energy Act (40 CFR Part 190), UMTRCA (40 CFR Part 192), and in 40 CFR Part 440. These standards may be ARARs for both EPA sites as well as sites that are not under EPA jurisdiction (e.g., DOE and NRC sites).

40 CFR Part 61: National Emissions Standards for Hazardous Air Pollutants (NESHAPs)

The standards in 40 CFR Part 61, established under the authority of the Clean Air Act, regulate radionuclide emissions to the air from various sources (i.e., active underground uranium mines, certain DOE facilities, certain NRC-licensed facilities and non-DOE federal facilities, and active NRC-licensed uranium mill tailings sites). Each source is addressed in a different Subpart. As explained below, most of the Subparts will only be relevant and appropriate to the cleanup of Superfund mining sites.

Subpart B: Standards for Active Underground Uranium Mines

- An owner or operator of an underground uranium mine shall install and maintain bulkheads (air-restraining barriers) to control radon-222 and radon-222 decay products from abandoned and temporarily abandoned areas of the mine.

Because Subpart B standards regulate *active* mines, they are unlikely to be applicable to Superfund cleanup actions. However, they may be relevant and appropriate if the response occurs at an underground uranium mine, or a site where radon-222 or radon-222 decay products are present.

Subpart H: Standards for DOE Facilities

- Emissions of radionuclides to air from all facilities owned or operated by DOE (except facilities regulated under 40 CFR Part 61 Subpart B, 191, or 192) shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr.

- Doses from radon-222 and its respective decay products are excluded from these limits.

Highlight D-6: Radioactive Waste Regulations as ARARs

Waste Type	Standard	Summary	Potential Applicability (for sites under all agency jurisdictions, unless otherwise noted)
Radon	• 40 CFR Part 61 Subpart B	Clean Air Act NESHAPs; Standards for active underground uranium mines	Relevant and appropriate only
	• 40 CFR Part 192 Subparts A - E	UMTRCA standards	Relevant and appropriate only
Radionuclides	• 40 CFR Part 61 Subpart H	Clean Air Act NESHAPs; Radionuclide emission standards for DOE facilities	Applicable for DOE sites, relevant and appropriate for EPA sites
	Subpart I	Clean Air Act NESHAPs; Radionuclide emission standards for NRC and non-DOE federal facilities	Applicable for NRC-licensed sites and non-DOE federal sites, relevant and appropriate for EPA sites
	• 40 CFR Part 141	SDWA Maximum Contaminant Levels	Applicable
	• 40 CFR Part 190	Radiation dose limits for nuclear power operations	Relevant and appropriate
Uranium mill tailings	• 40 CFR Part 61 Subpart W	Clean Air Act NESHAPs; Tailings impoundments disposal standards for active NRC-licensed uranium mill tailings sites	Relevant and appropriate only
	• 40 CFR Part 192 Subparts A - C	UMTRCA standards for designated inactive uranium processing sites	Relevant and appropriate only
	Subparts D and E	UMTRCA standards for active commercial licensed uranium or thorium processing sites	Applicable for active commercial processing sites licensed by NRC or state; otherwise, relevant and appropriate
Uranium, radium, and vanadium ores	• 40 CFR Part 440 Subpart C	Radionuclide concentration limits for surface water discharges of radioactive waste	Possibly applicable, probably relevant and appropriate
Byproduct, source, and special nuclear material	• 10 CFR Parts 30, 40, & 70	NRC licensing requirements for possession and use of byproduct, source, and special nuclear material, respectively	Applicable for NRC-licensed sites, relevant and appropriate for non-licensed sites

Highlight D-6: Radioactive Waste Regulations as ARARs			
Waste Type	Standard	Summary	Potential Applicability (for sites under all agency jurisdictions, unless otherwise noted)
Ore-processing residues containing > 5 pCi/g radium	• 40 CFR Part 192 Subparts A - E	UMTRCA standards	Relevant and appropriate only
Mixed radioactive and hazardous waste	• RCRA Subtitle C	RCRA requirements for management of hazardous waste (for hazardous components of mixed waste)	Applicable
All radiation sources	• 10 CFR Part 20	NRC standards for protection against radiation	Applicable for NRC sites, relevant and appropriate for EPA and DOE sites
	• 10 CFR Part 61	NRC licensing requirements for land disposal of radioactive waste	Potentially applicable for NRC sites, relevant and appropriate for EPA sites
	• DOE Internal orders	DOE requirements for radiation protection and radioactive waste management	Applicable for DOE sites, To-Be-Considered for sites under other agency jurisdiction

Subpart H standards are potentially applicable at sites with airborne emissions of radionuclides, where DOE is the lead agency. Where EPA is the lead agency, these requirements may be relevant and appropriate.

Subpart I: Standards for NRC-Licensed Facilities and Non-DOE Federal (e.g., DOD) Facilities

- Emissions of radionuclides including iodine to the ambient air from facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr. Emissions of iodine to the ambient air from facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 3 mrem/yr.

- Doses from radon-222 and its respective decay products are excluded from these limits.

Subpart I standards are potentially applicable at sites with NRC- (or state-) licensed or non-DOE federal sites with airborne emissions of radionuclides. Where EPA is the lead agency, these requirements may be relevant and appropriate.

Subpart W: Standards for NRC-Licensed Uranium Mill Tailings Sites During Their Operational Period

- Phased or continuous disposal is required for all new tailings impoundments at licensed uranium mill sites during their operational period.

Because they regulate *active* uranium mill tailings sites, Subpart W standards are unlikely to be applicable to Superfund cleanup actions. However, they may be relevant and appropriate if the response occurs at a uranium mill site.

40 CFR Part 141: Safe Drinking Water Act (SDWA) Maximum Contaminant Levels (MCLs)

Maximum Contaminant Levels (MCLs) have been set for radionuclides in the form of radioactivity concentration limits for certain alpha-emitting radionuclides in drinking water and as an annual dose limit for the ingestion of certain beta/gamma-emitting radionuclides. The standards are:

Radionuclide	MCL
Gross alpha particle activity	15 pCi/l
Gross beta particle activity	4 mrem/yr
Radium 226 and 228 (total)	5 pCi/l

For remedial actions addressing ground or surface waters that are potential sources of drinking water and that are contaminated with radionuclides, MCLs may be relevant and appropriate.

40 CFR Part 190: Environmental Radiation Protection Standards for Nuclear Power Operations (including uranium mill sites)

Applicability

These standards apply to normal operations and planned discharges from nuclear power operations (i.e., uranium milling, production of uranium hexafluoride, uranium enrichment, uranium fuel fabrication, operations of nuclear power plants using uranium fuel, and reprocessing of spent fuel), not cleanup actions such as those conducted under CERCLA. Therefore, they will not be applicable for Superfund mining sites. However, they may be relevant and appropriate to releases of radionuclides and radiation during the cleanup of radioactively contaminated sites. The standards address releases to all media and all potential exposure pathways, but do not apply to doses caused by radon and its daughters.

Standards

- Operations within the uranium fuel cycle (e.g., uranium milling, uranium enrichment) shall be conducted in a manner that limits the annual dose received by any member of the public to 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ.

40 CFR Part 192: Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings

UMTRCA standards govern the stabilization, disposal, and control of uranium and thorium mill tailings. Site managers at CERCLA mining sites should consider these standards as potential ARARs if:

- The site is an active commercial uranium or thorium processing site licensed by the NRC or a state;
- Uranium or thorium mill tailings are present (excluding inactive sites designated under UMTRCA - see below for further information);
- Radium or radon gas contamination is present; or
- Materials other than, but similar to, uranium or thorium mill tailings (i.e., radium components of copper, zinc, aluminum, and other ore-processing residues, contaminated soil, or any other waste containing more than 5 picocuries/gram of radium) are present.

Applicability

UMTRCA standards, which are promulgated in 40 CFR Part 192 Subparts A - E, regulate two categories of uranium and thorium processing sites:

- Subparts A, B, and C govern 24 inactive uranium processing sites designated for remediation by DOE under UMTRCA. These Subparts cover releases of radon from mill tailings and cleanup of residual radioactive material from land and buildings, and include supplemental standards.

- Subparts D and E regulate active commercial uranium or thorium processing sites licensed by the NRC or a state. The standards include requirements for general design, operation and closure of the sites.

Subparts A, B, and C are never applicable at CERCLA mining sites, because releases of source, byproduct, or special nuclear material (i.e., natural uranium and uranium mill tailings) *at the 24 designated sites covered by these standards* are excluded from CERCLA response actions by CERCLA section 101(22)(C). Instead, DOE conducts cleanup actions at these sites under the authority of UMTRCA, Title I, section 102. However, Subparts A, B, and C may be *relevant and appropriate* at CERCLA sites if:

- Uranium or thorium mill tailings are present, but the site is not one of the 24 inactive sites designated under UMTRCA;
- The site contains materials other than, but similar to, uranium or thorium mill tailings (i.e., radium components of copper, zinc, aluminum, and other ore-processing residues, contaminated soil, or any other waste containing more than 5 picocuries/gram of radium); or
- Radon decay products or gamma radiation are present.

Site managers should be aware, however, that the radon level standards will only be relevant and appropriate if the elevated radon levels are caused by human activity, because CERCLA section 104(a)(3)(A) and (B) prohibits Superfund response to releases of a naturally occurring substance "in its unaltered form" (such as naturally occurring radon).

Subparts D and E may be applicable for Superfund actions at licensed commercial uranium or thorium processing sites. They may be relevant and appropriate for sites with wastes similar to uranium mill tailings or with radon contamination. In addition, some of these standards have been incorporated into other radioactive waste regulations and may be applicable to sites covered by those regulations. For example, the NRC adopted the standards in Subpart D in the Uranium Mill Tailings Regulations at 10 CFR Part 40, Appendix A (discussed later in this section), and therefore these standards may be applicable to sites licensed to possess source material.

Standards for Inactive Uranium Processing Sites

Subpart A: Standards for the Control of Residual Radioactive Materials From Inactive Uranium Processing Sites

Performance standards for long-term effectiveness of remedial actions for controlling radioactive releases: (40 CFR 192.02(a)). Control of residual radioactive materials and their listed constituents shall be designed to be effective for up to one thousand years, to the extent possible, and, in any case, for at least 200 years.

Design requirements for remedial actions for controlling releases of radon-222: (40 CFR 192.02(b)). Remedial actions to stabilize or isolate uranium mill tailings should provide reasonable assurance that releases of radon-222 from residual radioactive material to the atmosphere will not:

- Exceed an average (i.e., average over the entire surface of the disposal site and over at least one year) release rate of 20 $pCi/m^2/sec$; or
- Increase the annual average concentration of radon-222 in air at or above any location outside the disposal site by more than one-half pCi/l.

Subpart B: Standards for Cleanup of Land and Buildings Contaminated with Residual Radioactive Materials from Uranium Processing Sites

Concentration limits for cleanup of radium-226 in land at a processing site: (40 CFR 192.12 (a)). Remedial action shall be conducted so as to provide reasonable assurance that, *as a result of residual radioactive materials from any designated processing site*, the concentration of radium-226 in land averaged over any area of 100 m^2 does not exceed the background level by more than:

- 5 pCi/g, averaged over the first 15 cm of soil below the surface; and
- 15 pCi/g, averaged over 15 cm thick layers of soil more than 15 cm below the surface.

Concentration limits for cleanup of radon decay products and gamma radiation in habitable or occupied buildings at a processing site: (40 CFR 192.12(b)). Remedial action shall be conducted so as to provide reasonable assurance that, *as a result of residual radioactive materials from any designated processing site*, in any occupied or habitable building:

- The objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product not to exceed 0.02 WL. In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL; and

- The level of gamma radiation shall not exceed the background level by more than 20 microroentgens/hour.

Subpart C: Supplemental Standards That May Be Applied if Certain Circumstances Exist At a Site

Criteria for applying supplemental standards: (40 CFR 192.21). Supplemental standards may be applied if *any* of the following circumstances exists:

- Remedial actions would pose a clear and present risk of injury to workers or to members of the public notwithstanding reasonable measures to avoid or reduce risk;

- Remedial actions would create environmental harm that is long-term, manifest, and grossly disproportionate to health benefits that may reasonably be anticipated;

- The estimated costs of cleaning up land are unreasonably high relative to the long-term benefits, and the residual radioactive materials do not pose a clear present or future hazard;

- The cost of cleaning up a building is clearly unreasonable high relative to the benefits;

- There is no known remedial action; or

- Radionuclides other than radium-226 and its decay products are present in significant quantities and concentrations.

- The groundwater meets one of the following criteria: (1) the concentration of total dissolved solids is in excess of 10,000 mg/l, or (2) widespread, ambient contamination not due to activities involving residual radioactive materials from a designated processing sites exists that cannot be cleaned up using treatment methods reasonably employed in public water systems, or (3) the quantity of water reasonably available for sustained continuous use is less than 150 gallons per day.

Supplemental Standards (40 CFR 192.22). On a site-specific basis, supplemental standards may be applied in lieu of the standards of Subparts A and B, if any of the criteria listed above applies. The implementing agency must select and perform remedial actions that come as close to meeting the otherwise applicable standard as is reasonable. If radionuclides other than radium-226 and its decay products are present in significant quantities and concentrations, this residual radioactivity must be reduce to levels that are as low as is reasonably achievable (ALARA) and conform to the standards of Subparts A and B to the maximum extent practicable. The implementing agency may make general determinations concerning remedial actions under this section that will apply to all locations with specified characteristics, or they may make a determination for a specific location. In certain situations the implementing agencies shall apply any remedial actions for the restoration of contamination of groundwater by residual radioactive materials that is required to assure, at a minimum, protection of human health and the environment. The implementing agencies may also need to ensure that current and reasonably projected uses of the affected groundwater are preserved.

Standards for Licensed Commercial Uranium or Thorium Processing Sites

Subpart D (for uranium) and Subpart E (for thorium): Standards for Management of Uranium and Thorium Byproduct Materials (i.e., mill tailings)

The standards of these Subparts apply to management of uranium and thorium byproduct materials during and following processing of uranium ores, as well as to restoration of disposal sites following the use of such sites under section 84 of the Atomic Energy Act (AEA).

The standards (see 40 CFR 192.32 - 192.33) incorporate the general design, construction, operation, closure, and corrective action requirements of RCRA. The standards supplement the groundwater protection standards under RCRA by adding molybdenum and uranium to the list of hazardous constituents in 40 CFR 264.93 and by specifying concentration limits for radioactivity.

Implementation of UMTRCA Standards

Site managers may find large amounts of wastes for which UMTRCA standards are ARARs in waste piles at mining sites or in disposal areas near mining sites. Because many of the sites for which these standards are relevant and appropriate have been abandoned for many years, contamination may have migrated to areas surrounding disposal sites. For example, wind may have blown contaminated material to other locations, or contaminated soil may have been used as fill or foundation for buildings and residential areas nearby. **UMTRCA standards may be relevant and appropriate for wastes in these areas as well as for the original mining or mineral processing site.**

CERCLA response actions for which Subparts A and B are relevant and appropriate must bring the levels of the affected wastes below those specified in the standards. Actions for which Subparts D and E are ARARs must meet the requirements given in those sections. Remedies required to meet the standards of 40 CFR 192 may include excavation and of contaminated material, capping, installation of radon reduction systems (if buildings are contaminated with radon gas due to the mining wastes), and institutional controls.

Highlight D-7:
UMTRCA Standards (40 CFR Part 192) as ARARs:
Two Example Sites

The *Montclair/West Orange Radium* site in New Jersey is a residential neighborhood contaminated with radioactive waste materials suspected to have originated from radium processing or utilization facilities located nearby. Radium-contaminated soil was used for fill and mixed with cement for sidewalks and foundations. The primary contaminant of concern is radium-226, which decays to radon gas. The requirements of 40 CFR Part 192 Subpart B, cleanup standards for land and buildings contaminated with uranium mill tailings, are relevant and appropriate for this site.

The *Monticello Vicinity Properties* site in Utah is a federally owned, abandoned vanadium and uranium mill site in a primarily residential area. The site, as part of the Surplus Facilities Management Program, is designated for remedial action by DOE. It is also included on the NPL and therefore must comply with CERCLA requirements to meet ARARs. Approximately 100,000 yd^3 of contaminated construction debris and wind-blown deposited contamination is estimated to be within the site. The primary contaminants of concern are thorium-230, radium-226, and radon-222 contained in vanadium and uranium mill tailings in the construction debris. Although the mill site is located on federal government property and is not subject to UMTRCA, the standards promulgated in 40 CFR Part 192 Subparts A, B, and C are relevant and appropriate for remediation of the vicinity properties. Therefore, the stabilization, disposal, and control requirements of these Subparts must be met.

40 CFR Part 440 Subpart C: Guidelines and New Source Performance Standards for Ore Mining and Dressing Point Source Category Effluent Limitations

Applicability

Radionuclide concentration limits in 40 CFR Part 440 are applicable to discharges from certain kinds of mines and mills. They may be relevant and appropriate to CERCLA actions involving discharges to surface waters of radioactively contaminated waste from other kinds of sites. These standards are more stringent than the NRC's concentration limits for discharges of uranium and radium (10 CFR Part 20). Therefore, when both 40 CFR Part 440 and 10 CFR Part 20 are ARARs for a site, the concentration limits in 40 CFR Part 440 will take precedence.

Standards

- Radionuclide concentration limits for liquid effluents from facilities that extract and process uranium, radium, and vanadium ore.

RCRA Subtitle C: Regulations for the Management of Mixed Hazardous Waste

Source, byproduct, and special nuclear material are excluded from the definition of solid waste under RCRA. These wastes are regulated by the NRC and DOE. However, if a waste is a mixture of RCRA hazardous waste and source, byproduct, or special nuclear material, RCRA may apply to the non-radioactive component of that waste. The radioactive component is regulated under the Atomic Energy Act. [See the section on the applicability of RCRA for more information on RCRA requirements.]

D.3.3 NRC Program. NRC regulations for radioactive wastes include those found in 10 CFR Parts 20, 61, 30, 40, and 70. They may be applicable to sites licensed by the NRC to possess and use source, byproduct, and special nuclear material, and they may be relevant and appropriate for non-licensed sites.

10 CFR Part 20: Standards for Protection Against Radiation

Applicability

These standards are potentially applicable to CERCLA actions at NRC-licensed facilities. They may also be relevant and appropriate to CERCLA actions at radioactively contaminated sites not licensed by the NRC.

Standards

Permissible dose levels, radioactivity concentration limits for effluents, precautionary procedures, and waste disposal requirements for NRC licensees.

- Protection of workers in restricted areas: a variety of radiation exposure limits, including dose limit of 1.25 rem/quarter to whole body. (10 CFR Part 20 Subparts C and G)

- Protection of the public: Radiation exposure is limited to

  - -- whole body dose of 0.1 rem/year
  - -- 0.002 rem/hour
  - -- the dose limits in 40 CFR Part 190 for environmental radiation standards. (10 CFR 20.1301)

- Discharge to air and water: Discharges must meet radionuclide-specific concentration limits in 10 CFR Part 20, Appendix B.

- Waste treatment and disposal: Include concentration limits for disposal into sewers and for incineration. (10 CFR Part 20, Appendix B)

10 CFR Part 61: Licensing Requirements for Land Disposal of Radioactive Waste

Applicability

Because these standards regulate new NRC-licensed land disposal facilities, they are not applicable to previously closed low-level waste disposal sites, including existing CERCLA sites containing low-level radioactive waste. The performance objectives and technical requirements of 10 CFR Part 61 may be relevant and appropriate to existing CERCLA sites containing low-level radioactive waste, if the waste will be left on site permanently. However, radioactive wastes at CERCLA sites often fall outside the definition of wastes covered by Part 61, particularly when naturally occurring and accelerator-produced radioactive material (NARM) is involved.

10 CFR Parts 30, 40, and 70: Licensing Requirements for Possession and Use of Byproduct, Source, and Special Nuclear Material

Applicability

In 10 CFR Parts 30, 40, and 70, licensing requirements are described for the possession and use of byproduct, source, and special nuclear material, respectively. These parts may be applicable to CERCLA actions at sites licensed under the respective parts. They may be relevant and appropriate for other, non-licensed sites that contain radioactive contamination.

Highlight D-8:
NRC Requirements at CERCLA Mining Sites: Example Sites

The *United Nuclear, NM* site is an inactive state-licensed uranium mill facility. Off-site migration of radionuclides and chemical constituents from uranium milling byproduct materials into the groundwater is a principal threat at the site. Some of the primary contaminants of concern are radioactive substances including radium-226/228 and gross alpha. The NRC has adopted the standards at 40 CFR Part 192 Subpart D, which set groundwater limits for combined radium-226 and radium-228 and for gross alpha (excluding radon and uranium), into its regulations at 10 CFR Part 40, Appendix A. Because the site is licensed by the NRC, 10 CFR Part 40 requirements are applicable.

The *Homestake Mining Company* site in New Mexico, which consists of a uranium processing mill and two tailings embankments, was found to have elevated radon levels. In New Mexico, the NRC has jurisdiction over uranium mills, and the NRC issued the Homestake Mining Company a radioactive materials license. Two NRC regulations were identified as ARARs for this site: 10 CFR Part 20 and 10 CFR Part 40 Appendix A. The 10 CFR Part 20 requirements, which are standards for protection against radiation, are considered relevant and appropriate. The 10 CFR Part 40 Appendix A requirements are applicable for this site, because they apply to mill closure and address the cleanup and removal of Ra-226 in soil. **(Note: At this site, no action was taken, because the radon was determined to be a result of natural soil concentrations.)**

Highlight D-9:
DOE Requirements at CERCLA Mining Sites: Example Site

The *Monticello Vicinity Properties* site in Utah, which contains thorium, radium, and radon contamination in uranium mill tailings, is a designated site under DOE's Surplus Facilities Management Program. It is also listed on the NPL and therefore must comply with CERCLA requirements. Because the properties are a DOE site, remedial actions must also comply with the DOE internal orders on radioactive wastes. DOE hot spot criteria from these internal orders were found to be applicable for actions at this site.

D.3.4 DOE Program. As explained above, DOE's requirements for radioactive wastes are contained in a series of internal orders that apply only to cleanups at DOE facilities. However, the requirements are potential "To-Be-Considered" information for non-DOE sites. The most important DOE order is DOE 5400.5 "Radiation Protection of the Public and the Environment," which includes standards and requirements to protect the public from risk from radiation, concentration guides for liquids discharged to surface waters, and guidelines for residual radioactive material at certain DOE sites. DOE Order 5400.11 establishes similar requirements for workers.

D.4 CLEAN WATER ACT

D.4.1 Regulatory Program. The Clean Water Act (CWA) regulates the discharge of any pollutant or combination of pollutants to waters of the U.S. from any point source. The substantive and/or administrative elements of CWA requirements are potential ARARs for CERCLA mining response (and other) actions that include an action resulting in:

- Direct discharges to surface water or oceans;
- Indirect discharges to a publicly owned treatment works (POTW);
- Storm water discharges; or
- Discharge of dredged or fill material into the waters of the U.S. (including wetlands).

These regulated discharges commonly occur at Superfund mining sites in the form of channeled runoff, treated wastewater discharge, and storm water runoff. In addition, many Superfund mining sites have uncontrolled discharges that are the source of much contamination and contaminant migration. The CWA-based standards also may be appropriate for discharges that are causing the contamination (e.g., mine drainage).

Various types of ambient and technology-based standards have been promulgated under the CWA to control discharges of pollutants to waters of the U.S. These include:

- **Technology-based Standards.** All direct dischargers must meet these standards. Requirements include, for conventional pollutants, application of the best conventional pollutant control technology (BCT), and for toxic and nonconventional pollutants, the best available technology economically achievable (BAT). (See Highlight D-10 for a description of the three categories of pollutants.) Technology-based standards are determined through the use of effluent limitation guidelines. There are no effluent guidelines for CERCLA sites. Therefore, technology-based treatment standards are determined on a site-specific basis using best professional judgment. Effluent discharge limits are then derived from the levels of performance of a treatment technology applied to a wastewater discharge.

Highlight D-10:
Categories of CWA Pollutants

The following are descriptions of the regulatory classes of pollutants regulated under the CWA:

- **Toxic pollutants.** The 126 individual priority toxic pollutants contained in 65 toxic compounds or classes of compounds (including organic pollutants and metals) adopted by EPA pursuant to the CWA section 307(a)(1);

- **Conventional pollutants.** The pollutants classified as biochemical oxygen demanding (BOD), total suspended solids (TSS), fecal coliform, oil and grease, and pH pursuant to the CWA section 304(a)(4); and

- **Nonconventional pollutants.** Any pollutant not identified as either conventional or toxic in accordance with 40 CFR 122.21(m)(2).

- **Federal Water Quality Criteria (FWQC).** FWQC are *nonenforceable* guidance established by EPA for evaluating toxic effects on human health and aquatic organisms. FWQC are used or considered by states in setting their water quality standards (WQS). In addition, they can be used as a baseline indicator of environmental risk at Superfund sites.

- **State Water Quality Standards (WQS).** Under CWA section 303, states must develop water quality standards. State WQSs may be numeric or narrative. They consist of designated uses (e.g., fishing, swimming, drinking water) for waters and criteria for pollutants set at levels that are protective of those uses.

D.4.2 Direct Discharge Requirements. Activities at mine sites that may trigger *direct* discharge requirements include:

- Discharge of mine water to a stream;

- Discharge of waters to a wetland or from a wetland to a river;

- Channeling site runoff directly to a surface water body via a ditch, culvert, storm sewer, or other means;

- On-site waste treatment in which wastewater is discharged directly into a surface water body in the area of contamination or in very close proximity to this area via pipe, ditch, conduit, or other means of "discrete conveyance;" and

- Off-site waste treatment in which wastes from the site are piped or otherwise discharged through a point source to an off-site surface water.

On-site direct discharges must meet technology-based standards (for conventional pollutants) and result in ambient standards that do not exceed state water quality standards or FWQC (for priority pollutants).[7] Off-site direct discharges must meet these substantive requirements as well as administrative requirements such as obtaining a permit from the state authority, reporting, and public participation requirements. (See Highlight D-11 for more detail on administrative requirements associated with NPDES program.)

The substantive requirements of the NPDES program include the federal water quality criteria and state water quality standards introduced above. State water quality standards are generally the applicable cleanup standards for surface water and discharges into surface waters. Because FWQC are not enforceable, EPA has determined in previous guidance that they are never applicable for CERCLA actions.[8] However, these criteria may be relevant and appropriate for Superfund actions involving direct discharges to surface water. Under CERCLA section 121, site managers must determine if a FWQC is relevant and appropriate "under the circumstances of the release or threatened release" based on:

- The state-designated or potential use of the water;
- The environmental media affected;
- The purpose of the criteria; and
- The latest available information.

[7] For CWA permitting purposes, "on-site" means the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action.

[8] *CERCLA Compliance With Other Laws Manual, Part I*, Draft, August 8, 1988, OSWER Directive 9234.1-01.

Highlight D-11:
Administrative Requirements of the NPDES Program

- **Certification.** CWA section 401 requires that any applicant for a federal license or permit to conduct an operation that may result in any discharge to navigable waters shall provide to the licensing/permitting agency a certification from the state that the discharge will comply with applicable provisions of CWA sections 301, 302, 303, 306, and 307.

- **Permit Application Requirements.** A discharge from a CERCLA site is considered a "new discharge" for regulatory purposes under the NPDES program. NPDES regulations (40 CFR 122.29) require that applications for permits for new discharges be made 180 days before discharges actually begin. The information required in a permit application will be collected during the RI/FS. States with NPDES authority may have slightly different permit application requirements for new discharges. The NPDES regulations require that pollution control equipment must be installed before the new discharge begins, and compliance must be achieved within the shortest feasible time, not to exceed 90 days. The substantive requirements of a permit must be achieved by CERCLA action even though CERCLA actions are not subject to permitting requirements.

- **Reporting Requirements.** The NPDES permit program requires dischargers to maintain records and to report periodically on the amount and nature of pollutants in the wastewaters discharged (40 CFR 122.44 and 122.48). Reports that are typically required include emergency reports (required in cases of noncompliance that are serious in nature) and discharge monitoring reports (routine monitoring reports).

- **Public Participation.** CERCLA site managers should also be aware that NPDES discharge limitations and requirements developed for a CERCLA site are subject to public participation requirements in 40 CFR 124.10, including public notice and public comment.

FWQC for protection of *human health* identify protective levels for two routes of exposure: (1) ingestion of contaminated drinking water and contaminated fish; and (2) ingestion of contaminated fish alone. For example, an FWQC reflecting drinking the water could be relevant and appropriate for waters designated as a public water supply; the criterion that reflects fish consumption and drinking the water should generally be used as the relevant and appropriate standard if fishing is also included in the state's designated use. If the state has designated a water body for recreation, a FWQC reflecting fish consumption alone may be relevant and appropriate if fishing is included in that designation. Generally, FWQC are not relevant and appropriate for other uses, such as industrial or agricultural use, because exposures assumed when setting FWQC are not likely to occur. FWQC may be relevant and appropriate for selecting cleanup levels for groundwater, if they are adjusted to reflect only exposure from drinking the water.

Although FWQC may often be ARARs, if a state has promulgated a WQS for the pollutants and water body at the site, the state standard would generally be the ARAR rather than the FWQC, because the state standards essentially represent a site-specific adaptation of the federal criteria.

If a promulgated MCL for a pollutant exists (see the Safe Drinking Water Act section of this appendix) and the water is a designated or potential drinking water supply, the MCL may supersede the FWQC as the cleanup standard for that pollutant. state drinking water standards also may be potential ARARs in this situation.

FWQC may also be used as the baseline against which to assess whether site conditions pose an environmental risk. The criteria for the protection of aquatic life can be compared to the ambient concentrations of a chemical as one measure of whether it is necessary to take actions to reduce contaminant levels. These "exceedances" of FWQC, however, may not fully reflect environmental risks, and should be used only after consultation with environmental risk experts.

Antidegradation Policy (40 CFR 131.12)

State antidegradation requirements vary widely in their scope and drafting. However, as a general rule, they are anti-pollution requirements (not cleanup requirements) designed to prevent further degradation of the surface water or groundwater. Antidegradation requirements typically accomplish their purpose in one of two ways: (1) by prohibiting or limiting discharges that potentially degrade the surface water or groundwater (typically action-specific requirements); or (2) by requiring maintenance of the surface-water or groundwater quality consistent with current uses.

Under the Clean Water Act, every state is required to classify all of the waters within its boundaries according to their intended use. As required by EPA regulation, all states have established *surface-water* antidegradation regulations. These requirements may be potential ARARs for CERCLA remediations involving discharges to surface water. Although not specifically required by EPA, the majority of states have also established some form of *groundwater* antidegradation provisions. These states may have enacted specific groundwater antidegradation statutes, or they may include groundwater protection provisions within general environmental statutes. These state provisions for groundwater may constitute potential ARARs for CERCLA remediations that have an impact upon the groundwater (e.g., groundwater reinjection or soil flushing).

State antidegradation requirements are often expressed as general goals. These requirements may be potential ARARs if they are: (1) directive in nature and intent; and (2) established through a promulgated statute or regulation that is legally enforceable. At a Superfund site, antidegradation requirements are generally action-specific requirements that may apply during the course of and at the completion of the Agency response action. They apply prospectively, and generally obligate the Agency only to prevent **further** degradation of the water during and at completion of the response action (not prior to it). Although anti-degradation requirements are not cleanup laws, in some limited cases they may, as relevant and appropriate requirements, be appropriate for establishing a cleanup level for past contamination.

Administrative Requirements

Certification (CWA section 401)

- Any applicant for a federal license or permit to conduct an operation that may result in any discharge to navigable waters shall provide to the licensing/permitting agency a certification from the state that the discharge will comply with applicable provisions of CWA sections 301, 302, 303, 306, and 307.

Permit Application Requirements (40 CFR 122.21 and 122.29)

A discharge from a CERCLA site is considered a "new discharge" under the NPDES program. Although CERCLA actions are not subject to the permitting requirements the substantive requirements of the permit must be achieved as discussed in Highlight D-12.

- Applications for permits for new discharges must be made at least 180 days before discharges actually begin.

- The information required in a permit application will be collected during the RI/FS.

- Pollution control equipment must be installed before the new discharge begins, and compliance must be achieved within the shortest feasible time, not to exceed 90 days.

(States with NPDES authority may have slightly different permit application requirements.)

Highlight D-12:
CWA Direct Discharge Requirements as ARARs: Example Site

At the *California Gulch* site in Colorado, tunnel discharge has resulted in cadmium, copper, lead, and zinc contamination in surface water. The selected remedy for the site will include discharge of treated effluent into surface water of the California Gulch. Aquatic life in both the California Gulch and the Arkansas River are potential receptors of contamination. The affected waters are designated for "cold water aquatic life," secondary contact recreation, and agriculture. Based on evaluation of the existing and potential uses of the waters, the environmental media affected, the purposes of the criteria, and the latest information available, EPA determined that water quality criteria for acute and chronic toxicity to freshwater aquatic life are relevant and appropriate. Certain state of Colorado water quality standards are also ARARs for the discharge of treated effluent. Finally, Colorado's antidegradation standard, which requires that existing uses be maintained and that no further water quality degradation occur that would interfere with or become injurious to existing uses is applicable.

One component of the selected remedy for the California Gulch site involves the construction of an interim treatment facility on site. Because the facility will be located on site, no permit is required. However, the facility must comply with appropriate substantive direct discharge requirements.

Reporting Requirements (40 CFR Part 122)

- Dischargers must maintain records and report periodically on the amount and nature of pollutants in the wastewaters discharged. Generally, Superfund would meet these requirements through monitoring that is conducted based on the selected remedy.

Public Participation (40 CFR 124.10)

- NPDES discharge limitations and requirements developed for a CERCLA site are subject to public participation requirements, including public notice and public comment.

D.4.3 Indirect Discharge Requirements.

Applicability

Indirect discharge means the discharge of a waste to a publicly owned treatment works (POTW), which in turn generally discharges the treated wastewater to receiving waters. Requirements for indirect discharges include pretreatment standards and the use of control measures such as permits or orders.

Indirect discharges are always considered an off-site activity. Therefore, CERCLA actions always must comply with both the substantive and administrative requirements for indirect discharges. Pretreatment standards for indirect discharges will generally be applicable for CERCLA activities. However, where pretreatment standards specify quantities or concentrations of pollutants or pollutant properties that may be discharged to a POTW by users in specific industrial categories, these standards are not applicable, because CERCLA actions do not fit into any of these categories. However, these standards may be relevant and appropriate if the consideration underlying the standard (e.g., type and concentration of pollutant, type of industrial process that produced the waste) are sufficiently similar to the conditions found at the site.

Standards

Pretreatment Standards (CWA section 307(b), 40 CFR Part 403)

- Pollutants introduced into POTWs by a non-domestic source shall not cause pass through (i.e., a discharge that exits the POTW in concentrations or quantities that cause a violation of the POTW's NPDES permit) or interference (i.e., a discharge that inhibits or disrupts a POTW, its treatment processes or operations, or its sludge processes, thereby causing either a violation of the POTW's NPDES permit or prevention of sewage sludge use or disposal in compliance with various statutory provisions and regulations).

- Pollutants may not be introduced to a POTW if they:

  -- Create a fire or explosion hazard in the sewers or treatment works;
  -- Will cause corrosive structural damage to the POTW (pollutants with a pH lower than 5.0);
  -- Obstruct flow in the sewer system resulting in interference;
  -- Are discharged at a flow rate and/or concentration that will result in interference;
  -- Increase the temperature of wastewater entering the treatment plant so as to inhibit biological activity resulting in interference (in no case shall the temperature of the POTW increase to above 104°F (40°C));
  -- Include petroleum oil, certain non-biodegradable oils, or products of mineral oil origin in amounts that cause interference or pass through;
  -- Result in toxic gases, vapors, or fumes within the POTW that may cause acute worker health and safety problems; or
  -- Are hauled to any location at the POTW except designated discharge points.

- Some POTWs must develop and enforce specific effluent limitations to implement the prohibitions specified above.

- POTWs may enforce local prohibitions on wastes with objectionable color, noxious or malodorous liquids, wastes that may volatize in the POTW, radioactive wastes, and other types of wastes that are incompatible with POTW operations.

The national pretreatment standards also specify quantities or concentrations of pollutants or pollutant properties that may be discharged to a POTW by existing or new industrial users in specific industrial subcategories. These categorical standards are not applicable requirements because CERCLA cleanup actions do not presently fit within any industrial category for which such standards exist. However, they may be relevant and appropriate if the considerations underlying the categorical standard (e.g., type and concentration of pollutant, type of industrial process that produced the waste) are sufficiently similar to the conditions of the hazardous substance found at the site.

POTW Control Mechanisms (CWA section 403.8(f)(1)(iii))

Control mechanisms (e.g., permits or orders) must be used to regulate indirect discharges to POTWs. POTWs have the authority to limit or reject wastewater discharges and to require dischargers to comply with control mechanisms such as permits or orders. These permits or orders contain applicable pretreatment standards including local discharge prohibitions and numerical discharge limits. In addition to incorporating pretreatment limitations and requirements, the control mechanisms may also include: (1) monitoring and reporting requirements to ensure continued compliance with applicable pretreatment standards; (2) spill prevention programs to prevent the accidental discharge of pollutants to POTWs (e.g., spill notification requirements); and (3) other requirements.

D.4.4 Storm Water Requirements. EPA promulgated the first of several regulations that establishes a permitting process and discharge regulations for storm water on November 16, 1990. Storm water is defined under these regulations as "storm water runoff, snow melt runoff, and surface runoff and drainage" (40 CFR 122.26(b)(13)). Under these regulations, the following discharges are subject to storm water requirements:

- Discharges associated with an industrial activity (further outlined at 40 CFR 122.26(b)(14)).
- Discharges from municipal separate storm sewer systems serving more than 100,000 people.
- Case-by-case designations: permit may be required if the Director determines that a discharge contributes to a violation of a water quality standard or is a significant contributor of pollutants to the waters of the U.S.

Under storm water requirements, dischargers must obtain a permit, under which the amount of pollutants in storm water discharged into surface waters (or conveyances leading to surface waters) will be regulated. "Storm water discharge[s] associated with industrial activity" (which are the regulated storm water discharges most likely to be found at a Superfund mining site) are discharges from any conveyance used for collecting and conveying storm water and directly related to manufacturing, processing or raw materials storage areas at an industrial plant. Permits for these discharges must cover areas:

- Directly related to an industrial process, (e.g., industrial plant yards, immediate access roads and rail lines, material handling sites, refuse sites, sites used for the application or disposal of process wastewaters, sites used for the storage and maintenance of material handling equipment, known sites that are presently or have been used in the past for residual treatment, storage, or disposal, shipping and receiving areas, manufacturing buildings, storage areas (including tank farms) for raw materials and intermediate and finished products).
- Where industrial activity has taken place in the past and significant materials remain and are exposed to storm water.
- That are facilities related to the mineral industry, including certain active and inactive mining operations.
- That are RCRA Subtitle C facilities that contribute to storm water discharges.

A permit application is required for *mining activities* when discharges of storm water runoff from mining operations come into contact with any overburden, raw material, intermediate product, finished product, byproduct, or waste product located on the site. Determination of whether a mining operation's runoff is contaminated will be made in the context of the permit issuance proceedings. If the determination is made that the runoff is not contaminated, a permit is not required. Mining areas that are no longer being mined but that have an identifiable owner/operator are included.

NPDES permits are *not* required for discharges of storm water runoff from mining operations that are composed entirely of flows from conveyances used for collecting and conveying precipitation runoff that are not contaminated by contact with any overburden, raw material, intermediate product, finished product, byproduct, or waste product located on the site of such operations.

Permit applications must be submitted within one year from the date of publication of this notice (i.e., November 16, 1991) but this date was extended for several types of activities in subsequent rulemakings. Facilities proposing a *new* discharge of storm water associated with industrial activity shall submit an application 180 days before that facility commences the industrial activity. Permits will require compliance with sections 301 and 402 of the CWA (requiring control of the discharge of pollutants that utilize the Best Available Technology (BAT) and the Best Conventional Pollutant Control Technology (BCT) and where necessary, water quality-based controls). General permits will require development of storm water control plans and practices (the conditions for these permits have not yet been finalized). In addition, permittees will have to meet effluent guidelines. EPA has established effluent guideline limitations for storm water discharges for nine subcategories of industrial dischargers, including cement manufacturing, feedlots, fertilizer manufacturing, petroleum refining, phosphate manufacturing, steam electric, coal mining, ore mining and dressing, and asphalt.

In an April 2, 1992 rule, EPA published general permit requirements for reporting for discharges associated with an industrial activity and minimum monitoring requirements. This rule also presented a strategy for issuing stormwater permits. Among the monitoring requirements for covered activities are the following:

- Monitoring frequency will be set on a case-by-case basis, but no less than at least once each year.
- Inactive mining operations can have inspections once every three years when annual inspections are impracticable.
- Monitoring results will be repeated at least once each year.

Storm water requirements will generally not be applicable at Superfund actions, because the requirements are intended to regulate active industrial activities. However, the requirements could be relevant and appropriate at mining sites where storm water runoff is contaminated.

D.4.5 Dredge and Fill Requirements. Dredge and fill activities at CERCLA sites may include dredging of a contaminated lake or river, disposal of contaminated soil or waste in surface water, capping of the site, construction of berms and levees to contain wastes, stream channelization, excavation to contain effluent, and dewatering of the site. Specific requirements, established under the CWA as well as other statutes, regulate the discharge of dredged or fill material to waters of the U.S.

Dredge-and-fill activities are regulated under the following authorities:

- **Section 10 of the Rivers and Harbors Act** prohibits the unauthorized obstruction or alteration of any navigable water of the United States.

- **Section 404 of the Clean Water Act** regulates the discharge of dredged or fill material to waters of the United States. It states that no discharge of dredged or fill material shall be permitted if there is a practicable alternative to the proposed discharge that would have less adverse impact on the aquatic ecosystem, as long as the alternative does not have other significant adverse environmental effects. "Practicable" is defined by the regulations to mean available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes.

- **Section 103 of the Marine Protection Research and Sanctuaries Act** regulates ocean discharges of materials dredged from waters of the United States.

- **40 CFR Part 6, Appendix A** contains EPA's regulations for implementing Executive Order 11990, Protection of Wetlands, and Executive Order 11988, Floodplain Management (see the section on these Executive Orders in this appendix), which require federal agencies to avoid, to the extent possible, long- and short-term adverse impacts associated with he destruction or modification of wetlands, to avoid direct or indirect support of new construction in wetlands where there are practicable alternatives, and to minimize potential harm to wetlands when there are no practicable alternatives. The proposed plan and selected remedial action should be evaluated in light of these requirements and the alternative modified, if necessary, to avoid or minimize adverse impacts.

The Army Corps of Engineers evaluates applications for permits for activities regulated under section 10 of the Rivers and Harbors Act and section 404 of the CWA. Although section 404 permits are not required for dredge and fill activities conducted entirely on site, the Corps' expertise in assessing the public interest factors for dredge and fill operations can contribute to the overall quality of the response action.

Section 404 applies to the discharger of dredged and fill materials and addresses the impacts caused by such discharges. In some CERCLA response actions, the wetland will already be severely degraded by virtue of prior discharges of waste. Part of the CERCLA remedy may be to fill in the wetland, with the intention that the fill would serve an environmental benefit. Where the function of the wetland has already been significantly and irreparably degraded, mitigation would be oriented towards minimizing further adverse environmental impacts, rather than attempting to recreate the wetland's original value on site or off site. That is, there would be no obligation under CWA section 404 for the lead agency to mitigate those impacts that preceded the remedial fill operation. Although section 404 is not applicable in such cases, mitigation, including wetland restoration and creation, may be appropriate in some circumstances to protect the environmental value of the site. Other provisions, such as 40 CFR 6.302, may require such mitigation (see the section on E.O. 11990, Protection of Wetlands in this appendix for more information on the mitigation of adverse effects on wetlands).

D.4.6 Implementation of CWA Requirements at Superfund Mining Sites. Certain conditions commonly found at mining sites may complicate attempts to comply with CWA requirements. Mine sites often have large areas and many sources from which large volumes of waste flow. Because of these conditions, it may be difficult to achieve water quality criteria or standards. In some cases, it may be necessary to construct an on-site treatment facility.

Existing sediment contamination may lead to continued exceedances even after discharges comply and/or streams are diverted or channeled. Likewise, storm water runoff from wide-spread contamination sources may produce contaminant loading. Other sources may also cause problems and may require multi-program strategy. Site managers should coordinate activities regulated by the CWA with the appropriate state agency, particularly if the state has an authorized NPDES program.

D.5 *SAFE DRINKING WATER ACT*

D.5.1 Regulatory Program. The Safe Drinking Water Act (SDWA) establishes regulations to protect human health from contaminants in current and potential sources of drinking water. SDWA requirements are potential ARARs for CERCLA sites that contain contaminated drinking water or where remedial actions will involve discharges to drinking water. In addition, sites where underground injection will be part of the remedial action may be subject to SDWA requirements.

Requirements from the following EPA programs established under the SDWA are potential ARARs for CERCLA actions:

- **Drinking Water Standards.** EPA has developed two sets of drinking water standards that may be ARARs for CERCLA actions:

  -- **Primary drinking water regulations.** These standards consist of contaminant-specific levels known as Maximum Contaminant Levels (MCLs). They are based on Maximum Contaminant Level Goals (MCLGs), which are purely health-based goals.

  -- **Secondary drinking water regulations.** These standards consist of Secondary MCLs (SMCLs) for specific contaminants or water characteristics that may affect the aesthetic qualities (e.g., odor, taste) of drinking water.

  States may also establish drinking water standards. Where drinking water standards cannot be attained, provisions exist for application for variances and exemptions from compliance with primary MCLs.

- **Underground Injection Control (UIC) Program.** Requirements under this program regulate the injection of hazardous waste and other wastewaters into wells.

- **Sole-Source Aquifer and Wellhead Protection Programs.** These programs are designed to protect these vital aspects of the nation's groundwater.

D.5.2 Drinking Water Standards.

Applicability

MCLs set under the primary drinking water regulations will be applicable where certain contaminants are found in drinking water that is directly provided to 25 or more people or supplied to 15 or more service connections. If MCLs are applicable, they must be complied with at the tap. MCLs are relevant and appropriate as cleanup standards where either surface water or groundwater is or may be used for drinking water. Where multiple contaminants or multiple pathways of exposure present extraordinary risks, a standard more stringent than an MCL may be needed (to reflect the additivity of risks). Site managers should make site-specific determinations in setting a level more stringent than the MCL.[9]

SMCLs are nonenforceable limits and therefore generally cannot be applicable to CERCLA actions. However, they may be relevant and appropriate, or, where a state has adopted SMCLs as additional drinking water standards, they may be applicable.

Primary Drinking Water Regulations (40 CFR Part 141)

MCLs have been promulgated for the following contaminants commonly found at mining sites. They are:

Contaminant	MCL (mg/l)
Arsenic	0.05
Barium	1
Cadmium	0.010
Chromium	0.05
Flouride	4
Lead	0.05
Mercury	0.002
Nitrate (as N)	10
Selenium	0.01

For MCLs for radionuclides, see the Radioactive Wastes section of this document.

[9] In the past, EPA's policy was that, in cases involving multiple contaminants or pathways where the risk exceeded 10^{-4}, MCLGs were to be considered when determining acceptable exposures. This policy was changed, however, by the NCP (55 FR 8750, March 8, 1990). Under the revised NCP, where an MCLG establishes a contaminant level above zero, that MCLG is a potential relevant and appropriate requirement, with determinations to be made on a site-specific basis as to the relevance and appropriateness of meeting that level under the circumstances of the release. Where an MCLG is equal to zero level of contaminants (as for carcinogens), that MCLG is not "appropriate" for the cleanup of ground or surface water at CERCLA sites. In such cases, the corresponding MCL will be considered as a potential relevant and appropriate requirement, and attained where determined to be relevant and appropriate under the circumstances of the release. In cases involving multiple contaminants or pathways where attainment of chemical-specific ARARs will result in cumulative risk in excess of 10^{-4}, criteria in NCP §300.430(e)(2)(I)(A) (55 FR 8848) may also be considered when determining the cleanup level to be attained.

Highlight D-13:
SDWA as ARARs: Example Site

California Gulch, CO

Surface water and groundwater at this site, which are contaminated with cadmium, copper, lead, and zinc, do not meet the SDWA definition of public water supply, but they connect in the lower California Gulch shallow alluvial system, which is an existing or potential drinking water source. Therefore, SDWA drinking water standards are relevant and appropriate for this site.

EPA anticipates that the selected remedy will not achieve a degree of cleanup in lower California Gulch surface water that attains primary and secondary MCLs. Numerous sources contribute to metals loadings in lower California Gulch, including mine wastes, tailings, and slag in the California Gulch drainage basin and tributaries. The tunnel plugging and interim treatment facility components of the selected remedy will achieve substantial reductions in metals loadings. In future operable units, it will be necessary to develop and evaluate additional source control measures to attain or exceed drinking water ARARs for specific metals.

Secondary Drinking Water Regulations (40 CFR 143)

SMCLs have been promulgated for the following contaminants commonly found at mining sites. They are:

Contaminant	Level
Aluminum	0.05 to 0.2 mg/1
Chloride	250 mg/1
Color	15 color units
Copper	1.0 mg/1
Corrosivity	Non-corrosive
Fluoride	2.0 mg/1
Foaming Agents	0.5 mg/1
Iron	0.3 mg/1
Manganese	0.05 mg/1
Odor	3 threshold odor #
pH	6.5-8.5
Silver	0.1 mg/1
Sulfate	250 mg/1
Total dissolved solids	500 mg/1
Zinc	5 mg/1

D.5.3 Underground Injection Control Program (40 CFR Part 144).

Applicability

In 40 CFR Part 144, five classifications of underground injection wells are established:

- **Class I:** wells that inject RCRA hazardous or other industrial or municipal waste beneath the lowermost formation containing, within 1/4-mile of the well bore, an underground drinking water source. An underground source of drinking water is defined as any aquifer or its portion that supplies a public water system or contains fewer than 10,000 mg/l total dissolved solids.

- **Class II:** injection wells associated with oil and natural gas production, recovery, and storage.

- **Class III:** wells that inject fluids for use in extraction of minerals.

- **Class IV:** wells used to inject RCRA hazardous waste into or above a formation that within 1/4-mile of the well, contains an underground drinking source.

- **Class V:** wells not considered to be Class I, II, III, or IV.

Requirements for Class I, IV, and V wells are most likely to be ARARs for CERCLA actions when wastes are disposed of into one of these units. The injection of wastes into on-site wells must meet the substantive requirements of this part; injections into off-site wells must meet both substantive and administrative requirements.

Certain UIC program standards require compliance with the LDRs before injection can occur. Mining wastes that are excluded from Subtitle C regulation by the Bevill amendment (see the RCRA section of this appendix) need not comply with these requirements. Mineral processing wastes that have been removed from the Bevill exclusion are also not required to meet the LDRs before injection, *at this time*. However, once the Agency has set LDR treatment standards for those wastes now subject to Subtitle C, compliance with the LDRs will be required.

Substantive Requirements

- No owner or operator may construct, operate, or maintain an injection well in a manner that results in the contamination of an underground source of drinking water at levels that violate MCLs or otherwise adversely affect the health of persons.

- Under the RCRA land disposal restrictions, before RCRA hazardous waste can be disposed of in a Class I well or contaminated groundwater can be reinjected into a Class IV well, the wastes or the groundwater must attain any promulgated treatment levels for each constituent disposed in the injection well, or obtain a variance.

- Class I wells must obtain a RCRA permit-by-rule as a condition for injecting hazardous waste. The owner or operator must comply with RCRA corrective action for releases from solid waste management units (40 CFR 264.101).

- Owners and operators of underground injection wells must prepare and submit a plugging and abandonment plan.

- Owners and operators of Class I wells are subject to the following additional requirements:

  -- Construction requirements;
  -- Operating requirements;
  -- Monitoring requirements.

Administrative Requirements

Off-site CERCLA actions must comply with the following administrative requirements of the UIC Program:

- **Application Requirements.** All existing and new underground injection wells must apply for a permit unless an existing well is authorized by rule for the life of the well;

- **Inventory and Other Information Requirements.** Existing underground injection wells that are authorized by rule are required to submit inventory information to EPA or an approved state. Other information may be required to determine whether injection will endanger an underground source of drinking water; and

- **Reporting Requirements.** Owners and operators of Class I wells are required to maintain records and report quarterly on the characteristics of injection fluids and groundwater monitoring wells and various operating parameters (e.g., pressure, flow rate, etc.).

D.5.4 Sole-Source Aquifer Program. EPA may designate aquifers that are the sole or principal drinking water source for an area and which, if contaminated, would present a significant hazard to human health, as "sole source aquifers." Federal financial assistance may not be committed for any project that may contaminate a sole source aquifer so as to create a significant public health hazard. In general, CERCLA activities will not increase preexisting contamination of sole source aquifers. Therefore, it is unlikely that CERCLA actions would be subject to restrictions on federal financial assistance. However, site managers should review potential problems associated with sole source aquifers as part of the RI/FS.

D.5.5 Wellhead Protection Program. States must develop and implement programs to protect wells and recharge areas that supply public drinking water systems from contaminants that flow into the well from the surface and sub-surface. Site managers should identify ARARs under these state wellhead protection programs.

D.5.6 Implementation of the SDWA at Superfund Mining Sites. Certain conditions commonly found at mining sites may complicate attempts to comply with drinking water standards. Mine sites often have large areas and many sources from which large volumes of waste flow. Because of these conditions, it may be difficult to achieve drinking water standards. In these circumstances, close coordination with appropriate regulatory offices is necessary to devise an acceptable strategy. In some cases, an ARAR waiver may be required if it is not practicable to meet MCLs. Other approaches to consider may include well head treatment, alternate water supplies, and institutional controls.

D.6 CLEAN AIR ACT

The Clean Air Act (CAA) places controls on stationary and mobile sources of emissions into the air. CAA requirements, including those promulgated since the passage of the 1990 Clean Air Act Amendments, are potential ARARs for emissions of gas or particulate matter (e.g., dust) from uncontrolled CERCLA hazardous waste sites both that may occur naturally (i.e., without disturbance during remediation) and those that are a result of response activities. Types of activities likely to result in air emissions problems at mining sites include:

- Blowdown from wastes in piles, ponds, or other locations;
- Soil or waste excavation and movement; and
- Activities involving construction and operation of waste management units.

Other types of remedial activities that could result in air emissions are:

- Air stripping (used to volatilize contamination both in groundwater and in soil);
- Thermal destruction (e.g., incineration), which may produce emissions through volatilization of organic contaminants and through volatilization or suspension of particulate matter into the stack gases;
- Handling of contaminated soil, which can result in volatilization of organic contaminants and wind entrainment of particulates;
- Gaseous waste treatment (e.g., flaring used when capping and venting a site, usually abandoned or inactive landfills;
- Biodegradation, especially when aeration of liquids is involved; and
- Demolition projects, which may cause emission of contaminants to the air.

Under the Clean Air Act, EPA has established three types of standards: National Ambient Air Quality Standards (NAAQS), National Emission Standards for Hazardous Air Pollutants (NESHAPs), and New Source Performance Standards (NSPS). These standards are chemical- and/or source-specific. In deciding which standards are applicable or relevant and appropriate for mining sites, site managers should determine:

- If a pollutant regulated by the standards is or will be emitted at the site; and
- If the pollutant is or will be emitted from one of the sources specified by the standards.

D.6.1 National Ambient Air Quality Standards for Criteria Pollutants (40 CFR Part 50).

Applicability

These standards (listed in Highlight D-14) are national limitations on ambient concentrations of carbon monoxide, lead, nitrogen dioxide, particulate matter (PM_{10}), ozone, and sulfur oxides. Although they are not source-specific emissions limitations, they apply only to major sources. The definition of major source depends on whether the source is located in an attainment or non-attainment area (designated in 40 CFR Part 81). In general, emissions from CERCLA activities do not qualify as major. However, even if a site is not a major source, NAAQS may be relevant and appropriate.

Because CERCLA mining sites often contain large volumes of waste, these sites may, when the aggregate of all source emissions at the site is considered, qualify as a major source. A major source is:

- For an **attainment area**: a site that emits 250 tons or more per year of any regulated pollutant, or a site that contains certain specific types of facilities, such as an incinerator or chemical processing plant that emits 100 tons or more per year.

- For a **non-attainment area**: a site that emits 100 tons or more per year of the pollutant for which the area is designated non-attainment.

Each state has the primary responsibility for assuring that NAAQS are attained and maintained. Each state must submit a State Implementation Plan (SIP) to EPA for approval. Once approved, the SIP becomes federally enforceable. Thus, state requirements can become federal requirements through the SIP approval process. Elements of approved SIPs, which can include more stringent state requirements, are potential ARARs for CERCLA sites.

Pre-construction Review

- New and modified stationary sources of air emissions must undergo a pre-construction review to determine whether the construction or modification of any stationary source will interfere with the attainment or maintenance of NAAQS or will fail to meet other new source review requirements, which would result in a denial of a permit to construct.

Prevention of Significant Deterioration (PSD) Requirements

PSD requirements for **attainment areas** apply to new major stationary sources and major modifications in areas designated as being in attainment of the NAAQS for criteria pollutants. They also apply in areas where no data exist and the area is defined as unclassified. Part C of the CAA requires SIPs to contain "adequate provisions" for the prevention of significant deterioration of air quality in an attainment area.

Under the PSD program, a CERCLA site would not be considered a major source unless it was expected to emit 250 tons or more per year of any regulated pollutant (or unless the site contains certain specific types of facilities, such as an incinerator or chemical processing plant, for which the threshold is 100 tons per year.

Highlight D-14:
National Ambient Air Quality Standards (NAAQS)

Criteria Pollutant	Primary Standards	Averaging Time	Secondary Standards
Carbon Monoxide	9 ppm	8-hour[a]	None
	35 ppm	1-hour[a]	
Lead	1.5 μg/m^3	Quarterly average	Same as primary
Nitrogen dioxide	0.053 ppm	Annual (arithmetic mean)	Same as primary
Particulate Matter (PM_{10})	50 μg/m^3	Annual (arithmetic mean[b]	Same as primary
	150 μg/m^3	24-hour[c]	
Ozone	0.12 ppm	1-hour[d]	Same as primary
Sulfur oxides	0.03 ppm	Annual (arithmetic mean)	---
	0.14 ppm	24-hour[a]	---
	---	3-hour[a]	0.5 ppm

[a] Not to be exceeded more than once per year.
[b] The standard is attained where the expected annual arithmetic mean concentration, as determined in accordance with Appendix K (52 FR 24667, July 1, 1987), is less than or equal to 50 μg/m^3.
[c] The standard is attained when the expected number of days per calendar year with a 24-hour average concentration above 150 μg/m^3 is equal to or less than 1.
[d] The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is equal to or less than 1.

Where there is an existing major stationary source, a Superfund site could trigger a modification to that source. A major modification is generally a physical or operational change in a major stationary source that would result in a significant net emissions increase for any regulated pollutant. Specific numerical cutoffs that define significant increases are identified in 40 CFR 52.21(b)(23). A Superfund site would be considered a modification to an existing source only where:

- The site is physically connected to or immediately adjacent to the existing source;
- A responsible party (RP) is conducting the cleanup;
- The RP is also the owner or operator of the existing source; and
- The CERCLA site is somehow associated with the operations of the existing source.

Fugitive emissions are not to be considered in determining whether a source would be a major source, except when such emissions come from source categories listed in 40 CFR 52.21(b)(1)(iii) (see Highlight D-15). Fugitive emissions would not be counted in with CERCLA site emissions unless the site is considered a modification to one of the listed source categories. However, operations resulting in emissions are not considered fugitive and would be subject to the NAAQS standards.

D.6.2 National Emissions Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR Part 61).

Applicability

NESHAPs are emission standards for certain hazardous air pollutants for which no NAAQS exists. They are promulgated for emissions from specific sources. NESHAPs are generally not applicable to CERCLA remedial actions because Superfund sites do not usually contain any of the specific source categories regulated. Furthermore, they are generally not relevant and appropriate, because the standards of control are intended for the specific type of source regulated and not all sources of that pollutant.

In general, only NESHAPs for radionuclides and asbestos are likely to be ARARs for CERCLA sites. NESHAPs for radionuclides, which are discussed in detail in the radioactive wastes section of this appendix, regulate radionuclide air emissions from active underground uranium mines, certain DOE facilities, certain NRC-licensed facilities and non-DOE federal facilities, and active NRC-licensed uranium mill tailings sites. Most of these NESHAPs will be only relevant and appropriate for CERCLA mining site actions.

Asbestos NESHAPs govern inactive waste disposal sites for asbestos mills and manufacturing and fabricating operations, active waste disposal sites, and disposal of asbestos-containing waste from demolition and renovation operations. Although these requirements are not applicable to CERCLA sites, they may be relevant and appropriate when they are sufficiently similar to the site situation and appropriate to the circumstances of the release.

Under the authority of the 1990 amendments to the Clean Air Act, additional NESHAPs will be promulgated for certain sources not currently regulated. Several of these NESHAPs, when promulgated, may be relevant and appropriate for activities at mining sites. The sources added by the amendments include primary copper smelters, primary lead smelters, zinc smelting, and other facilities that process nonferrous metals. In addition, under the CAA amendments, emissions of greater than 10 tons per year of a pollutant will be subject to NESHAPs. Such quantities could be generated by response activities such as remining at a Superfund mining site.

Standards

Asbestos NESHAPS (40 CFR Part 61 Subpart M).

- 40 CFR 61.145: Standard for Demolition and Renovation: Procedures for Asbestos Emission Control

    -- This section sets requirements for removing friable asbestos during building demolition, including wetting, exhaust systems, and removal procedures.

- 40 CFR 61.150: Standard for Waste Disposal for Manufacturing, Fabricating, Demolition, Renovation, and Spraying Operations

    -- Owners/operators must deposit all asbestos-containing waste material at waste disposal sites in accordance with 40 CFR 61.154; and

    -- Discharge no visible emissions to the outside air during the collection, processing (including incineration), packaging, or transporting of any asbestos-containing waste material generated by the source, or use one of the emission control and waste treatment methods specified in this section.

Highlight D-15:
Source Categories Listed in 40 CFR 52.21(b)(1)(iii)

- Coal cleaning plants (with thermal dryers)
- Kraft pulp mills
- Portland cement plants
- Primary zinc smelters
- Iron and steel mills
- Primary aluminum ore reduction plants
- Primary copper smelters
- Municipal incinerators capable of charging more than 250 tons of refuse per day
- Hydrofluoric, sulfuric, or nitric acid plants
- Petroleum refineries
- Lime plants
- Phosphate rock processing plants
- Coke oven batteries
- Sulfur recovery plants
- Carbon black plants (furnace process)
- Primary lead smelters
- Fuel conversion plants
- Sintering plants
- Chemical processing plants
- Secondary metal production plants
- Fossil-fuel boilers (or combination thereof) totaling more than 250 million British thermal units per hour heat input
- Petroleum storage and transfer units with a total storage capacity exceeding 300,000 barrels
- Taconite ore processing plants
- Glass fiber processing plants
- Charcoal production plants
- Fossil fuel-fired steam electric plants of more than 250 million British thermal units per hour heat input
- Any other stationary source category which, as of August 7, 1980, was regulated under section 111 or 112 of the Clean Air Act.

- 40 CFR 61.151: Standard for Inactive Waste Disposal Sites for Asbestos Mills and Manufacturing and Fabricating Operations

  -- Owners/operators of inactive waste disposal sites for asbestos mills and manufacturing and fabricating operations must comply with one of the following:

    - Discharge no visible emissions to the outside air from an inactive waste disposal site subject to these requirements;

    - Cover the asbestos-containing waste material with at least 15 cm (6 inches) of compacted nonasbestos-containing material, and grow and maintain a cover of vegetation on the area adequate to prevent exposure of the asbestos-containing material, or in desert areas where vegetation would be difficult to maintain, place at least 8 additional cm (3 inches) of well-graded, nonasbestos crushed rock on top of the final cover instead of vegetation and maintain it to prevent emissions;

    - Cover the asbestos-containing waste material with at least 60 cm (2 feet) of compacted nonasbestos-containing material, and maintain it to prevent exposure of the asbestos-containing waste; or

    - For inactive waste disposal sites for asbestos tailings, apply a resinous or petroleum-based dust suppression agent that effectively binds dust to control surface air emissions, using the agent as recommended by its manufacturer. (Obtain prior written approval of the Administrator to use other equally effective dust suppression agents, excluding any used, spent, or other waste oil).

-- Unless a natural barrier adequately deters access by the general public, install and maintain warning signs and fencing (as directed by 40 CFR 61.151(b)(1) and (2)) or comply with the standards listed above.

-- With EPA approval, an owner/operator may use an alternative control method.

-- Notify the Administrator in writing at least 45 days prior to excavating or otherwise disturbing any asbestos-containing waste material that has been deposited at a waste disposal site under this section.

-- Within 60 days of a site becoming inactive, record a notation on the deed to the facility property and on any other instrument that would normally be examined during a title search.

- 40 CFR 61.154: Standard for Active Waste Disposal Sites

  -- Either there must be no visible emissions to the outside air from any active waste disposal site where asbestos-containing waste material has been deposited; or

  -- At the end of each operating day or at least once every 24-hour period while the site is in continuous operation, the asbestos-containing waste material that has been deposited during the operating day or previous 24-hour period should be covered with at least 15 cm (6 inches) of compacted nonasbestos-containing material or a resinous or petroleum-based dust suppression agent; or

  -- An alternative control method for emissions is used, with prior EPA approval.

  -- Unless a natural barrier adequately deters access by the general public, either warning signs and fencing must be installed and maintained or at least 15 cm (6 inches) of compacted nonasbestos-containing material must cover the asbestos-containing waste material.

  -- Owners or operators of active waste disposal sites must maintain waste shipment records as specified, send a copy of the signed waste shipment record to the waste generator, correct discrepancies to the records as specified, and keep copies of all the records and reports for at least 2 years, to be made available to the Administrator for inspection upon request.

  -- Upon closure of the site, owners or operators must comply with provisions for inactive waste disposal sites and submit records of asbestos quantities and locations to the Administrator.

  -- Owners or operators must notify the Administrator in writing at least 45 days prior to excavating any asbestos-containing waste material that has been deposited and covered at a waste disposal site.

Under RCRA, EPA is also regulating air emissions of some organics from process vents and surface impoundments and tanks in three phases. Phase I, which was promulgated on June 21, 1990 (55 FR 25454), limits organic emissions from (1) process vents associated with distillation, fractionation, thin-film evaporation, solvent extraction, and air or steam stripping operations that manage hazardous wastes with 10 ppm by weight or greater total organics concentration, and (2) leaks from equipment that contains or contacts hazardous waste streams with 10 percent by weight or greater total organics. Phase II, which was proposed July 22, 1992 (56 FR 33490), consists of air standards for organic air emissions from other sources not covered or not adequately controlled by existing standards, specifically from surface impoundments, tanks, containers, and miscellaneous units. Under Phase III, EPA will assess the residual risk from Phases I and II and will, if necessary, develop further regulations or guidance to address the effects of organic air emissions.

D.6.3 New Source Performance Standards (NSPS). These standards cover categories of stationary sources that emit particular pollutants. The purpose of these standards is to ensure that new stationary sources are designed, built, equipped, operated, and maintained to reduce emissions to a minimum. The standards affect all new stationary sources, regardless of whether they are located in an attainment or non-attainment area. Because they are source-specific, the standards are generally not applicable to Superfund remedial actions. An NSPS may be applicable if the facility at the Superfund site is a new source subject to an NSPS (e.g., an incinerator). An NSPS may be relevant and appropriate if the pollutant emitted and the technology employed during the remedial action are sufficiently similar to the pollutant and source category regulated by an NSPS. (As these standards are source-specific, they are located at various points in the regulations, dependent upon the sources. For example, NSPS's addressing coal mining, mineral mining and processing, and ore mining and dressing appear at 40 CFR Part 434, 40 CFR Part 436, and 40 CFR Part 440 respectively).

D.6.4 State Programs. As discussed above, states must adopt a plan to implement, maintain, administer, and enforce NAAQS. These State Implementation Plans (SIPs) must be approved by EPA. States also may be authorized to enforce NSPS and NESHAPs. States have the authority to adopt emissions standards and limitations and control strategies more stringent than federal standards. State standards are potential ARARs for Superfund sites, as are Regional or local air program requirements that are a part of a SIP.

In addition, many states have adopted programs to regulate "toxic air pollutants." Requirements under these programs are likely to be the most significant ARARs for Superfund activities. These programs differ from state to state in terms of the pollutants and sources regulated and the safe levels adopted. Site managers should determine if the state in which the CERCLA site is located has adopted such a program.

A typical state air toxics program will require a source to do the following:

- Identify pollutants of concern by comparing anticipated emissions with the state air toxics list;
- Estimate emissions of toxic air pollutants using procedures by the state;
- Estimate off-site concentrations, normally by air quality modeling procedures approved by EPA or the state;
- Compare off-site concentrations to permissible state levels; and
- Require additional controls (beyond what would otherwise be required) if a new source is likely to exceed the state limits.

D.6.5 Implementation of CAA Requirements. Where NAAQS are applicable, certain pollution controls may be required. At CERCLA sites, these may include vapor recovery on air strippers, controls on emissions of particulates from incinerators, and controls on sources of fugitive particulate emissions. Construction and demolition sites are areas of Superfund sites that are commonly regulated by Clean Air Act requirements.

Highlight D-16:
CAA Requirements as ARARs: Example Site

Anaconda Smelter/Mill Creek, MT

Arsenic, cadmium, and lead contamination in several media in Mill Creek, Montana posed an imminent and substantial danger to human health. The selected remedy for the first operable unit called for relocation of residents and temporary stabilization of the area, including demolition activities. It was determined that remedial actions were subject to NAAQS for total suspended particulates and lead (40 CFR Part 50) and to the Montana Air Quality Bureau's requirements for particulate matter and construction/demolition sites. Under these requirements, all buildings had to be wetted with water inside and outside prior to demolition. A dust-suppressing mist had to be applied at demolition to control airborne particles. In addition, all haul roads and demolition debris had to be watered to prevent excessive dust.

D.7 *SURFACE MINING CONTROL AND RECLAMATION ACT*

D.7.1 Scope. The Surface Mining Control and Reclamation Act of 1977 (SMCRA) governs activities associated with coal exploration and mining. Because the standards promulgated under SMCRA are intended for active coal mines, they will not be *applicable* to actions at Superfund mining sites. However, the standards found in 30 CFR Parts 816 and 817, which govern surface mining activities and underground mining activities, respectively, may be relevant and appropriate at inactive CERCLA mining sites where activities similar to SMCRA-regulated activities occur. This is because SMCRA regulations often address circumstances that are similar and establish performance objectives that are consistent with the objectives of a CERCLA investigation.

D.7.2 Implementation.

Under SMCRA, states may be authorized to implement their own programs for controlling coal mining operations. Regulations passed by an authorized state may be more stringent than federal requirements. States also have the authority to conduct reclamation programs for abandoned coal mines, which may be financed using the Abandoned Mine Land Reclamation Fund (AMLRF), a Fund established by SMCRA. In states where more stringent standards are promulgated, these standards (and not the federal requirements) will be ARARs.

Although EPA, under CERCLA, and the Office of Surface Mining Reclamation and Enforcement (OSMRE) of the Department of the Interior, under SMCRA, *both* have authority to clean up abandoned coal mine sites, it has been EPA's policy until this time not to assert its authority and list coal mine sites on the NPL. EPA's position has been that because the AMLRF was designed specifically to address reclamation and restoration of land and water resources adversely affected by past coal mining activities, it is a more efficient use of resources to allow this Fund to address abandoned coal sites than to clean up these sites under Superfund. Therefore, coal mining sites will seldom, if ever, be addressed by CERCLA cleanup actions, and the SMCRA requirements will not be applicable.

Like Superfund requirements, SMCRA performance standards are often established based on the environmental provisions of other laws. For example, regulations may require compliance with established numerical standards, such as applicable water quality standards. In other cases, the standards may be technology-based or may simply require that activities minimize adverse effects.

SMCRA standards may be relevant and appropriate for CERCLA actions at mining sites if remedial activities include those covered by these standards. SMCRA will generally be considered ARARs for activities that are not regulated under other laws. For example, none of the units regulated under SMCRA is regulated under other environmental laws, nor is revegetation regulated. In some cases, however, CERCLA requirements for achieving a protective remedy may be more stringent than SMCRA standards. For example, revegetation needs at a Superfund mining site may exceed the SMCRA performance standard for revegetation. In such instances, site managers must ensure that the remedy for the site is protective of human health and the environment, even after standards determined to be ARARs are met. A discussion of when each SMCRA requirement in 30 CFR Part 816 may be relevant and appropriate is included in the table below. (The standards of 30 CFR Part 817, which cover underground mines, are similar to those in Part 816.)

Although the above table lists only the SMCRA requirements of 30 CFR Part 816, standards found in Part 817, which govern underground mining activities at coal mines, should also be considered at Superfund mining sites. In most cases, they will not be ARARs, but they may offer standards for activities not regulated elsewhere, such as for tunnel plugging. The standards in Part 817 regulate many of the same activities as Part 816. Additional regulated activities include sealing of underground openings, use of explosives, and disposal of excess spoil and coal mine waste.

Highlight D-17:
SMCRA Requirements as ARARs: 2 Example Sites

At the *Cherokee County* site in Kansas, the selected remedial action includes the removal, consolidation, and on-site placement of surface mine wastes in mine pits, shafts, and subsidences. It also includes diversion and channelization of surface streams with recontouring and vegetation of land surfaces. The site manager determined that the SMCRA standards for backfilling and grading, revegetation, postmining land use, and rehabilitation of sedimentation ponds, diversions, impoundments, and treatment facilities are relevant and appropriate for the site.

At the *California Gulch* site in Colorado, the selected remedial action includes tunnel plugging and water control measures. Although EPA and the state identified no ARARs related to tunnel plugging, they considered 30 CFR Part 817 requirements as guidance to ensure that the tunnel plugging activities were protective. They also considered 30 CFR Part 817 for guidance to see that activities associated with water control measures are protective.

D.8 *FISH AND WILDLIFE COORDINATION ACT*

D.8.1 Prerequisites for Applicability. The Fish and Wildlife Coordination Act is designed to protect fish and wildlife when federal actions result in the control or structural modification of a natural stream or body of water. If remedial actions at a CERCLA site will include control or structural modification of a natural stream or body of water, site managers should consider the Fish and Wildlife Coordination Act as a potential ARAR.

Fish and Wildlife Coordination Act requirements will generally be applicable to remedial actions that include:

- Construction of dams, levees, impoundments;
- Stream relocation;
- Water diversion structures; or
- Discharges of pollutants into a body of water or wetlands.

D.8.2 Standards.

- Federal agencies must take into consideration the effect that water-related projects would have on fish and wildlife and take action to prevent loss or damage to these resources.

- Agencies must consult with the Fish and Wildlife Service or the National Marine Fisheries Service as well as the state Wildlife Resources Agency if alteration occurs as a result of off site actions. Consultation is recommended for on site actions involving alteration.

Circumstances Under Which Some SMCRA Standards May Be Relevant and Appropriate at CERCLA Mining Sites

SMCRA Requirement That May Be Relevant and Appropriate	Summary of SMCRA Requirement	Discussion of When Requirement is Potentially Relevant and Appropriate for CERCLA
Casing and Sealing of Drilled Holes (816.15)	Exposed underground openings no longer needed for monitoring or as water wells, will be capped, sealed, and backfilled. Permanent closure methods will be designed to prevent access to mine workings and to keep acid and other toxic drainage from entering ground/surface waters.	Probably not relevant and appropriate to CERCLA unless attaining remedial action objectives requires sealing of drilled holes or other mine openings. May be relevant and appropriate to CERCLA if containment of mine drainage is required to meet remedial action objectives. These requirements should be considered especially at sites where Acid Mine Drainage is a source of contamination. They may be appropriate, for example, if there is a release or threat of a release of acid that could mobilize a related release of acid-soluble metals that could disrupt the hydrologic balance.
Diversions (816.43)	Diversions shall be designed to minimize adverse impacts to hydrologic balance within permit area. Diversions shall not be used to divert water into underground mines without approval of regulatory authority. Diversions shall: • be stable; • provide protection against flooding; • prevent outside sediment from entering into streamflow; and • comply with all applicable local, State, and Federal regulations. Temporary diversions shall be replaced with permanent diversions. Additional requirements may be required of diversions by a regulatory authority.	When diversions of surface water are used to meet remedial action objectives, the performance standards may be relevant and appropriate. These standards are most likely to be relevant and appropriate at sites where stream and/or runoff channelization is part of the remedy.
Sediment Control Measures (816.45)	Sediment control measures consist of proper mining and reclamation methods and sediment control practices. Sediment control methods include §816.45 (b) (1) - (3): • disturbing the smallest practicable area at any mining operation by backfilling, grading, and revegetation;	May be relevant and appropriate to CERCLA. If remedial action involves sediment control measures, performance standards should be met, except for certain elements of §816.45 (b) (1) - (3) that address active sites (e.g., disturbing smallest practicable area). These standards are most likely

	• stabilizing backfill material to promote a reduction in the rate and volume of runoff; • retaining sediment in disturbed area; • diverting runoff; • reducing overland velocity, run off volume, and trap sediment; and • treating with chemicals. Sediment control measures shall be designed, constructed, and maintained to: • prevent additional sediment from entering the streamflow; • meet more stringent State or Federal effluent limitations; and • minimize erosion.	to be relevant and appropriate for remedial actions involving runoff diversion and/or slope stabilization designed to control sedimentation.
Hydrologic Balance: Siltation Structures (816.46)	Surface drainage from a disturbed area shall be passed through a siltation structure before leaving permit area. Siltation structures shall be maintained until removal is authorized. The land on which a siltation structure was located shall be regraded and revegetated. When sedimentation ponds are used they shall be: • located as near as possible to the disturbed area; • designed to: - provide adequate sediment storage volume; - meet effluent regulations by State and Federal effluent limitation; - contain or treat 10-year, 24-hour precipitation events; and - provide a non-clogging dewatering device adequate to maintain detention time; and • contain spillways.	When siltation structures (e.g., sedimentation ponds) are required as part of the remedial action, these requirements may be relevant and appropriate and performance standards should be met.
Hydrologic Balance: Discharge Structures (816.47)	To reduce erosion, prevent deepening or enlargements of stream channels, and minimize disturbance of hydrologic balance, discharge from sedimentation ponds, coal processing waste dams, embankments, and diversions shall be controlled by: energy dissipators, riprap channels, and other devices.	May be relevant and appropriate to CERCLA when remedial action involves sedimentation ponds; performance standards should be met.
Post-mining rehabilitation of sedimentation ponds, diversions, impoundments, and treatment facilities (816.56)	Before abandoning a permit area or seeking bond release, all temporary structures shall be removed and all permanent sedimentation ponds, diversions, impoundments, and treatment facilities will meet permanent structure requirements. (in §816.49 (b)), which include:	May be relevant and appropriate to CERCLA when remedial action involves sedimentation ponds; performance standards should be met.

	• A permanent impoundment of water may be created, if authorized by a regulatory authority and the following is demonstrated: - size and configuration of such impoundment is adequate for purposes; - quality of water will be suitable for intended use, will meet applicable State and Federal water quality standards, discharges will meet applicable effluent limitations, and will not degrade receiving water below applicable State and Federal water quality standards; - water level will be sufficiently stable and capable of supporting use; - final grading will provide adequate safety and access for water users; - impoundment will not result in diminution of quality and quantity of water used by surrounding landowners for commerce or regulation; and - impoundment is suitable for approved postmining land use.	
Backfilling and grading (816.102)	Disturbed areas shall be backfilled and graded to: • achieve original contour; • eliminate highwalls, spoil piles, and depressions; • achieve a postmining site that prevents slides; • minimize erosion and water pollution; • support approved postmining; • return spoil to mined-out areas; • compact spoil and waste materials outside the mined-area in non-steep slope areas to restore contour; • dispose of coal processing waste and underground development waste in accordance with §§816.81 and 816.83; and • cover exposed coal seams, acid- and toxic-forming materials, and combustible materials, exposed, used, or produced during mining with nontoxic and noncombustible material, or treat these materials to control their impact on surface and groundwater. Cut and fill-terraces may be allowed.	If the objectives of the remedial action involve backfilling and grading, these requirements may be relevant and appropriate to CERCLA, and SMCRA performance standards should be met. These requirements also should be evaluated for remedial actions involving filling in of mined areas, excavation pits, etc.
Backfilling and grading: previously mined areas (816.106)	Remining operations on previously mined areas, containing a preexisting highwall shall comply with §§816.102 through 816.107, except as provided:	When remedial action involves remining, CERCLA should follow performance standards. These are especially likely to be relevant and appropriate where remedial actions will involve on-site place-

	• Requirements of §816.102(a) (1) and (2) requiring the elimination of highwalls do not apply where the volume of spoil is insufficient to completely backfill the reaffected or enlarged highwall. • The highwall shall be eliminated to the maximum extent technically practical, in accordance with the following: - all spoil by remining operation shall be used to backfill area and any reasonably available spoil in immediate vicinity will be included; - backfill shall be graded to a slope which is compatible with approved postmining land use; - any highway remnant must be stable, not posing a hazard to safety; and - if moving spoil, placed on the outslope during previous mining operations, will cause instability to remaining spoil, it will not be disturbed.	ment of surface mine wastes in mine pits, shafts, and subsidences, or where previous openings must be sealed.
Backfilling and grading: steep slopes (816.107)	Surface mining activities on steep slopes will be conducted to meet requirements of §§816.102 - 816.106 and requirements of this section except where mining is conducted on flat or gently rolling terrain with an occasional steep slope through which mining proceeds. The following materials shall not be placed on a downslope: • spoil; • waste material of any type; • debris from clearing and grubbing; and • abandoned or disabled equipment. Land above highwall shall not be disturbed unless regulatory authority finds disturbance will facilitate compliance. Woody materials shall not be buried in the backfilled area, unless the regulatory authority determines otherwise.	When remedial action involves backfilling and grading on steep slopes, performance standards should be met. Remedial actions affected by these requirements may include slope stabilization and other measures to prevent erosion and/or runoff.
Revegetation - general requirements (816.111)	On regraded areas and all other disturbed areas (except water areas and surface area roads), the permittee shall establish a vegetative cover that is: • diverse, effective, and permanent; • comprised of species native to the area or desirable and necessary species; • a cover equal to the natural vegetation of the area; and • capable of stabilizing surface soil from erosion.	Revegetation requirements may be relevant and appropriate to CERCLA when standards do not exist for non-coal mining lands. In some cases, these requirements may not be sufficient to protect human health and the environment at a Superfund site. However, they should be considered for sites that are subject to erosion and soils are contaminated as well as for sites where the

	Reestablished plant species shall be: • compatible with approved postmining use; • have same seasonal characteristics as the area; • capable of self-regeneration; • compatible with plant and animal species of the area; and • meet State and Federal seed and plant regulations. Regulatory authority may grant exceptions. When regulatory authority approves of cropland postmining, the authority may grant exceptions.	remedial action involves stream diversion/channelization or filling of mine shafts.
Timing	Disturbed areas shall be planted during: • first normal period for favorable plant growth after plant-growth medium has been replaced; and • the planting time generally accepted locally for the plant materials selected.	These timing requirements may be relevant and appropriate to CERCLA, if remedial action involves revegetation.
Mulching and other soil stabilizing practices	Suitable mulch and other stabilizing practices will be used on all regraded areas, covered with topsoil. Regulatory authority may waive this requirement if seasonal, soil, or slope factors do not require mulching and soil stabilization to control erosion or maintain an effective cover.	Mulching and other soil stabilizing practices may be relevant and appropriate to CERCLA, if remedial action involves revegetation.
Standards for success	Judged on effectiveness of vegetation for postmining land use, extent of cover vs. natural cover, and implementation of general requirements. Evaluation requires: • Valid sampling approach • Comparison to unmined lands • Meeting different criteria for grazing, cropping, fish/wildlife, and industrial/ commercial/residential use Specifies period of required husbandry, based on average precipitation amounts	Revegetation requirements may be relevant and appropriate to CERCLA when standards do not exist for non-coal mining lands. Superfund may incorporate additional goals into successful revegetation related to specific plant and animal conditions, as well as species appropriate given remaining wastes on site. Post-revegetation activities are considered operation and maintenance and would be addressed accordingly.
Post mining land use (816.133)	All disturbed areas must be restored in a timely manner to conditions capable of supporting • Use capable of supporting before mining; or • Higher or better uses	

D.8.3 Implementation of the Fish and Wildlife Coordination Act at Superfund Mining Sites. Remedial actions at Superfund mining sites will often require alteration of natural bodies of water, due to the nature of the sites. For example, at many mining sites, tunnel plugging will be necessary, or surface water may have to be diverted around tailings or away from mine areas.

The RI/FS should describe any reports or recommendations of the FWS. When control or modification of a water body is involved, the ROD should state whether each alternative will meet substantive Fish and Wildlife Coordination Act requirements, and should briefly describe requirements for the remedy selected, including the impacts, if any, of the response alternatives on wildlife and the mitigation measures that would be employed.

D.9 *EXECUTIVE ORDER 11990, PROTECTION OF WETLANDS AND EXECUTIVE ORDER 11988, FLOODPLAIN MANAGEMENT*

E.O. 11990, Protection of Wetlands, requires federal agencies conducting certain activities to avoid, to the extent possible, the adverse impacts associated with the destruction or loss of wetlands and to avoid support of new construction in wetlands if a practicable alternative exists. The requirements of this E.O. are spelled out in 40 CFR 6.302(a) and 40 CFR Part 6, Appendix A. E.O. 11988, Floodplain Management, requires federal agencies to evaluate the potential effects of actions they may take in a floodplain to avoid, to the extent possible, adverse effects associated with direct and indirect development of a floodplain. The requirements of this E.O. are spelled out in 40 CFR 6.302(b) and 40 CFR Part 6, Appendix A. CERCLA actions at mining sites must consider these Executive Orders and comply with the promulgated requirements, where they are determined to be ARARs.

The procedures for meeting the requirements of each Executive Order are similar. There are three steps to meeting the requirements:

- The site manager must determine if proposed actions will be in or will affect a flood-plain/wetlands. **If it is determined that actions will not be located in or will not affect a floodplain/wetlands, no further consideration of the requirements of these Executive Orders is necessary.**

- If actions will be in or will affect a floodplain/wetland, the site manager must prepare a floodplains/wetlands assessment. This assessment will be part of the environmental assessment.

- The site manager must either avoid adverse impacts or minimize them if no practicable alternative exists.

Highlight D-18:
Fish and Wildlife Coordination Act as ARARs: Example Site

At the *California Gulch* site in Colorado, the remedial action included tunnel plugging that would modify streamflow. It also required surface water diversions and construction of surge ponds that could affect the California Gulch. Because of these remedial activities and their potential impact on fish and wildlife, EPA was required to consult with the FWS and the Colorado Department of Natural Resources to determine the means and measures necessary to mitigate, prevent, and compensate for project-related losses of wildlife resources and to enhance the resources. EPA received and responded to comments on the FS alternatives and the proposed plan from both the Department of the Interior and the State of Colorado. In addition, the state was consulted on the ROD.

D.9.1 Standards (40 CFR 6.302(a) and (b), 40 CFR Part 6, Appendix A).

Floodplain/Wetlands Determination

- Before undertaking an action, EPA must determine whether or not the action will be located in or affect a floodplain or wetlands.

- The Agency shall utilize maps prepared by the federal Insurance Administration of the federal Emergency Management Agency, Fish and Wildlife Service, and other appropriate agencies to determine whether a proposed action is located in or will likely affect a floodplain or wetlands.

- If there is no floodplain/wetlands impact identified, the action may proceed without further consideration of the remaining procedures set forth below.

Early Public Notice

- When it is apparent that a proposed or potential Agency action is likely to impact a floodplain or wetlands, the public should be informed through appropriate public notice procedures.

Floodplain/Wetlands Assessment

- If the Agency determines a proposed action is located in or affects a floodplain or wetlands, a floodplain/wetlands assessment shall be undertaken.

- For those actions where an environmental assessment (EA) or environmental impact statement (EIS) is prepared pursuant to 40 CFR Part 6, the floodplain wetlands assessment shall be prepared concurrently with these analyses and shall be included in the EA or EIS. In all other cases, a "floodplain/wetlands assessment" shall be prepared.

- Assessments shall consist of a description of the proposed action, a discussion of its effect on the floodplain/wetlands, and a description of alternatives.

Public Review of Assessments

- Where an EA/EIS is prepared, opportunity for public review will be provided by EIS provisions. In other cases, an equivalent public notice shall be made.

Minimize, Restore, or Preserve

- If there is no practicable alternative to locating in or affecting the floodplain or wetlands, the Agency shall act to minimize potential harm to the floodplain/wetlands.

- The Agency shall act to restore and preserve the natural beneficial values of flood-plains/wetlands as part of the analysis of alternatives under consideration.

Agency Decision

- After consideration of alternative action, the agency shall select the desired alternative.

- For all Agency actions proposed to be in or affecting a floodplain/wetlands, the Agency shall provide further public notice announcing this decision.

- This decision shall be accompanied by a Statement of Findings, which shall include:

  - The reasons why the proposed action must be located in or affect the flood-plain/wetlands;
  - A description of significant facts considered in making the decision;
  - A statement indicating whether the proposed action conforms to applicable state or local floodplain protection standards;
  - A description of the steps taken to design or modify the proposed action to minimize potential harm to or within the floodplain or wetlands; and
  - A statement indicating how the proposed action affects the natural or beneficial values of the floodplain or wetlands.

- If the provisions of 40 CFR Part 6 apply, the Statement of Findings may be incorporated in the final EIS or in the environmental assessment. In other cases, notice should be placed in the *Federal Register* or other local medium and copies sent to federal, state, and local agencies and other entities which submitted comments or are otherwise concerned with the floodplains/wetlands assessment.

Additional Floodplain Management Provisions

- EPA controlled structures and facilities must be constructed in accordance with existing criteria and standards set forth under the National Flood Insurance Program (NFIP) and must include mitigation of adverse impacts wherever feasible. Deviation from these requirements may occur only to the extent NFIP standards are demonstrated as inappropriate for a given structure or facility.

- If newly constructed structures or facilities are to be located in a floodplain, accepted floodproofing and other flood protection measures shall be undertaken. EPA shall, wherever practicable, elevate structures above the base flood level rather than filling land.

- The potential for restoring and preserving floodplains and wetlands so that their natural and beneficial values can be realized must be considered and incorporated into any EPA plan or action wherever feasible.

- If property used by the public has suffered damage or is located in an identified flood hazard area, EPA shall provide on structures, and other places where appropriate, conspicuous indicators of past and probable flood height to enhance public knowledge of flood hazards.

- When property in flood plains is proposed for lease, easement, right-of-way, or disposal to non-federal public or private parties, EPA shall reference in the conveyance those uses that are restricted under federal, state, and local floodplain regulations and attach other restrictions to uses of the property as appropriate.

D.9.2 Applicability of E.O. 11990 and Other Wetlands Protection Requirements. In addition to the requirements of 40 CFR Part 6, which requires that EPA initiate activities to avoid, to the extent possible, long- and short-term adverse impacts associated with the destruction or modification of wetlands, to avoid direct or indirect support of new construction in wetlands where there are practicable alternatives, and to minimize potential harm to wetlands when there are no practicable alternatives, section 404 of the Clean Water Act contains provisions for wetlands protection. Section 404 requires that no discharge of dredged or fill material shall be permitted if there is a practicable alternative to the proposed discharge that would have less adverse impact on the aquatic ecosystem, as long as the alternative does not have other significant adverse environmental consequences. (For more information on CWA section 404, see the CWA section of this appendix.) Also, E.O. 11990 adopts a policy for federal agencies that wherever wetlands are destroyed or lost, wetlands of the same magnitude will be enhanced or created.

Section 404 requirements and the 40 CFR Part 6 requirements are ARARs for different types of actions and require different analyses. Section 404 requirements are only applicable when dredged or fill material is placed into a wetland; therefore, excavation of wastes from a wetland would not trigger these standards or require any analysis of "practicability." The 40 CFR 6.302 requirements are potential ARARs whenever wetlands are affected, but E.O. 11990 itself is never an ARAR because it is not legally promulgated or enforceable against the Agency by the public.

In deciding whether a wetland requirement is an ARAR, there may be some flexibility in determining the meaning of "minimizing adverse effects to the extent possible" (under 40 CFR 6.302). Some interpretation may be necessary because, in some cases, a response action at a Superfund site may involve a discharge that may destroy an undegraded, functioning wetland. Examples of such an action include the diversion of surface or groundwater through an existing wetland and building access roads in wetlands. As a further example, a wetland may be contaminated, but if the wastes are removed, the wetland will become a lake and the wetland will be destroyed. If the waste is left in place, the wetland will be preserved, but the risk to human health and the environment will remain.

Site managers should try to avoid adverse impacts wherever possible; however, in some cases the benefits gained by the response action may outweigh the adverse effects to the wetland. In fact, avoiding the adverse effects may even be more harmful to human health and the environment than preserving the wetland. In such instances, an ARARs waiver for greater risk to human health and the environment may be appropriate (see the section on ARARs waivers in this appendix). (Wetlands creation to replace destroyed wetlands may also be required.)

D.9.3 Implementation of Wetlands Protection Requirements at Mining Sites. An innovative technology for treating acid mine drainage (AMD) from Superfund mining sites may be affected by wetlands protection requirements. In this treatment, AMD is allowed to flow through artificial wetlands, which filter out contaminants. If these artificial wetlands are constructed in a natural wetland, the requirements of 40 CFR Part 6 may be applicable. Also, if construction involves placing dredged or fill material into a natural wetland, the site manager should consider CWA section 404 as a potential ARAR. Finally, if natural wetlands rather than artificial wetlands are used for this type of treatment, this may also trigger Part 6 requirements.

Highlight D-19:
Wetlands/Floodplains Requirements as ARARs: Example Site

The *Anaconda Smelter/Mill Creek* site in Montana is located within the 100-year floodplain of Mill Creek. EPA also determined that riparian woodland/shrubland at the site is a wetland. Demolition activities will occur within the wetland area. The following management practices will be utilized during demolition and site stabilization activities:

- Mechanized equipment will be used in a manner that minimized effects to wetland vegetation.
- No new roads will be constructed.
- Following demolition, building foundations will collapsed and filled, and the area regraded and smoothed to conform to the existing topography and to facilitate drainage.
- Riparian vegetation rendered non-viable during demolition activities will be removed and replaced with like vegetation.
- Disturbed areas will be mulched with straw and seeded with grasses.

D.10 *NATIONAL HISTORIC PRESERVATION ACT*

The Historic Sites Act (HSA) of 1935, The National Historic Preservation Act (NHPA) of 1966, and the Archeological and Historic Preservation Act (AHPA) of 1974 are designed to protect the Nation's historical heritage from extinction. Because of the CERCLA section 121 mandate to comply with those requirements of other federal and state environmental laws that are ARARs, Superfund actions are required to take into account the effects of any response activities on any historic properties or cultural resources regulated under these laws. If no cultural resources or historic properties are present at an NPL site, the NHPA and other laws are not considered an ARAR for the proposed response activity. If a cultural resource on or eligible for inclusion on the National Register of Historic Places is present at an NPL site, however, the NHPA may be considered an ARAR. In this case, EPA must determine what effect a Superfund response activity (i.e., a removal or remedial cleanup activity) will have on an identified cultural resource. If cultural resources are present, the ROD or removal action memorandum should identify the NHPA as an ARAR. For each alternative, the ROD should identify whether the alternative will comply with substantive NHPA requirements. For the selected remedy, the ROD or action memorandum should also include a brief statement describing what compliance with the NHPA entails.

This section discusses how to determine whether the NHPA and other historic preservation laws are ARARs and the steps that must be taken to ensure that remedial activities at mining sites comply with the NHPA. Highlight D-20 provides more information on the historic preservation laws.

D.10.1 Implementing Historic Preservation Requirements. The Department of Interior has formed the Advisory Council on Historic Preservation (ACHP) and the National Register of Historic Places to implement these historic preservation laws. The National Register of Historic Places lists the nation's cultural resources that should be considered for protection from destruction or impairment. The National Register is not an all inclusive list (i.e. not every historical site that should be protected has been included in the National Register at this time). Consequently, historic properties that may be eligible for inclusion on the National Register must also be protected under these laws. Procedural requirements for listing properties on the National Register are listed in 36 CFR 60.1. The criteria applied to evaluate whether cultural resources will be eligible for inclusion on the National Register, including those found at Superfund sites are found in 36 CFR 60.4 and are summarized in Highlight D-21. Executive Order 11593, revised on May 13, 1971, "Protection and Enhancement of the Cultural Environment," requires federal agencies to locate, inventory and nominate all sites, buildings, districts, and objects under their jurisdiction or control for listing on the National Register of Historic Places. Under this Executive Order, EPA must undertake these activities when such sites are addressed as part of the Superfund program.

Highlight D-20:
Historic Preservation Laws

The Historic Sites Act of 1935 authorizes the Secretary of the Interior to designate areas as national landmarks for listing on the National Registry of Natural Landmarks. Under this Act, federal agencies, or responsible parties under the direction of a federal agency, are required to avoid undesirable impacts on such landmarks. Under the Archeological and Historic Preservation Act, if a federal agency, or responsible party under the direction of a federal agency, conducts an activity that may cause irreparable loss or destruction of significant scientific, prehistoric, historic, or archeological data, the Secretary of the Interior is authorized to undertake data recovery and preservation activities. The National Historic Preservation Act (NHPA) of 1966 established a program for the preservation of historic properties throughout the nation. The NHPA requires the federal government to encourage government agencies and individuals undertaking activities to preserve the cultural foundations of the Nation. The NHPA also requires that the federal government assist state and local governments to expand their historic programs and activities.

The ACHP oversees the protection of properties of historical, architectural, archeological, and cultural significance at the national, state, and local level. Under section 106 of the NHPA and Executive Order 11593, federal agencies must provide the Advisory Council on Historic Preservation a reasonable opportunity to comment on activities that may affect properties on or eligible for listing on the National Register of Historic Places. For Superfund, a Memorandum of Agreement (MOA) between EPA and DOI provides the framework of the actions agreed upon to implement the NHPA at Superfund sites.

The State Historic Preservation Officer (SHPO) is the official responsible pursuant to section 101(b)(1) of the NHPA for administering the state historic preservation program within each state or jurisdiction. For Superfund response actions, the SHPO serves as a liaison between EPA and the ACHP, and should be viewed as a technical resource to assist in determining if NHPA requirements are ARARs, and if so, how EPA must comply. The SHPO participates in the review process established by the NHPA when a federal agency's proposed activity occurs within the SHPO's jurisdiction. Although compliance with the NHPA rests with the federal agency implementing the action, EPA staff may not be as familiar with historic issues as the SHPO. Consequently, the SHPO can and should play an important role in the ARARs evaluation compliance process for this law. Coordination should be maintained among EPA, the state environmental protection department, and the SHPO to ensure full utilization of existing staff expertise in the historic preservation planning process and in the treatment of historic properties affected by the proposed remedial or removal actions. If mitigation measures are necessary to comply with the NHPA, they will occur more readily if the SHPO is involved *early* in the RI/FS process.

Highlight D-21:
Criteria for Inclusion of a Cultural Resource on the National Register of Historic Places

Cultural resources that may be placed on the National Register include those that:

- Are associated with events that have made a significant contribution to the broad patterns of our history;
- Are associated with the lives of persons significant in our past;
- Embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or
- Have yielded, or may be likely to yield, information important in prehistory or history.

D.10.2 Complying With the Historic Preservation Laws. Compliance with the NHPA during Superfund response action requires that EPA, the state lead agency, or the private party taking a CERCLA section 104 or CERCLA section 106 action:

- Identify cultural resources on or eligible for inclusion on the National Register of Historic Places;
- Determine the effect a proposed activity will have on the identified cultural resources; and
- Avoid, minimize, or mitigate any adverse effects during implementation of the action.

In order for the Record of Decision (ROD) to be developed in a timely manner, the demonstration of compliance with the NHPA must be done as part of the Feasibility Study. During the Feasibility Study the various alternatives being considered must be evaluated for compliance with all ARARs. To ensure compliance with the NHPA, the EPA site manager should begin working with the SHPO and ACHP in the very early stages of the Superfund process. If at any point in the compliance process it is determined that cultural resources are not present or will not be affected by the proposed activity, no further investigation is required.

Identification of Properties on or Eligible for Inclusion on the National Register of Historic Places

Identification of cultural resources on, or that may be eligible for inclusion on, the National Register of Historic Places is the first step towards compliance with the NHPA. Identification should be made in the very early stages of an RI/FS (e.g., scoping), before conducting investigation activities that disturb the site, (e.g. well drilling). EPA or lead agency consultation with the SHPO is the first stage in the identification process. EPA in conjunction with the SHPO, is responsible for determining whether the area of planned remedial action includes any historic properties. "The Agency Official shall consult the State Historic Preservation Officer, the published lists of National Register and eligible properties, public records, and other individuals or organizations with historical and cultural expertise, as appropriate, to determine what historic and cultural properties are known to be within the area of the undertaking's potential environmental impact" (40 CFR section 800.4(1)). In many cases, mining sites may be historical landmarks, and when they are subject to remedial actions, it may be necessary to consider the effects of the actions on the landmark. (See Highlight D-22.)

Highlight D-22:
Examples of the NHPA as an ARAR

California Gulch

The Yak tunnel at the California Gulch mining site in Leadville, Colorado is considered a historical landmark due to its historical association with mining engineering in the 19th and 20th centuries. Therefore, CERCLA must take into account any adverse effects at this facility.

Clark Fork

Many mining areas along the Clark Fork, including the areas around the city of Butte, Montana, are considered historical landmarks due to their historical association with mining. Cleanup activities at the Clark Fork sites could alter certain historical structures within the local community. In order to comply with the NHPA, EPA and the state have produced a historical film to document historical resources prior to any cleanup activities.

When determining whether the area of planned remedial action includes any historic properties, the SHPO and EPA should consider the following factors:

- The area of potential effects of the remedial action (i.e., extent of the effects of potentially disturbing investigation activities and response action);

- Existing information on historic properties already identified that are potentially affected by the action;

- The likelihood that there are unidentified historic properties within the area of potential effects; and

- Further actions that may be necessary to identify historic properties that may be affected.

The MOA between EPA and DOI specifies that once contacted, the SHPO will respond to EPA's request to determine whether the area of planned remedial action includes any historic properties within 30 days.

After consulting with the SHPO, the lead agency determines what, if any, further actions are necessary to locate and identify cultural resources. If the SHPO has inadequate information to document the presence or absence of historic properties in the project area, the SHPO may suggest that the lead agency conduct a professional cultural resource survey (CRS). **The analysis to determine whether a CRS is necessary should be conducted prior to developing the RI/FS workplan.** In this way, requirements to conduct a CRS can be met during the course of early RI activities, allowing a determination to be made whether the detailed analysis of alternatives will have to evaluate compliance with the historic preservation laws as ARARs. In some cases, cultural resources may not be discovered until after the RI/FS has started, or until after the ROD or Action Memo is signed and implementation of the design or action has started. Where the resource is identified before the ROD is signed, the RI/FS plans should be revised to accommodate and include the CRS. Where the resource is discovered after the ROD or action memo is signed, the site manager should work with the SHPO to undertake a CRS. If the CRS shows potential impacts of the action on the resource, an explanation of significant differences (ESD) may be used to make any necessary adjustments in the remedy.

The purpose of the CRS is to identify cultural resources within the project area and develop information required to apply the National Register's criteria for evaluation (see Highlight D-21). The CRS includes research conducted on each identified resource to determine:

- Whether the resource is eligible for listing on the National Register;
- The effects an activity will have on the cultural resource; and
- Ways to avoid or reduce the effects on any cultural resources.

Highlight D-23 highlights the factors to consider when determining the need for a CRS.

If EPA determines that a CRS is necessary, cultural resource plans outlining the scope of work and schedule for completion of the CRS should be incorporated into the appropriate RI/FS and/or RD workplans. Data from the CRS report should be incorporated into the RI/FS environmental evaluation. The decision whether to undertake a CRS rests with EPA, but SHPO opinions should be strongly considered in making the final determination.

Stage I of a CRS is designed to determine the presence or absence of cultural resources in the potential impact area. This process generally requires conducting documentary research and/or a field investigation (e.g., limited excavation or site surveillance in a potentially affected area, interviews with knowledgeable resources). The activities of a Stage I investigation should be part of RI work conducted on the site. **Stage II** of the CRS, if necessary, is a detailed evaluation of an identified cultural resource that may be affected by the remedial alternatives being considered. Stage II of a CRS is conducted only if it is determined that a proposed response activity will affect resources identified in Stage I. Highlight D-24 defines in more detail the major components of each stage of a CRS.

Highlight D-23:
Factors to Consider When Determining the Need for a CRS[1]

- Type and scope of the response activity under preliminary consideration;
- Nature and extent of the physical disruption likely to be associated with the undertaking;
- Environmental characteristics of the planning area;
- Type of direct and indirect impacts anticipated in the planning area;
- Data gathered from a field inspection of the proposed planning area, including photo-documentation of any potential cultural resources that may be directly or indirectly impacted; and
- Recommendations of the SHPO and other appropriate state agencies, and state and local historic preservation groups, local governments, Indian Tribes, and other parties likely to have knowledge of historic properties in the area.

[1] The effect of these factors on making a decision whether to undertake a CRS should be documented in the RI/FS report.

If the lead agency and the SHPO agree that no identified property on, or eligible for inclusion on, the National Register is located within the area of the proposed activity, the lead agency official should document this finding in the RI/FS report. Unless the Secretary of the Interior disagrees with this determination, the response action may proceed with the proposed activities. If the SHPO and agency official identify a cultural resource in the area of a proposed response, however, the criteria listed in Highlight D-21 are applied to determine whether the property is eligible for inclusion on the National Register (if it is not already being considered or listed). Provided that the SHPO and EPA agree that a property should be included in the National Register, either the SHPO or EPA site manager official should forward the following documentation to the Keeper of the National Register:

- A letter signed by EPA stating that EPA and the SHPO agree that the property is eligible for inclusion on the National Register; and

- A statement signed by the SHPO that in his opinion the property is eligible for the National Register.

Highlight D-24:
Major Components of a Cultural Resource Survey

Stage I:

- **Documentary Research** activities include researching sources at the State Historic Preservation Office, local governments, universities, local libraries, museums, and historical societies. The Stage I research survey should also include a synthesis of land use patterns, and prehistoric and historic cultural development of the project area.

- **Field Investigation** involves subsurface testing. A record and description of cultural resources including their location on the site is also completed during the Field Investigation of Stage I.

Stage II:

- The Stage II report of the CRS should include information on boundaries, integrity, and significance of the resource(s), and evaluation of the effect of the proposed project.

The Keeper of the National Register will give written notice of his determination to both the SHPO and the EPA site manager 10 working days of receipt. If the SHPO and agency official disagree about the eligibility for inclusion on the National Register, the EPA site manager should submit a letter of request for a determination of eligibility with a description, statement of significance, photographs, and a map to the Keeper of the National Register. The opinion of the SHPO should also be forwarded with the request, if available. The Keeper of the National Register will respond in writing to the agency's request within 45 days of receipt of the request. **Only properties subsequently listed on the National Register will have to comply with the step of the NHPA process that determines if the proposed activity will affect the resource. For properties not listed at this stage, the NHPA and other laws are not considered ARARs.**

Determination of Effect

Identifying the possible effects of response actions on each cultural resource that is on, or eligible for inclusion on, the National Register is the second step towards compliance with the NHPA. "A federal activity is considered to have an effect on a cultural resource whenever the activity causes or may cause any change, beneficial or adverse, in the quality of the historical characteristics that qualify the cultural resource for inclusion on the National Register." (36 CFR 800.3(a)) The EPA site manager, in consultation with the SHPO, will make one of the following determinations of the effect of the response action for each of the alternatives considered in the RI/FS Detailed Analysis of Alternatives Stage:

- No effect;
- No adverse effect; or
- Adverse effect

Determination Of No Effect

If the SHPO and agency official agree that a response action will have no effect on historic properties, the agency official should document this determination which is then made available for public review. If either the SHPO or the agency official objects, the Executive Director of the ACHP reviews the determination and notifies the objecting party of his decision within 15 days.

Determination of No Adverse Effect

If the agency official or Executive Director of the ACHP determines that a response action will affect a cultural resource eligible for inclusion on the National Register, the agency official in consultation with the SHPO, shall determine whether the effect is an adverse effect. Highlight D-25 provides several definitions of adverse effects. If the agency official and the SHPO determine that a response action will have no adverse effect on the cultural resource, the agency official is responsible for submitting adequate documentation of this determination to the Executive Director of the ACHP which is available for public review. Highlight D-26 lists the information to be included in the RI/FS report or action memo to document a no adverse effect finding as required by 36 CFR 800.13(a). The regulation also states that there must be the opportunity for public review and comment on this finding.

Provided that no objection has been made by the public, the SHPO, or any interested party, upon receipt of the documentation of no adverse effect, the Executive Director of the ACHP will normally concur without delay. If the Executive Director determines that the documentation of no adverse effect is inadequate, the Executive Director will notify the agency official within 15 days. Unless the Executive Director objects within 30 days, the agency official will have satisfied the requirements under the NEPA and may proceed with the proposed activity. If the Executive Director objects, the Executive Director will specify conditions that will eliminate the objection. The agency official may either accept the Executive Director's conditions in writing and proceed with the proposed activity, or reject the Executive Director's conditions, in which case the Executive Director should initiate the consultation process.

Determination of Adverse Effects

Should the agency official determine that an activity, including ones designed by Superfund to protect human health and the environment, will have an adverse effect on an historic property, or the Executive Director of the ACHP rejects the agency's determination of no adverse effect, the lead agency should prepare and submit documentation that outlines how the lead agency is going to avoid, minimize, or mitigate the adverse effects of a remedial activity to the Advisory Council for comments. This type of documentation is referred to as a Preliminary Case Report. A separate case report does not need to be prepared for a site. Instead, this information should be incorporated into the RI/FS Report, Proposed Plan, and the ROD. Highlight D-27 lists the type of information that should be included in the ROD or action memo to document a finding that the action will have an adverse effect.

Upon receipt of the Council's comments, the lead agency shall take the comments into account when reaching a final decision regarding the proposed activity. Highlight D-28 provides examples of mitigation measures the ACHP has suggested in the past. Given the lack of specific guidance in terms of what mitigation measures might encompass, EPA, PRPs, and the local community should negotiate with each other to clarify what mitigation measures are and how they should be implemented. If parties do not identify mitigation measures at appropriate times, mitigation measures change after the ROD is signed, or financial requests are not within available resources, EPA may not be able to fund implementation of the measures. Given a lack of funding, other parties (e.g., PRPs, communities) may be more appropriate to implement certain mitigation measures requested by the SHPO.

When agreement is reached on how the effects will be taken into account, the Executive Director of the ACHP will prepare a Memorandum of Understanding (MOU) reflecting such agreement. Typically, the RPM prepares a proposal for inclusion in the MOU that details the actions agreed upon to avoid, mitigate, or accept the adverse effects on the property. If the Executive Director determines that the proposal accurately represents the agreement, the RPM's proposal is forwarded to the Chairman of the ACHP for ratification.

Highlight D-25:
Definition of Adverse Effects

Adverse effects may include, but are not limited to, the following:

- Physical destruction, damage, or alteration of all or part of the property;
- Isolation of the property from or alteration of the character of the property's setting when that character contributes to the property's qualification for the National Register;
- Introduction of visual, audible, or atmospheric elements that are out of character with the property or alter its setting;
- Neglect of the property resulting in its deterioration or destruction; and
- Transfer, lease, or sale of the property.

SOURCE: CERCLA Compliance With Other Laws Manual.

Highlight D-26:
Information to be Included in Documentation of No Adverse Effect

The requirements of 36 CFR 800.13(a) state the following must be included when documenting a "no adverse effect" finding.

- A description of the agency's involvement with the proposed activity with citations of the agency's program authority and applicable implementing regulations, procedures, and guidelines;
- A description of the proposed activity, including as appropriate, photographs, maps, drawings, and specifications;
- A list of National Register and eligible properties that will be affected by the proposed activity, including a description of the property's physical appearance and significance;
- A brief statement explaining why the proposed activity will have no adverse effect on the cultural resource;
- Written views of the SHPO concerning the determination of no adverse effect, if available; and
- An estimate of the cost of the proposed activity, identifying federal and non-federal shares.

SOURCE: 36 CFR 800.13(a)

Highlight D-27:
Information Required in the ROD or Action Memo to Document Adverse Effect

The ROD or action memo should include the following information, as required by 36 CFR 800.13(b):

- A description of the proposed activity, including, as appropriate, photographs, maps, drawings, and specifications;
- A description of the National Register or eligible properties affected by the proposed activity, including a description of the properties' physical appearance and significance;
- A brief statement explaining why the proposed activity will adversely affect the cultural resource;
- Written views of the SHPO concerning the effect on the property, if available;
- The views of other federal agencies, state and local governments, and other groups or individuals, when known;
- A description and analysis of alternatives that would avoid the adverse effects;
- A description and analysis of alternatives that would mitigate the adverse effects; and
- An estimate of the cost of the proposed activity, identifying federal and non-federal shares.

Highlight D-28:
Examples of Mitigation Measures

- Producing historical films;
- Videotaping\photographing landscape for documentary purposes;
- Designating land to the historical society;
- Modifying workplans to preserve historical structures (One mining facility preserved historical wooden pipes by revising design plans around the pipes); and
- Constructing state parks or museums.

D.10.3 Cultural Resources Discovered After Complying with the NHPA. In some cases, a federal agency may identify a cultural resource eligible for inclusion on the National Register of Historic Places after completing all its responsibilities under section 106 of the NHPA. Unless the Secretary of the Interior determines that the significance of the property, the effect, and any proposed mitigation actions warrant Council consideration, the federal agency may fulfill its responsibilities under section 106 of the NHPA by complying with the requirements of the Archeological and Historic Preservation Act. The Archeological and Historic Preservation Act provides for the preservation of historical and archeological data that might be lost or damaged as a result of a proposed activity. If a federal activity may cause irreparable loss to significant scientific, prehistorical, or archeological data, the Act requires the federal agency to preserve the data or request the Department of the Interior to do so. The Archeological and Historic Preservation Act mandates only the preservation of the data. If the Secretary of the Interior determines that the Council's comments are warranted, the agency official should request the comments of the Council and repeat the procedure discussed in section 3.0.

If it is determined that the identified cultural resource will not be affected by the remedial activity, EPA must document this determination. Provided that the Executive Director of the ACHP does not object to this determination, EPA will have satisfied the requirements of the NHPA. If EPA and the SHPO determine that a remedial activity will have no adverse effect on a cultural resource, EPA shall document that determination, carry out any agreed-upon conditions accompanying the SHPO's concurrence, and provide the Advisory Council on Historic Preservation with the determination.

D.10.4 Summary of RPM's Responsibilities to Ensure Compliance with the NHPA. Compliance with the NHPA can be broken down into five major steps:

1. Determine whether cultural resources that are on, or eligible for inclusion on the National Register of Historic Places are located in or near the area under study in the RI;

2. Determine whether a cultural resource survey is necessary;

3. Determine whether identified resources are on or eligible for inclusion on the National Register of Historic Places;

4. Determine the effect affect a proposed response activity will have on a property on, or eligible for inclusion on the National Register of Historic Places; and

5. Develop mitigation measures if proposed activities will have an adverse effect on a cultural resource.

The RPM should complete the first four steps in the very early stages of an RI/FS, prior to conducting sampling activities on mine waste NPL sites. The RPM should conduct the fifth and final step during the Feasibility Study, when the various alternatives are evaluated for compliance with all ARARs. It is not realistic to select a remedial action and then determine what the appropriate compliance/mitigation procedures will be during the ROD process. Developing mitigation measures during the Feasibility Study will ensure that the Record of Decision can be developed in a timely manner.

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Appendix E
X-Ray Fluorescence

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Table of Contents

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Appendix E
X-Ray Fluorescence

The purpose of this appendix is to identify the parameters that must be considered when applying the x-ray fluorescence (XRF) analytical method at a field site to achieve the necessary quality of chemical data for soils and other heterogeneous solids to meet project objectives. This appendix presents information about the use of XRF based on two extremes: enforcement-quality on-site analysis and field screening analysis. It is a supplement to existing EPA guidance providing procedures for determining a quantifiable degree of certainty upon which to make site-specific decisions focusing on the use of the XRF method of analysis at the site.

E.1 Introduction

XRF technology has greatly expanded since Moseley discovered the importance of x-ray spectra in 1913. Instruments with reduced detection limits have been developed for a broad spectrum of elements and have become portable. XRF instruments can now be taken to the sample by a single individual and a screening analysis performed in less than a minute, with reasonable precision and accuracy.

XRF is being applied to Remedial Investigation/Feasibility Study (RI/FS) and cleanup sites to increase the representativeness of sampling, expedite the activity by performing real-time data analysis to support decisionmaking, and decrease both the time and cost of these activities. XRF analytical determinations are nondestructive and total analyses of chemical elements require minimal sample preparation. Consequently, XRF instruments are finding increased use in environmental studies.

Application of the XRF method depends on the project objectives and associated data quality objectives. The decision to use XRF at a site may occur during the first stage of developing the data quality objectives, but the application is generally defined in the second and third stages.[1] As with any method of analysis, precision and accuracy start with the sample collection and continue through each stage of the analysis until the chemical data are reported. Comparability of data produced by XRF with data from EPA's Contract Laboratory Program (CLP) has been established by field tests of XRF instruments. Representativeness and completeness are two of the major advantages of XRF use. On-site, real time chemical analysis can document representativeness and allows critical samples to be collected and analyzed, which typically ensures completeness.

E.2 Elements of Interest and Detection Limits

Radioisotope sources used in field-portable and semi-portable instruments include iron-55, cadmium-109, americium-241, and curium-244. Different sources are used for different elements of interest. For example, Cdl09 and Cm244 are typically used for chromium, manganese, iron, cobalt, nickel, copper, zinc, arsenic, and lead, and Am241 is typically used for silver, cadmium, antimony, and barium.

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[1] U.S. Environmental Protection Agency, 1987, Data Quality Objectives for Remedial Response Activities, Development Process: EPA/540/g-87/004 (OSWER Directive 9355.07B).

EPA's Environmental Monitoring Systems Laboratory (EMSL) has produced a sampling and analysis protocol for the use of a field portable XRF. Examples of the chemical analysis is by a field portable instrument are documented to produce instrument detection limits of 15 to 90 milligrams per kilogram (mg/kg) for arsenic (two sites) and 30 to 140 mg/kg for lead, copper, zinc, and iron.[2] Typical method detection limits are not less than 50 mg/kg with a coefficient of variation between 5 and 10 percent but are often in the 100 to 200 mg/kg range with a coefficient of variation of 3 to 25 percent. The increase in detection limit is a result of using a lower x-ray source (radioisotopes) and a gas proportional detector in the field portable XRF instruments.

Prototype lithium drifted silicone (Si(Li)) probes are being developed that have the potential to lower the detection limit to less than 100 mg/kg for most heavy metals (copper, zinc, arsenic, lead, etc.).[3] A semi-portable unit is currently available that uses sample cups for sample input rather than a surface probe. The semi-portable XRF instrument probably has an intermediate detection limit range between the field portable and the mobile unit. However, in selected instances, the semi-portable instrument may function almost as well as the mobile XRF instrument for selected elements. Similar to the field portable instrument, the semi-portable instrument uses a radioisotope as a source.

Mobile laboratory results have well-documented lower limits of detection of 4 mg/kg for cadmium, 7 for lead, 12 for arsenic, 19 for zinc and iron, 21 for manganese, and 26 for copper.[4] In these tests, the samples were sieved and pulverized to a powder. A fundamental parameters model was used to calculate concentration from measured XRF intensity.

E.3 Equipment Options and Turnaround Times

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. These detection limits are not appropriate for typical surface and ground water; therefore, CLP laboratories are recommended for samples of these media. Samples analyzed by XRF, especially critical samples, are submitted to a CLP laboratory or equivalent laboratory for calibration and consultory chemical analysis.

Field portable instruments are more useful than mobile instruments in a site investigation. Field-portable instruments are those equipped with radioisotope source(s), generally gas proportional tube detectors, usually weighing less than 20 pounds (including batteries) and can be carried in one hand to the sample location. Semi-portable instruments are those instruments

[2] Chappell, R.W., Davis, A.O., and Olsen, R.L, 1986, Portable X-Ray Fluorescence as a Screening Tool for Analysis of Heavy Metals in Soils and Mine Wastes: Proc. Natl. Conf. on Management of Uncontrolled Hazardous Waste Sites, Washington, DC, pp. 115-119.

[3] Piorek, S., and Pasmore, J.R., 1991, A Si(Li) Based High Resolution Portable X-Ray Analyzer for Field Screening of Hazardous Waste: Second Intl. Symposium, Field Screening Methods for Hazardous Wastes and Toxic Chemicals, EMSL, Las Vegas, NV, 5p.

[4] Harding, A.R., 1991, Low Concentration Soil Contaminant Characterization Using EDXRF Analysis: Second Intl. Symposium, Field Screening Methods for Hazardous Wastes and Toxic Chemicals, EMSL, Las Vegas, NV, 7p.

that may be equipped with radioisotopes but are equipped with a Si(Li) detector, weighing more than 20 pounds (including batteries) but can still be carried by one person to a site, and samples are placed in a cup for analysis by the instrument. Mobile instruments use an x-ray-tube for the x-ray source and, therefore, require line voltage, and are usually placed within a specific building near or at the site to generate enforcement quality data. Instruments can also be installed in a van. They can be moved from site to site but normally would be retained at a site until analytical data are no longer necessary (potentially months).

An initial field investigation using a field portable XRF involves gridding the site and determining relative concentrations for a suite of elements at all points in the grid. Hot spots are identified and their nature and extent characterized before leaving the field. A suite of representative samples are collected and sent to a CLP laboratory for a "broad spectrum analysis" that documents the concentrations of hot spot and peripheral elements for the site. Contaminated areas of concern within the site are thereby documented from the initial XRF work by converting field readings to absolute concentrations with a known, documented accuracy and precision.

Mobile XRF instruments are more appropriate for sites undergoing cleanup activities. A mobile XRF instrument can be installed in a section of a typical room near the site. Samples can be collected, prepared, brought to the instrument, and analyzed in a matter of a few hours. Analytical quality can be comparable to a CLP or equivalent laboratory. Comparability is documented by split samples sent to a CLP laboratory. 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 almost immediate decisions to be made concerning an action level in the field that can be confirmed by the mobile laboratory doing routine remedial action samples. Ultimately, a representative composite sample from the site area under remedial action is sent to the CLP or equivalent laboratory for final documentation of the clean up level.

E.4 Special Considerations When Using XRF

All XRF instruments begin with the total counts received by the detector for an energy that is specific for each element. The detection limit, accuracy, and precision of the measurement is directly determined by the magnitude of the total counts and resolution width of the peak. The total counts are expressed as intensity in counts per second.

The analytical capability of an XRF instrument depends on excitation source, source-to-sample geometry, instrument stability, counting time, and sample matrix. Commercial instruments are available for both enforcement and screening analysis. Analysis for enforcement data requiring low concentrations of a broad spectrum of selected elements (on the order of 10 mg/kg) uses semi-mobile, x-ray-tube-sourced instruments equipped with crystal detectors (for example, Si(Li) detectors). Analysis for screening data allows a broad spectrum of elements to be semiquantitatively determined using radioactive sources that are limited by safety regulations to 5 and 6 orders of magnitude lower x-ray emission than x-ray tubes. This limitation is partially compensated for by the nearly monochromatic x-ray source with closer source-to-sample geometry that allows a reasonably low detection limit for many elements. High resolution gas--proportional tubes are the most common detectors but Si(Li) detectors are available for both semi-portable and most recently for portable instrumentation.

E.4.1 Site-Specific Calibration Samples

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 (hydrofluoric acid digestion) analysis by a CLP or equivalent laboratory. The samples should be prepared by the laboratory using the same protocol that will be used at the site. This initial set of samples is best collected using the field screening instrument to determine that samples are representative of media (potential for stratification), elements of concern, and concentration ranges. Similarly, preparation of samples for XRF analysis by the field preparation facility is preferable to preparation by a fixed laboratory using other equipment and protocols. EMSL has protocols for the collection, preparation, and analysis of a suite of site-specific calibration standards.

E.4.2 Sample Preparation

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. It 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. Instruments vary in the amount of data processing that they provide. Some give minimal processing, reporting in intensity (total counts or total counts divided by backscatter). Others are capable of processing the data to report in mg/kg concentration units.

The semi-portable instruments have a potential detection limit equal to that of the larger mobile instruments. The semi-portable instrument requires the use of a sample cup, therefore, some preparation may be necessary unless the sample particle size is small enough to be placed in a sample cup (soils, slurries, liquids, etc.).

For mobile instruments, sample preparation is part of the analytical schedule and includes sieving and pulverizing. A CLP level of quality control is used and data are typically processed through a computer for conversion to mg/kg concentration units. Fundamental parameter computer models are commonly used. A typical detection limit will range from 5 to 30 mg/kg, depending on the sample matrix. Sample preparation may include making pressed powder briquettes for analysis, but does not typically extend to fusing or dissolution. If these more aggressive techniques are is required to achieve enforcement quality data, commercial laboratories are better equipped to prepare and analyze the samples.

E.4.3 Interferences

The overlap of fluorescence peaks must be corrected for in both screening and quantitative XRF analytical work. This effect is responsible for more errors in reporting analytical results than all the other effects combined. Comparing the peak energy levels of the element of interest with other peaks for the same or nearly the same energy level is a trivial but extremely important aspect of using the XRF for the analytical determination of any element.

One of the most commonly encountered peak overlaps is that between the k-alpha peak for arsenic (10.5 keV) with the l-alpha peak of lead (also 10.5 keV). The overlapping peaks for both elements are the peaks contributing the highest primary fluorescence. If both arsenic and lead are present in variably high concentrations at a site, the k-beta peak for arsenic (11.8 keV) and the l-beta peak for lead (12.6 keV) are used or the overlap peak is separated by mathematically subtracting the lead contribution to the overlapped peak intensity. The arsenic k-beta peak has only about 15 percent of the k-alpha peak intensity. The lead l-beta peak has about two-thirds of the l-alpha peak. Therefore, even though the l-level peaks are lower in intensity than that of k-level peaks, the detection limit for lead is less affected by the lower energy peak than the arsenic. Other elements will involve peak overlap and can usually be handled in a similar fashion.

E.4.4 Sample Variance Calibration

Sample preparation and particle size variance are major potential sources of error. If enough of the original suite of calibration samples has been collected, they are the preferred suite for determining potential sources of error in sample preparation. If volatile elements are involved (or mercury and arsenic to a lesser extent) sample drying should be performed at approximately 85 degrees celsius or less). Air drying versus any other method of drying should be investigated. If samples are to be split, stored for long periods of time, or transported from one point to another, they should be homogenized before any other preparation procedure. Complete mixing is imperative if a representative sample is to be prepared or analyzed.

Particle size variance is a two part problem. The first part concerns the field particle size that potentially contains most of the elements of concern. The second concerns the pulverized particle size. To determine the field particle size distribution, a suite of approximately 10 samples should be selected that cover the media, elements, and concentration ranges of a primary metal of concern. Each of the samples should be wet sieved through a minimum of three sieve sizes. For example, 8, 80, and 200 mesh sieves could be selected. A sample of the unsieved material (with root mat, pebbles, and extraneous material removed) and each size fraction is pulverized using the design protocol for pulverization. A split should be analyzed by both the XRF and a CLP laboratory (using the hydrofluoric acid digestion method for total metals). In some instances, sieving is preferable to pulverizing.

Particle size is one of the operator-controlled heterogeneity effects that is the most difficult to deal with without resorting to fusion or dissolution, both of which are time-consuming laboratory procedures. Particle size effects are minimized by using a rigidly consistent procedure for both sample preparation (drying, disaggregating, pulverizing, etc.) and pelletizing a constant volume of sample. In most instances, pelletizing is necessary for defensible quantitative chemical analyses. Liquids and properly prepared soils are potential exceptions. Site-specific samples should be used for the determination of potential particle size effects.

E.4.5 Counting Time

There are two methods of controlling the coefficient of variation or relative percent difference (RPD) of the analytical results generated by an XRF instrument: fixed count time or fixed count. Most operators of XRF instruments use a fixed counting time instead of a fixed count because fixed count may require very long counting times. The fixed count time allows a known RPD to be calculated and sample turn-around time to be managed. The statistical error is equal to the inverse of the square root of the total counts. For example, a total count of 1,000 would produce a relative standard deviation of approximately 3 percent; 100 counts, 10 percent, and 10,000 counts, 1 percent.

X-ray tubes, with their higher x-ray flux can produce much higher counts than radioisotope sources, and therefore, the detection limit, precision, and accuracy of instruments equipped with these sources are, accordingly, comparably higher. Typically, 200 second counting times are used for enforcement analysis using mobile instruments. On the other hand, screening analysis using field portable instruments rarely uses counting-times of more than 100 seconds to make effective use of field time. In addition to the other factors described in this section, the counting time is one of the major reasons for differences in the quality of analytical data.

E.5 Quality Control

Exceptionally high expectations and indiscriminate use of the instruments outside the design limits has sometimes led to discouragement in the application of field-portable XRF instruments. Litigation-defensible quantitation limits are possible for selected elements using properly applied field-portable 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 are performed by a CLP or comparable fixed analytical laboratory. A comparable metals analysis would require the addition of hydrofluoric acid to the normal CLP digestion. Typically, there are no differences between the methods for most metals but some metals (for example, chromium) can occur as a refractory phase that is fully digested by the normal CLP analysis.

Commercial laboratories are an integral part of the use of any of the sampling instruments. The calibration and verification of analytical data generated by the use of the XRF instruments depend on laboratory determination of the same elements. Samples sent to the laboratory for these purposes must be the same samples analyzed by the XRF. Sample splits are acceptable but duplicate samples should not be used for these purposes without the support of splits. Homogenization at the laboratory is even more important than for the XRF because a smaller sample is typically used at the laboratory than for the XRF sample. A total digestion of the sample is necessary, involving hydrofluoric acid in the digestion process. EMSL has an excellent protocol for the preparation of samples for both XRF and specifications for the laboratory. The laboratory should also analyze a subset of approximately 20 samples covering the range of elemental concentrations of concern to determine if a difference exists between normal CLP total metals analysis and hydrofluoric acid digested total metals.

E.6 Examples of Site Projects Using XRF

The total extent of XRF application to abandoned mine 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

[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.

instrument 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 nature and extent RI/FSs.

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. Unlike anthropogenic organic solvents that can occur as discrete species (with degradation even organics have multiple compounds), inorganics, particularly metals, share interrelated characteristics of migration that allow detection through other associated elements that occur at higher, detectable concentrations.

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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.

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Appendix F
Risk Assessment Scoping, Problem Formulation, and Additional Risk Assessment Guidance

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Table of Contents

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Appendix F
Risk Assessment Scoping, Problem Formulation, and Additional Risk Assessment Guidance

F.1 The Ecological Risk Assessment in the RI/FS

EPA defines ecological risk assessment as "a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors."[1] Ecological risk assessments in Superfund can be divided into three main phases as follows (see Highlight F-1):

> **Problem Formulation** - establishes the goals, breadth, and focus of the ecological risk assessment. This phase includes qualitative evaluation of contaminant release, migration, and fate; identification of contaminants of concern, receptors, exposure pathways, and known ecological effects of the contaminants; identification of assessment and measurement endpoints (see section F.4 of this appendix for a definition of assessment and measurement endpoints) for further study; and development of exposure scenarios.
>
> **Analysis** - technically evaluates data on the potential exposure and effects of the contaminants.
>
> -- **Characterization of Exposure** - evaluates the interaction of the contaminant with ecological receptors. This step includes contaminant characterization (quantifying release, migration, and fate); ecosystem characterization (characterizing exposure pathways and receptors); and development of an exposure profile that quantifies the magnitude and spatial and temporal distributions of exposure for the scenarios developed during problem formulation (measuring or estimating exposure concentrations).
>
> -- **Characterization of Ecological Effects** - analysis of the relationship between the contaminant and the assessment and measurement endpoints identified during problem formulation. This step may include literature reviews, field studies, and toxicity tests to quantify the contaminant-response relationship and to evaluate evidence for causality.
>
> **Risk Characterization** - evaluates the likelihood of adverse ecological effects or impacts occurring as a result of exposure to a contaminant; analyzes and summarizes uncertainties; and presents weight-of-evidence discussion. This phase includes risk estimation, risk description, and discussion between the risk assessor and the risk manager allowing full and clear presentation of the results to the risk manager.

Although the elements of exposure characterization and of ecological effects characterization are most pronounced in the analysis phase, aspects of these characterizations are considered also during problem formulation. This is illustrated in Highlight F-1 by the arrows flowing from the problem formulation phase to the analysis phase.

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[1] Environmental Protection Agency (EPA). 1997. *Process for designing and Conducting Ecol*ogical Risk Assessments . EPA/540-R-97/006, June 5, 1997.

F.2 Relationship to Overall Remedial Investigation/Feasibility Study (RI/FS) Process

The ecological problem formulation step described above occurs during the scoping phase of the RI/FS. The ecological assessment described in this appendix occurs during site characterization. Highlight F-2 illustrates the overall RI/FS process and Highlight F-3 provides an overview of the ecological assessment process at Superfund sites.

Many mining waste sites are divided into different operable units to address different areas or sources, and RI/FS investigations for each may proceed in a phased manner. The eight-step process for logical assessments at Superfund sites is described in *Process for Designing and Conducting Ecological Risk Assessments*[2]. More details of the process are described below.

Scoping and ecological problem formulation. RI/FS scoping consists of the components listed in Highlight F-4. The scoping step includes both human health and ecological concerns, and coordination is needed among the scoping team members. The outcome of the ecological problem formulation is a conceptual model of the site. Components of this conceptual site model, potential ARARs, data quality objectives, and remedial action objectives are likely to differ for the human health and ecological assessments; therefore, these need to be integrated throughout scoping. In particular, when identifying operable units and response scenarios, both sets of concerns must be addressed as thoroughly as possible.

Phased approach to site characterization. For most sites, the project plans for site characterization should incorporate a phased approach to the ecological assessment with expert review at each phase. The data or observations from one phase can be used to determine the most appropriate studies for the next phase. Thus, a goal of the scoping phase of the assessment is to establish detailed project plans for the first phase of an ecological assessment. If the results of the first phase so indicate, an additional ecological assessment may be conducted during the site characterization phase.

Scoping the ecological assessment. Highlight F-5 summarizes the steps in scoping a remedial investigation. It shows that a primary objective of scoping is to prepare project plans for the RI/FS, including a work plan (WP), sampling and analysis plan (SAP), and field sampling plan (FSP) for site characterization, (i.e., determine the data required to characterize both human health and ecological threats). The RPM is responsible for a scope or statement of work (SOW). The contractor or other group (e.g., the Potentially Responsible Party (PRP)) performing the field assessment is responsible for project plans that address the elements of the SOW. Highlight F-6 illustrates the elements of these plans.

Site characterization ecological risk assessment. The three primary goals of the site characterization phase are:

- To conduct a field investigation to define the nature and extent of contamination (waste types, concentrations, distributions);
- To conduct the baseline risk assessment to determine if a site poses a current or potential threat to the environment; and
- To help determine remediation goals for site contaminants.

Following the ecological risk assessment, the RPM evaluates whether the data collected are sufficient to make decisions concerning remedial alternatives and cleanup goals or whether additional ecological information is needed.

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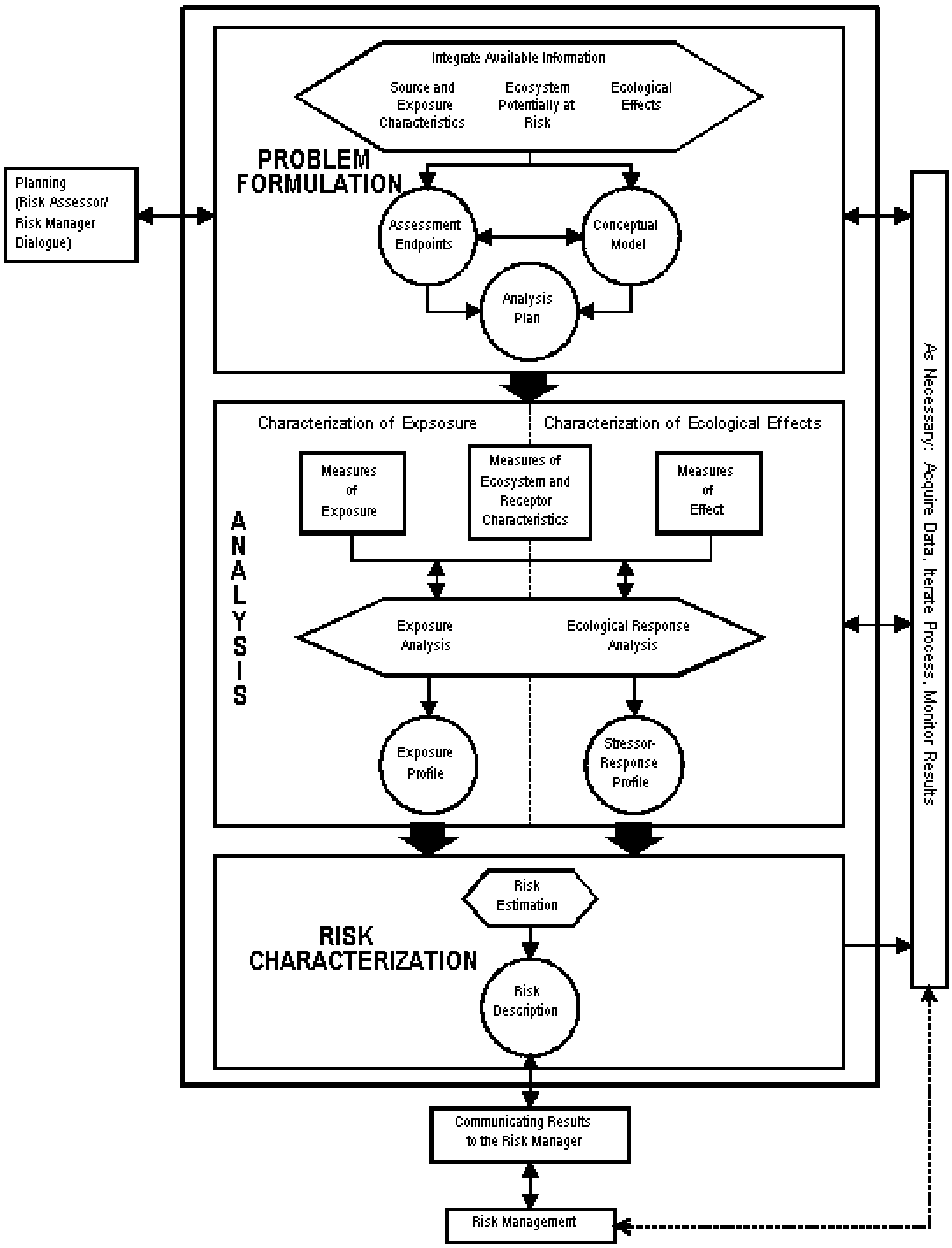
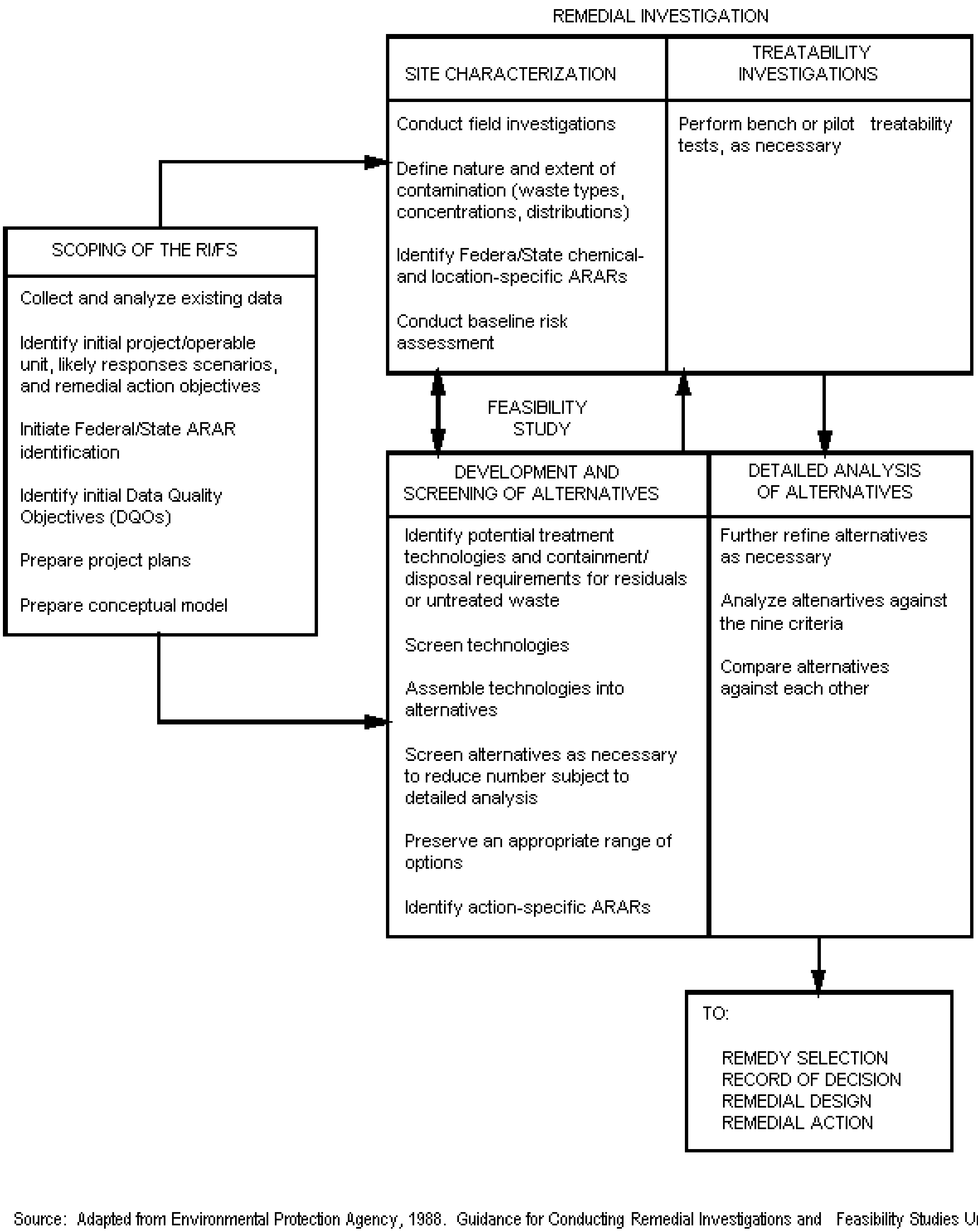
[2] U.S. Environmental Protection Agency (EPA). 1997. *Process for Desgining and Conducting Ecological Risk Assessments.* EPA/540-R-97-006. June 5, 1997.

Highlight F-1
Ecological Risk Assessment Framework



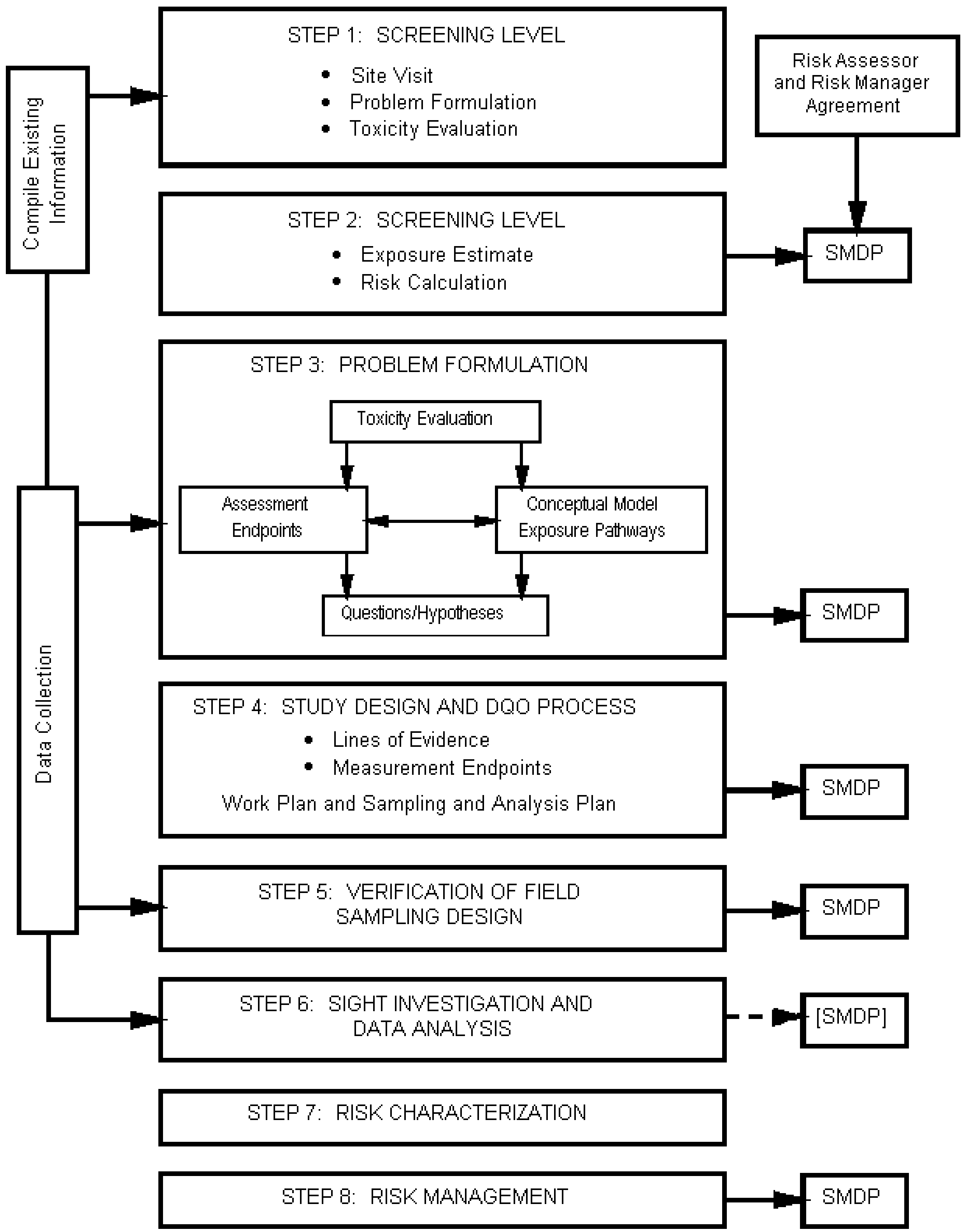
Source: Environmental Protection Agency (EPA) 1998. Guidelines for Ecological Risk Assessment. EPA/630/R-95/003F.

Highlight F-2
Remedial Investigation/Feasibility Study Process



Source: Adapted from Environmental Protection Agency, 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response, Washington, D.C. OSWER Directive No. 9355.3-01.

Highlight F-3
Ecological Risk Assessment Process for Superfund



Source: Environmental Protection Agency (EPA) 1997 EPA/540-R-97-006

Highlight F-4:
Components of Scoping an RI/FS

- Evaluate existing data
- Develop conceptual site model
- Identify initial project/operable unit, likely response scenarios, and remedial action objectives
- Initiate potential federal/state ARARs identification
- Identify initial data quality objectives (DQOs)
- Prepare statement of work and project plans for the site characterization phase of study

F.3 General Principles

The following three principles can serve as useful guidelines when planning and conducting ecological risk assessments at Superfund mining sites:

An ecological risk assessment usually requires data in addition to that obtained for a human health risk assessment. While much of the data obtained for a human health risk assessment is useful in an ecological risk assessment, additional information usually is required (e.g., a description of the surrounding habitats and species of concern, additional chemical sampling locations).

Criteria, standards, or other measures for the protection of human health and welfare are not always protective of ecological systems. Many ecological receptors are more sensitive than humans to some chemicals. Moreover, a given environmental concentration of a chemical may result in a greater level of exposure for an ecological receptor than for a human.

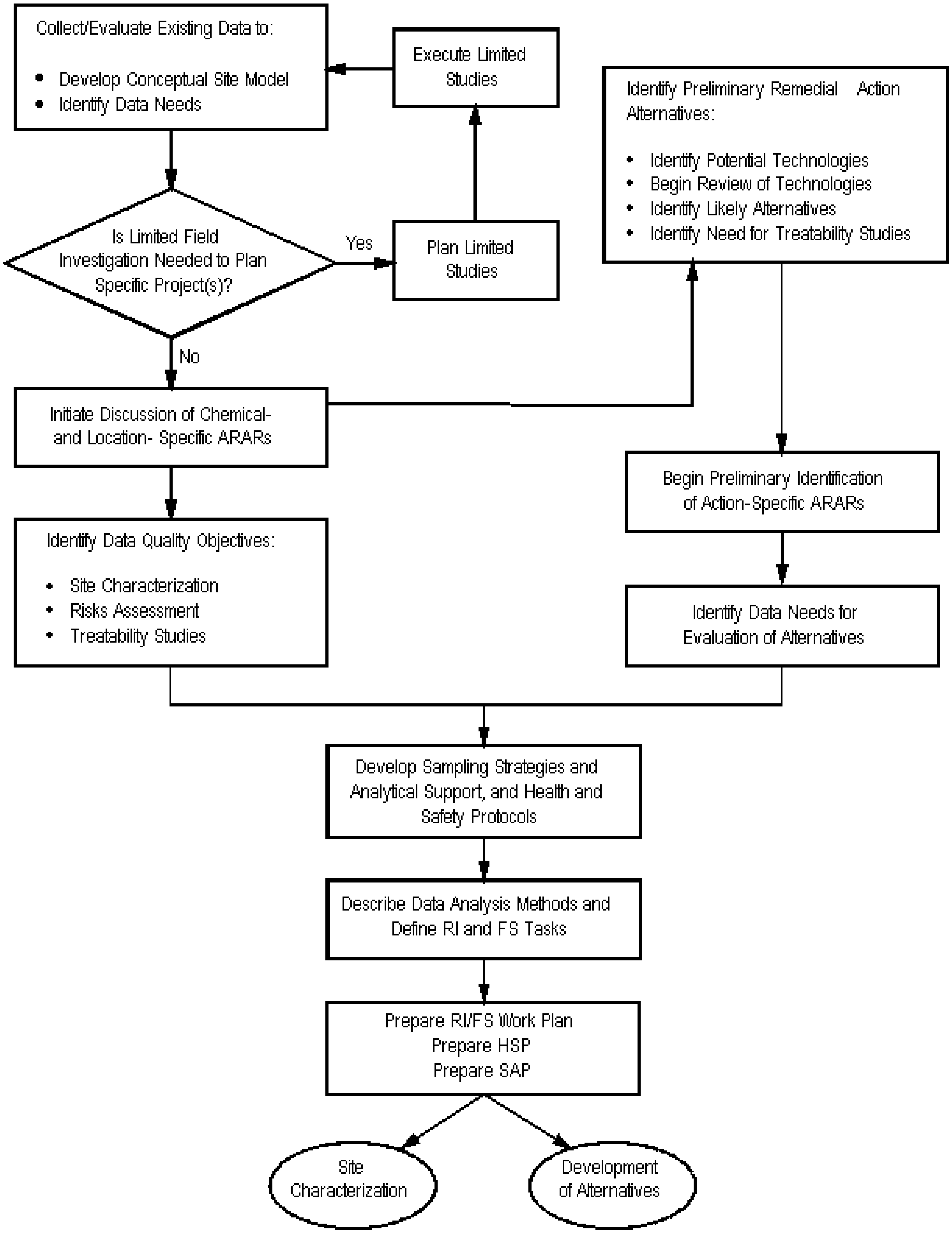
A detailed ecological risk assessment during site characterization will not be necessary or appropriate for every site. The level of detail in an ecological risk assessment should be appropriate to the level of information required to make risk management decisions. A purpose of the ecological assessment is to determine whether additional site investigations will be required before risk management decisions can be made at a particular site.

F.4 RI/FS Scoping and Ecological Problem Formulation

Highlight F-5 shows the steps involved in scoping the remedial investigation. The first step is to collect and evaluate existing data in order to develop a conceptual model of the site and to identify data gaps that will prevent effective formulation of study plans. Highlight F-7 provides a list of useful data sources. For ecological assessments, a site walk-through with a trained ecologist/biologist should be performed. It may be determined at this time that a limited field investigation is required to fully scope the RI. If this is the case, a field sampling plan needs to be formulated and executed.

After collecting data to scope the RI, the assessment team should identify chemical- and location-specific ARARs, preliminary remedial action alternatives, preliminary action-specific ARARs, data quality objectives, and data needs for evaluating alternative remedial strategies. Then the assessors can develop sampling strategies, required analytic support, and data analysis methods for the RI site characterization.

Highlight F-5
Steps in Scoping a Remedial Investigation



Source: Adapted from Environmental Protection Agency (EPA) 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response, Washington, D.C. OSWER Directive No. 9355.3-01.

Highlight F-6:
Elements of Project Plans

Elements of a Work Plan (WP)	Elements of the Sampling and Analysis Plan (SAP)
A comprehensive description of the work to be performed, the information needed for each task, the information to be produced during and after each task, and a description of work products submitted to the RPM; The methods that will be used during each activity; A schedule for completing activities; The rational for performing or not performing an activity; A background summary and history of site; A site conceptual model; Identification of preliminary site objectives including preliminary remediation goals; The need for additional data when future site unknowns are identified; The manner of identifying federal and state ARARs; An identification of preliminary alternatives and RI/FS guidance; and A plan for meeting treatability study requirements.	Sampling procedures; Sample custody procedures; Analytical procedures; Data reduction, data validation, and data reporting; Personnel qualifications; The qualifications of each laboratory to conduct work; and The use of internal controls, such as unannounced site, performance, and system audits. **Elements of the Field Sampling Plans (FSP)** The sampling objectives; Sample locations; Sampling frequency and when to sample; Sampling equipment and procedures; Program for sample handling and analysis. **Note: Project Plans also include a health and safety plan (HSP) for the personnel conducting the sampling.**

Source: Adapted from Environmental Protection Agency (EPA). 1991. *Guidance on Oversight of Potentially Resonsible Party Remedial Investigations and Feasibility Studies, Volume 1.* Office of Solid Waste and Emergency Response, Washington, DC. OSWER Directive 9835.1 (c). EPA/540/G-91/010a.

At enforcement lead sites, it is crucial to compile documentation for cost recovery and to make sure that natural resources trustees have been notified of site activities so that they can conduct their investigations.

EPA has published guidance to help develop a scope of work for Ecological Assessments.[3] This guidance provides an overview of the role of the BTAG, points to consider in developing a scope of work, elements of an ecological assessment scope of work, ensuring contractor capability to do the work, and a sample work scope. The remainder of this section provides additional details and sources of information to supplement the existing guidance, emphasizing elements that are likely to be important for mining sites.

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[3] Environmental Protection Agency (EPA). 1992b. *Developing a Work Scope for Ecological Assessments. ECO Update*, Intermittent Bulletin, Volume 1, Number 4. Office of Emergency and Remedial Response, Hazardous Site Evaluation Division, Washington, DC. Publication 9345.0-05I.

F.5 Evaluate Existing Data and Visit the Site

The first step of scoping for the RI is evaluating all existing data for the site. As scoping begins for the RI, some data already should be available from previous site studies, studies from similar sites, available aerial photographs, and other sources. Initial site data from the Preliminary Assessment (PA), Site Investigation (SI), Hazard Ranking System (HRS) Scoring Package, and supporting materials included in the docket established as part of the NPL listing process should be obtained. Existing RI/FS studies from similar types of mining waste sites also may be helpful in identifying background information that can help to develop hypotheses about potential problems at the site. During this process, it is critical for the ecological assessment team to work with those conducting the scoping study from the human health perspective. Ten tasks are outlined below.

Task 1: Contact BTAG, Appropriate Agencies and Experts, and Natural Resource Trustees

Contact the Biological Technical Assistance Group (BTAG). The role of BTAGs in ecological assessments at Superfund sites is described in *ECO Update* Volume 1, Numbers 1[4] and 4[5]. If a BTAG or equivalent advisory group exists in the Region (or is otherwise accessible), begin the process of involving group members in the scoping ecological assessment as early as possible. The BTAG can screen the initial site data (e.g., PA, SI, HRS data) to recommend the nature and extent of an ecological assessment that is likely to be needed at the site and to identify the most relevant exposure pathways for further study. BTAG members also can be extremely helpful throughout the ecological assessment, including:

- Assisting the RPM to scope the ecological assessment effort;
- Reviewing the conclusions of the scoping phase;
- Recommending study objectives, field and laboratory protocols, QA/QC requirements, and other elements of the RI SOW; and
- Reviewing draft RI/FS work plans for site characterization.

In some Regions, RPMs present a brief oral description of a site and its history to the BTAG to begin the consultation process. Eco Update Volume 1, Number 5[6] discusses this initial briefing.

Contact appropriate state or local fish and game agencies. Other agencies may have statutory responsibility for involvement in management of the resource(s) of concern (e.g., state Fish and Game Departments). Personnel from these agencies who are familiar with the area should be contacted to determine whether any adverse ecological impacts have been reported that might be attributable to contaminants from the site. Types of impacts that may be expected include fish kills (particularly following storms), reduced or absent fish or wildlife populations, and reduced abundance of particular plant species. Note that these types of impacts may or may not be site-related. It also will be important to determine the state-designated uses of any potentially affected surface waters, whether the surface water quality meets the requirements for the designated use, and if not, the possible causes of use impairment.

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[4] Environmental Protection Agency (EPA). 1991b. *The Role of BTAGs in Ecological Assessment. ECO Update*, Intermittent Bulletin, Volume 1, Number 1. Office of Emergency and Remedial Response, Hazardous Site Evaluation Division, Washington, DC. Publication 9345.0-05I.

[5] Op. Cit. 3.

[6] Environmental Protection Agency (EPA). 1992. *Briefing the BTAG: Initial Description of Setting, History, and Ecology of a Site. ECO Update*, Intermittent Bulletin, Volume 1, Number 5. Office of Emergency and Remedial Response, Hazardous Site Evaluation Division, Washington, DC. Publication 9345.0.05I.

Highlight F-7: Useful Sources of Existing Data

Federal Sources of Existing Data	State Sources of Existing Data	Local Sources of Existing Data
Preliminary Assessment/Site Inspection Hazardous Ranking Scoring (HRS) documentation PRP search — Section 104(e) letters — waste-in list — data requests to the PRP Records on removals and disposal practices Permits for discharges — Toxic Releases Inventory System (TRIS) National Pollutant Discharge Elimination System (NPDES) Prior Contract Laboratory Program (CLP) work RCRA manifests, notifications, and permit applications and Section 3007 information requests EPA databases (see Appendix A of source)	EPA-equivalent agency Planning board Geological Survey Fish and Wildlife Service Historic Preservation Office Natural Resource Department Natural Heritage Program Department of Conservation	Public library Chamber of Commerce Audubon Society Planning board Town/city hall or court house Water authority Sewage treatment facility Previous site employees/ management Residents near site Universities (information on local areas) Historical societies Newspaper files

Source: Adapted from Environmental Protection Agency (EPA). 1991. *Guidance on Oversight of Potentially Responsible Party Remedial Investigations and Feasibility Studies, Volume 1.* Office of Solid Waste and Emergency Response, Washington, DC. OSWER Directive 9835.1 (c). EPA/540/G-91/010a.

Contact CERCLA natural resource trustees. The NCP outlines formal notification and coordination requirements for EPA and the CERCLA natural resource trustees throughout the RI/FS process. These requirements and recommendations for additional involvement of the natural resource trustees are described in *ECO Update* Volume 1, Number 3[7]. In general, it is important to notify natural resource trustees early and often and always to notify the U.S. Fish and Wildlife Service (FWS; representing the Department of the Interior (DOI)) and the National Oceanic and Atmospheric Administration (NOAA; representing the Department of Commerce). It also may be beneficial to invite trustees' representatives to accompany the assessment team on site visits. Appropriate personnel from FWS, NOAA, and other natural resource trustees can be extremely helpful in identifying and describing signs of exposure or impacts or noting the absence of species expected to be present. In many Regions, natural resource trustee representatives are members of the BTAG.

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[7] Environmental Protection Agency (EPA). 1992f. *The Role of Natural Resource Trustees in the Superfund Process. ECO Update*, Intermittent Bulletin, Volume 1, Number 3. Office of Emergency and Remedial Response, Hazardous Site Evaluation Division, Washington, DC. Publication 9345.0-05I.

In accordance with the NCP §300.615(c)(1) and through Memoranda of Understanding between EPA and both DOI and NOAA, the RPM can request a representative of one of the natural resource trustees to conduct a Preliminary Natural Resource Survey (PNRS) or another form of preliminary site survey. A PNRS consists of a site survey and a brief report identifying the natural resources, habitat types, endangered or threatened species, and any potential impacts or injuries to trust resources. The PNRS may be funded by EPA and conducted at any stage of the remedial process, from pre-listing to pre-Record of Decision (ROD). If the PNRS is conducted before RI scoping, it may provide information useful for sampling design and other aspects of the RI ecological assessment.

Other agencies that represent natural resource trustees at many mining sites include the states and the Bureau of Land Management (BLM). Given the large size of many mining sites, potentially affecting large proportions of entire watersheds, it can be helpful to establish a cooperative group to coordinate actions on a watershed basis. The group might be comprised of more than one EPA Office (e.g., Superfund, Office of Water) and appropriate state and other federal agencies (see Highlight F-8).

Task 2: Identify the ecological risk assessment team

Once the principal attributes of the site that may need evaluation have been identified, an ecological assessment team can be identified. Determine which types of technical expertise are required to evaluate the site. The team may be comprised of EPA Superfund staff and include representatives from NOAA, the FWS, or state agencies (see Highlight F-9). The BTAG may be able to recommend appropriate individuals for the team.

Task 3: Map the site

Mapping attributes of the site will assist in formulating a conceptual model for the site. Obtain all available background information on the site and its setting and begin to prepare a map. Specific objectives in this step are to identify and map:

(a) Sources of contaminants and areas of suspected contamination (e.g., deposition areas);
(b) Likely contaminant migration pathways; and
(c) Location and extent of on-site and nearby aquatic, wetland, and terrestrial habitats.

The first two steps (a and b) should be coordinated with the human health assessment team when developing the conceptual site model (section H.6). The final step (c) will be the responsibility of the ecological risk assessment team. For recently listed sites, much of this information should be described in the HRS materials, although additional investigation may be required. The initial map should be consulted or updated in all of the following steps.

Task 4: Develop a history of site operations

In conjunction with the human health assessors, compile information on when mining began, duration of the mining activities, volumes of materials handled, and technologies used in excavation, beneficiation, and refining. This information can indicate what types and how much hazardous waste is present, where it is located on site, and where it has migrated off site. Historical information helps in identifying locations of past activities at which hazardous wastes are likely to be found. Site history should be described in some detail in the HRS materials, although additional investigations may be required.

Highlight F-8: Example of a Multi-Agency Task Force for a Superfund Mining Site

Water quality of the Upper Arkansas River Basin has been impacted due to mining, beneficiation, post-mill smelting, farming, and urbanization over the past century. Water quality impacts in the Arkansas drainage have been especially acute in the Leadville mining district, including the California Gulch Superfund site, the Leadville mine drainage tunnel discharge, and mine discharges from the Cripple Creek mining district, the Chalk Creek mining district, and miscellaneous mines in the watershed. The primary threat to aquatic life in the Arkansas and its major tributaries is the inflow of dissolved metals (i.e., zinc, manganese, cadmium, lead, copper, iron, and nickel) at levels exceeding the state water quality standards. The majority of the problem creeks are acidic (pH between 2.5 and 3.0). In recent years, toxic metal pollution of Chalk Creek was noted when over 800,000 trout fingerlings died in the spring of 1985 and spring of 1986 after placement in the Colorado Division of Wildlife's Chalk Creek Fish Rearing Unit.

Given the large number of sources impacting the Arkansas drainage, a multi-agency demonstration project has been established to reduce, and possibly eliminate, the existing mining-related nonpoint sources of pollution in Chalk Creek so that the salmonid (i.e., trout) fishery can be returned. EPA has provided grants to the State of Colorado Water Quality Control Division (CWQCD), Department of Health and the State of Colorado Department of Natural Resources, Mine Land Reclamation Division (MLRD) to conduct the Chalk Creek - St. Elmo Nonpoint Source Water Improvement Demonstration Project. At the request of CWQCD, a Colorado Nonpoint Source Task Force (CNSTF) was formed. The Task Force is comprised of four subcommittees, including one on mining. The subcommittee on Abandoned and Inactive Mines is comprised of agencies and individuals involved in efforts to control inactive mine pollution of the Basin. Groups or organizations that are contributing funds or services to the Chalk Creek demonstration project include Coors Pure Water, Cyprus Coal Company, the U.S. Bureau of Mines, the U.S. Bureau of Reclamation, the Soil Conservation Service, and Volunteers for Outdoor Colorado tree planting, among others.

Highlight F-9: Ecological Risk Assessment Team

The ecological risk assessment team may include personnel from the following resources:

EPA Regional Offices
- Environmental Services Division
- Environmental Response Team
- Water Division

EPA National Offices
- Office of Research and Development

Other Federal Agencies
- US Geological Survey
- US Fish and Wildlife Service
- US Department of Agriculture
- National Oceanic and Atmospheric Administration

States
- State Fish and Wildlife Service

Task 5: Evaluate aerial and other photographs of the site

Aerial photographs are helpful to both the ecological and human health risk assessors for several purposes:

Verifying the existence and precise location of various site features and determining the spatial extent of waste piles and other sources;

Identifying erosion patterns and other topographic features that can influence contaminant migration pathways and the location of deposition areas;

Locating evidence of past mining operations that are not included in the historical record (or whose existence is uncertain); and

Documenting and/or verifying the site history, if a time series of aerial photographs dating from near the beginning of mining operations to the present is available.

For ecological risk assessors, aerial photographs can provide additional information:

Delineating the location and extent of various on-site and nearby habitats, although some ground-truthing (i.e., confirming designations by visiting key locations on the ground) usually is required even at the scoping phase (see Task 7); and

Documenting vegetation loss over time and identifying sources that may have caused the losses, if a time series of aerial photographs is available.

Task 6: Evaluate infrared aerial photographs of the site

Infrared aerial photography taken during the growing season can be useful in identifying areas of stressed vegetation. Locating such areas may help identify contaminant sources or areas where hazardous wastes have migrated that otherwise might be overlooked. Although this step can be somewhat expensive (e.g., photointerpretation by a skilled expert is essential), a good series of infrared photographs can save money in the long run by allowing one to identify and bound areas that might require additional investigation. Some ambiguities are possible, however, and ground-truthing usually is necessary. These photographs should not be considered a substitute for a site visit.

Task 7: Plan a site visit

When scoping an ecological assessment, the site and surrounding areas should be visited at least once. Site visits allow the RPM to become familiar with the location, size, and general condition of the site and nearby environments. Some signs of impacts can be observed via careful examination by a trained ecologist/biologist. To be effective, site visits require careful planning, as described in the following paragraphs. The site visit should be coordinated with any site visits planned for scoping the human health assessment.

Ensure that the right personnel are included in the site visits. Ensure that at least one person who is familiar with site-specific fauna and flora takes part in all site visits. No written guidance can replace the expertise of a trained field ecologist/biologist in identifying and describing signs of exposure or impacts, noting the absence of species expected to be present, and locating appropriate reference habitats. Such an individual also may be helpful in characterizing the overall condition of various habitats and in developing or refining specific hypotheses to be tested. Types of individuals who may be helpful during site visits include:

Representatives of natural resource trustees (e.g., FWS, NOAA) who have appropriate training and expertise;
Appropriate representatives of state or local wildlife, fish and game, natural resource, or equivalent agencies; and
Members of BTAGS (although this is not their usual role).

Prepare a list of areas to visit. Areas to visit should include all main contaminant migration pathways as well as on-site, nearby, and reference habitats and other specific areas that may need to be sampled. Specific areas to visit should include habitats that are:

Known to be contaminated;
Located between contaminant sources and areas known to be contaminated;
Located along known or potential contaminant migration pathways; and
Appropriate reference areas.

Reference areas. In general, an appropriate reference area is one that includes similar habitats/ecosystems, yet is relatively unimpacted by contaminants from the site. There are two approaches to identifying these areas: (1) trying to identify an area upgradient (e.g., upstream) of the site that is otherwise similar; or (2) trying to locate a similar habitat (e.g., stream order, surrounding vegetation, altitude) elsewhere in the same drainage basin that has not been affected by mining activity. The first approach is preferable because the closer the reference area to the site, the more similar to the site its ecological setting is likely to be. Care must be taken to establish a reference area sufficiently far upgradient that it is unlikely that site contaminants have reached the reference area by any means. Sometimes, however, the upgradient area is significantly different from the area potentially affected by the site (e.g., lower order streams, different stream bottom type, different cover and temperature). If this is the case, the second approach may be preferable. A trained biologist is needed to identify appropriate reference areas or to design alternative studies in the absence of an adequate reference area.

Determine when to visit each area. Timing can be critical for characterizing the overall condition or quality of a given environment. Many plants and animals are markedly seasonal in occurrence or abundance; snow cover and other seasonal events may interfere with observations. During a given season, activity patterns of most animals exhibit diel (i.e., daily) variability (e.g., owls and most mammals are active largely at night, birds sing largely in the early morning, dragonflies are active primarily during the warmer parts of the day). For each area, determine which areas to visit in early morning, mid-day, late afternoon, and/or night.

Task 8: Conduct the site visit

Visit reference areas and habitats first. It may be helpful to visit all known or potential reference environments prior to conducting site visits in order to characterize or become familiar with typical conditions in the area.

Visit all study areas. Visits to each area should include walks down streams or rivers, along the edge of other surface water bodies, and downwind of tailings piles, open landfills, and other large areas of surface contamination. During these visits, the locations of all important habitats should be noted and any previously uncharacterized areas should be mapped.

Document signs of potential impacts. During visits to each area, a trained ecologist/biologist may be able to detect signs of potential impacts and note the location of these observations on the site map. When looking for signs of potential impacts, focus first on those portions of each area that are most likely to be contaminated (e.g., the most likely point at which contaminants would enter a surface water body or a wetland, the portion of an environment closest to the source, deposition areas such as river bends where sediments are likely to accumulate).

Subtle indicators of potential impacts (e.g., changes in community structure or species diversity) may not be evident during relatively brief site visits. However, unusual colors or odors or the *absence* of certain characteristic features of healthy environments can be noted during a site visit and provide evidence of potential impacts. For example, lack of dragonflies or other insects typically found at or near the edges of rivers and streams or lack of insects typically associated with leaf litter may indicate ecological impacts. In shallow streams, fish, crayfish, snails, and aquatic insects often can be seen if present. If definitive documentation of reduced abundance or diversity of species is needed, however, it would be necessary to include a systematic biological survey in the RI.

Task 9: Modify maps and hypotheses

Subsequent steps in scoping will be facilitated by a scale map that identifies the following:

Location and type of sources (e.g., waste rock piles, tailings piles, tunnel entrances);

Hazardous wastes and substances known or suspected to be present in each source;

Potential discharge or release areas (e.g., tunnel discharge areas, groundwater seeps);

Topographic features that would facilitate migration of contaminants from sources to nearby habitats (e.g., drainage ditches, creeks, depressions) and would facilitate deposition of contaminants (e.g., river bend);

Location and areal extent of known adverse impacts that might be site-related (e.g., locations of fish kills, areal extent of stressed vegetation).

Location of on-site and nearby habitats; and

Location of potential reference habitats.

It is important to remember that for most mining sites, the large-scale physical disturbances of the terrain can be responsible for a large proportion of observed impacts on vegetation (e.g., once a hilly terrain is stripped of vegetation and top soil, native plants may not be able to reestablish for decades). Thus, maps also should include indications of where physical disturbance and erosion may have occurred.

At this time, hypotheses about contamination and threats may need to be refined or otherwise modified. In certain areas, observation may confirm contamination, indicate that contamination is unlikely, and/or identify new potential threats.

Task 10: Characterize the ecological setting and potential receptors

Using the results of the previous steps, it now should be possible to identify and characterize the potentially exposed habitats on or near the site and potential species, communities, or functions such as wetlands impacted in these habitats. This task includes several steps:

- Describing and delineating the terrestrial, wetland, and aquatic habitats;
- Identifying the species indicative of the healthy functioning of similar habitats (e.g., top level carnivore, trout in cold water streams, naturally dominant vegetation, aquatic insect larvae);
- Identifying endangered or threatened species potentially on or near the site; and
- Identifying other species protected under federal or state law (e.g., Migratory Bird Treaty Act, Marine Mammal Protection Act).

If contaminants at the site are known to bioaccumulate (e.g., cadmium, mercury), it is important to consider trophic relationships among the wildlife species so that the potential for food-chain effects can be assessed. Descriptions of potentially affected habitats should include as much detail as is necessary to scope the work. For example, stream aquatic communities vary considerably depending on depth, width, flow, type of bottom, and types of vegetation in and adjacent to the stream. These attributes affect both the kinds of studies required to evaluate possible effects and the level of effort needed to conduct the studies.

F.6 Develop Conceptual Site Model

The end product of the ecological problem formulation process is a conceptual site model (Highlight F-10). The model should identify possible contaminant sources, primary and secondary release mechanisms, exposure pathways, and environmental receptors. The model also should identify additional data needs and the analyses to be used. The steps for developing a conceptual model are listed in Highlight F-10 and discussed in the remainder of this section.

Task 1: Qualitatively evaluate contaminant release, migration, and fate

Evaluate contaminant release, migration, and fate in conjunction with the human health assessors. Compile a list of possible contaminants and describe existing information on contaminated media, contaminant migration, and the geographical extent of current and potential contamination.

Identify sources that have released contaminants. Information used to support HRS scoring may include the identity, approximate size, and location of sources known to have released contaminants. Information obtained when developing the history of site operations might help to identify other sources that have released contaminants.

Identify contaminant migration pathways. It is important to identify the key contaminant migration pathways. Considerations at mining sites in particular include the following:

- Runoff from and erosion of contaminated soils, tailings piles, or surficial materials into rivers, streams, and lakes;

- Leaching of contaminants in soils and waste piles to groundwater and subsequent discharge to surface water and wetlands;

Collapse of tailings piles into surface waters;

Tunnel surges (e.g., from collapse of a tunnel roof that temporarily dams water until the water pressure is sufficient to break through the debris);

Tunnel seepage (often very acidic);

Surface water transport and redistribution of contaminated sediments;

Air transport of contaminated soils or surficial materials (e.g., flue dust from smelter activities); and

Bioaccumulation and bioconcentration of contaminants in food chains.

Highlight F-10:
Ecological Problem Formulation (Scoping) Conceptual Model

Qualitatively evaluate contaminant release, migration, and fate

Identify:
- contaminants of ecological concern
- potential ecological receptors
- potential exposure pathways
- known effects

Select endpoints of concern

Develop conceptual model; identify:
- scope
- data needs

For surface water contamination, it also is important to determine the critical conditions affecting surface water contaminant loading (e.g., is it low flow during the winter or the spring flush?).

Identify potential or actual areas of contamination. Delineate the spatial extent of known contamination to the extent possible. Sampling efforts used to determine the HRS score for the site may have identified at least some areas known to be contaminated above background levels. For sites scored with the revised HRS, there also may be information on existing contamination of sensitive and other nearby habitats. Identify any habitats known to be contaminated or located within, between, or downgradient of areas of known contamination. Also, identify potential deposition areas for contaminated soils and sediments (e.g., bends in rivers) and other types of hot spots.

Task 2: Identify contaminants of ecological concern

EPA's *ECO Update*, Volume 1, Number 2[8] describes factors to consider in identifying contaminants of ecological concern. We review those factors here. From the list of possible contaminants developed in the qualitative evaluation (Task 1), identify those contaminants that may be of ecological concern, considering the following:

Amount of contaminant:
- Environmental concentrations in media that represent ecological exposure pathways (i.e., soil, surface water, sediment, and biota);
- Known extent of contamination in on-site and off-site media; and
- Background levels, indicating contamination that cannot be attributed to the site.

Attributes of contaminant:
- Physical-chemical properties (e.g., volatility, solubility, and persistence);
- Bioavailability (i.e., presence in a form that can adversely affect organisms);
- Potential for bioaccumulation or bioconcentration (e.g., log K_{ow} between 3 and 7);
- Toxicity (i.e., the amount of toxicant capable of producing adverse effects in organisms)[9];
- Time necessary to produce adverse effects (i.e., days, weeks, years); and
- Type of effects (e.g., lethal or sublethal responses).

Task 3: Identify potential ecological receptors

Ecological receptors include individual organisms, populations, or communities that can be exposed to contaminants. After the fate, migration, and potential release of contaminants have been reviewed, potential receptors can begin to be identified. Identify potentially exposed terrestrial, wetland, and aquatic habitats on or near the site and develop lists of species known or likely to occur in each habitat. Identified receptors should include species on or near the site that are:

Endangered or threatened;
Protected under other federal or state law (e.g., the Migratory Bird Treaty Act);
Rare or unique; or
Considered indicative of the healthy functioning of the community.

The revised Hazard Ranking System (HRS) contains a list of sensitive aquatic and terrestrial environments as shown in Highlight F-11. For NPL sites listed after March 14, 1991, all sensitive environments within the HRS target distance limits (generally a 4-mile radius for terrestrial environments and 15 miles downstream for aquatic environments) should be identified in the HRS scoring package and related materials. At mining sites, however, further distances from the site may need to be considered (e.g., entire drainage basins because of the large quantities of waste present). The HRS scoring package also may provide some information as to whether or not any sensitive environments are contaminated.

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[8] Op. Cit. 2.

[9] One source of information on relative toxicity to aquatic organisms can be EPA's ambient water quality criteria (AWQC) for the protection of aquatic life. See section H.14.

Sources of Information. Several sources of information can be helpful in identifying habitats and species on or near the site:

- Aerial photography and satellite imagery;
- Site visits;
- HRS guidance materials in Regional offices (may include catalogues, maps, or other compilations of some types of sensitive environments);
- National Wetland Inventory maps;
- U.S. Geological Survey topographic maps;
- Natural Resource Trustees;
- State or local fish and game agencies (e.g., any history of ecological effects from site);
- Water monitoring programs for surface water quality; and
- State Natural Heritage Programs.

Task 4: Identify potential exposure pathways

An exposure pathway is the link between a contaminated area and a receptor. Potential exposure pathways for ecological receptors can be identified from the analysis of contaminant release, migration, and fate, and from the receptors present. In evaluating exposure pathways, consider all relevant media (i.e., surface water, sediment, soil, and biota) that are or potentially could be contaminated. For example, organisms may be exposed by direct contact with contaminated media or by indirect contact through the food chain. Consider all potential receptors when identifying exposure pathways. There are several exposure pathways that often are of concern at mining sites:

- Direct contact with contaminated sediments for benthic invertebrates, bottom-dwelling fish, fish eggs and fry, and amphibian eggs and tadpoles;
- Direct contact with water column contaminants for fish;
- Ingestion of contaminated sediments by benthic invertebrates, bottom-dwelling fish, and waterfowl;
- Ingestion of contaminated soils by worms, other invertebrates, and burrowing mammals;
- Ingestion of contaminated soils and forage plants by grazing herbivores (e.g., deer, domestic livestock);
- Ingestion of contaminated aquatic prey by piscivorous birds and mammals and by waterfowl; and
- Ingestion of contaminated small mammals by raptors and carnivorous mammals.

Task 5: Identify known effects

In contrast to other types of Superfund sites, the contaminants at mining sites typically are limited to metals and a few other types of substances (e.g., cyanide, sulfuric acid, phosphorus). For aquatic communities, EPA's ambient water quality criteria (AWQC) for the protection of aquatic life can be used to identify contaminant levels in the water column below which adverse effects on aquatic communities are unlikely to occur. It is important to remember that these criteria are not necessarily protective of benthic aquatic communities (i.e., organisms that live in close association with sediments). Possible contaminant effects on terrestrial mammalian species can be identified from the toxicological literature compiled in support of criteria developed for the protection of human health (e.g., EPA Reference Doses (RfDs)). Data on the effects of most of these substances on other terrestrial groups (e.g., birds, amphibians) are available in the published literature.

In the event that an unusual organic or metal compound is of concern, other sources can be consulted. For example, the AQUatic Toxicity Information REtrieval (AQUIRE) data base contains data that can be used to evaluate the effects of contaminants on aquatic organisms. Where appropriate, data on chemicals similar but not identical to site contaminants can help characterize likely effects. Modeling techniques, such as Quantitative Structure Activity Relationships (QSAR), also can be used to estimate the toxicity of untested chemicals. These methods require specialized expertise to ensure proper interpretation of results.

The RPM also should obtain information from appropriate investigations conducted on or near the site to help target the ecological assessment toward the most relevant questions. Examples of useful studies include:

Studies in support of fish or wildlife consumption advisories issued by state or local government agencies;

Corroborative reports of unusual events such as stressed vegetation, fish kills, other mortality events, or absence of species expected in the habitat; and

Field or laboratory studies from previous investigations of the site (e.g., preliminary investigations).

Task 6: Select endpoints of concern

A critical step in selecting endpoints is deciding what effects are important to the remedial decision-making process (i.e., assessment endpoints) and what measurements can be used to evaluate these effects. *An assessment endpoint is any specific value to be protected,* for example, a supply of uncontaminated fish for anglers to catch, survival of an endangered species, or maintenance of a particular population. *A measurement endpoint is a quantifiable characteristic related to an assessment endpoint,* such as the chemical concentration in water that correlates with contaminant levels of concern in fish tissues.

Ideally, measurement and assessment endpoints are the same, but this seldom is possible. For example, one can't trap endangered species and analyze their organs for contaminants. In this case, separate measurement endpoints are needed. Usually several measurement endpoints must be evaluated to determine the status of an assessment endpoint. It must be possible to link clearly the measurement endpoints to their respective assessment endpoints.

In addition, measurement endpoints should provide information about the source of the effects on the assessment endpoint. For example, it is not enough to know that eagles are not reproducing well at a site; a substance that can cause this effect (e.g., DDT) also must be present at the site, and the eagles must be exposed to it in some way (e.g., through contaminated fish). In this example, the assessment endpoint is eagle population maintenance, and the measurement endpoints are DDT residues in site soils and in fish (and perhaps facility records showing releases).

The linkages between the endpoints are as follows: Eagle population maintenance is of concern at the site   DDT was produced there and released   DDT causes reproductive failure in eagles   DDT is found in fish species that the eagles consume within their feeding areas eagles can reasonably consume enough DDT to cause reproductive effects.

It is not uncommon to redefine measurement endpoints during the analysis phase or after the scoping process given the heterogeneity of site habitats and the constraints of our knowledge base. Rationale for any changes should be documented.

Highlight F-11:
List of Sensitive Environments in the Hazard Ranking System.[a/]

Critical habitat for Federal designated endangered or threatened species
Marine Sanctuary
National Park
Designated Federal Wilderness Area
Areas identified under the Coastal Zone Management Act
Sensitive areas identified under the National Estuary Program or Near Coastal Waters Program
Critical areas identified under the Clean Lakes Program
National Monument
National Seashore Recreational Area
National Lakeshore Recreational Area

Habitat known to be used by Federal designated or proposed endangered or threatened species
National Preserve
National or State Wildlife Refuge
Unit of Coastal Barrier Resources System
Coastal Barrier (undeveloped)
Federal land designated for protection of natural ecosystems
Administratively Proposed Federal Wilderness Area
Spawning areas critical for the maintenance of fish/shellfish species within river, lake, or coastal tidal waters
Migratory pathways and feeding areas critical for maintenance of anadromous fish species within river reaches or areas in lakes or coastal tidal waters in which the fish spend extended periods of time
Terrestrial areas utilized for breeding by large or dense aggregations of animals
National river reach designated as Recreational

Habitat known to be used by state designated endangered or threatened species
Habitat known to be used by species under review as to its Federal endangered or threatened status
Coastal Barrier (partially developed)
Federal designated Scenic or Wild River

State land designated for wildlife or game management
State designated Scenic or Wild River
Stage designated Natural Areas
Particular areas, relatively small in size, important to maintenance of unique biotic communities

State designated areas for protection or maintenance of aquatic life

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[a/]The categories are listed in groups from those assigned higher factor values to those assigned lower factor values in the HRS. See *Federal Register*, Vol. 55, p. 51624 for additional information regarding definitions.

Other examples of assessment endpoints established at some mining sites include the following:

Reestablishing a self-sustaining trout (or other sport) fishery in affected surface waters;
Revegetation to control fugitive dust and erosion and to improve wildlife habitat;
Attainment of designated beneficial use for surface waters (although attainability analysis can indicate use limitations for a variety of reasons unrelated to the mining site); and
Attainment of the same level of water quality as upstream of the site.

Examples of measurement endpoints include:

Contaminant concentrations in surface water, sediments, and soils;
Contaminant concentration in fish tissues or other biota;
Toxicity of surface waters using surrogate species (e.g., fathead minnow) or assessment species (e.g., trout fry);
Plant root and shoot elongation bioassays using site soils; and
Presence/abundance of biological indicators of stream water quality (e.g., insect larvae).

Task 7: Use flow diagrams and maps to help define a conceptual model

In finalizing the conceptual model for the site, establish the following:

(1) A flow chart depicting how contaminants move from sources to receptors, including release mechanisms, secondary sources (e.g., contaminated soil), secondary release mechanisms (e.g., wind erosion), contaminant migration pathways (e.g., air, surface water), receptors (e.g., aquatic community) and routes of exposure (e.g., direct contact, food chain);

(2) A flow chart depicting how the proposed measurement endpoints can be used to infer the status of the assessment endpoints; and

(3) A map of the site depicting contaminant sources, migration pathways, key habitats, and potential exposure areas for receptors of concern. The map will be particularly helpful in establishing the spatial aspects of the field sampling plan.

Flow charts and maps can facilitate discussions among members of the site assessment team and the RPM, help identify gaps in data or logic, and identify the field sampling needs. Highlight F-12 provides an example of a flow chart for a conceptual model for the ecological risk assessment.

F.7 Identify Initial Project/Operable Unit and Remedial Action Objectives

Once the existing site information has been analyzed and a conceptual model of the site developed, the assessment team can identify the project/operable units, likely response scenarios, and remedial action objectives. This step requires close coordination of the ecological and human health assessment teams and is described in detail in EPA's Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA[10]. For each contaminated medium:

Identify potential remedial action technologies;
Begin review of technologies;
Identify likely alternatives; and
Identify need for treatability studies.

This step is particularly important for ecological concerns at mining sites, because restoration to pristine conditions generally is not possible and options for remediation can be limited by the magnitude and scope of the environmental contamination. *The ecological assessment should be focused within these constraints; otherwise, more effort may be expended on the assessment than is necessary or useful.*

Many of the adverse impacts of mining waste sites on terrestrial and aquatic habitats result from non-chemical stressors. The large-scale physical disturbances associated with former surface mining operations in particular can result in severely degraded landscapes. Once vegetation is lost and exposed soils erode for many years, decades may be required for reestablishment of vegetative cover by natural processes. Severe sedimentation of streams also is a common result of surface mining operations. Loss of trees on river banks can cause

[10] Environmental Protection Agency (EPA). 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA.* Office of Emergency and Remedial Response, Washington, DC. OSWER Directive No. 9355.3-01.

bank degradation and increase surface water temperatures. Even for those impacts or potential impacts that can be attributed to mining-related chemical stressors, options for remediation can be limited:

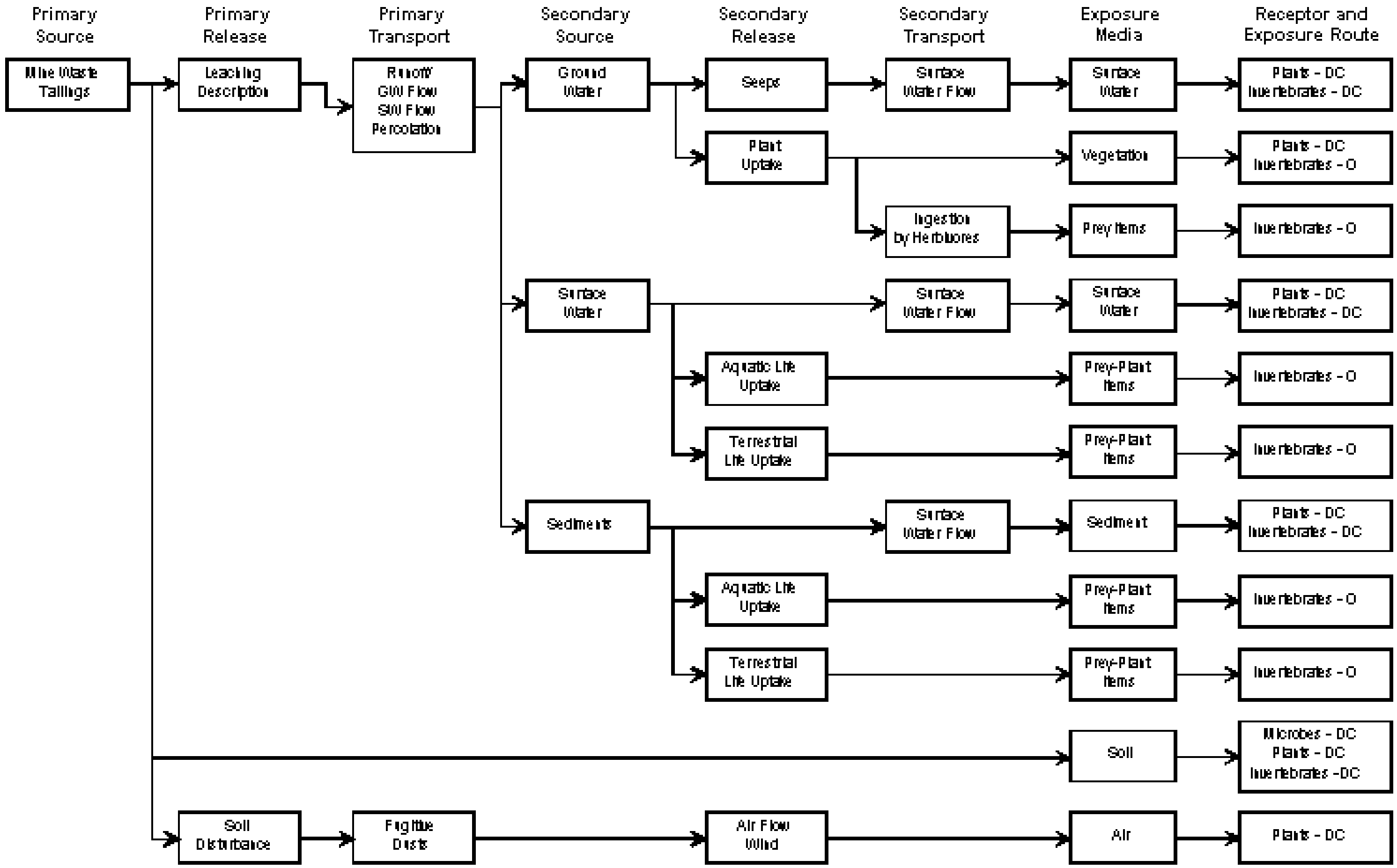
> Because of the large areas involved, it generally is not possible to reduce substantially contaminant levels in soils;
>
> Because of residual metal contamination in soils, it often is not possible to reestablish native vegetation; and
>
> Again, because of the large areas involved, it generally is not possible to excavate contaminated sediments in affected surface waters.

Sometimes more moderate goals can be met:

> Containment of sources of contamination to surface waters usually is possible; and
> Establishing some type of vegetative ground cover may be possible and important for control of erosion due to wind and precipitation as part of a containment strategy.

For older mining sites at which revegetation already has occurred naturally over waste pile areas, it may be preferable to leave the piles in place rather than to remove or disturb the piles and eliminate the established vegetation.

Highlight F-12
Example Flow Chart for a Conceptual Model for the Ecological Risk Assessment



Legend:

DC = Direct Contact
O = Oral

F.8 Initiate Potential Federal/State ARARs Identification

CERCLA requires that Superfund remedial action meet other federal and state standards, requirements, criteria, or limitations that are "applicable or relevant and appropriate" (ARARs). The on-scene coordinator (OSC) or the RPM must identify potential ARARs for each site. EPA's *Risk Assessment for Superfund: Volume 2 - Environmental Evaluation Manual*[11] summarizes ARARs relevant to ecological concerns at Superfund sites.

For mining sites with on-site or nearby surface water or wetlands, state water quality standards for designated uses of rivers, streams, or lakes are ARARs. These may include narrative free from toxics and antidegradation standards. State chemical-specific numeric standards usually are adopted or modified from EPA's Federal Ambient Water Quality Criteria (AWQC), which are ARARs in the absence of state standards for a particular contaminant or water condition. EPA's AWQC include criteria to protect fresh and salt water plants and animals and their habitats from acute and chronic exposures to toxic substances in surface waters (but not in sediments). EPA AWQC were promulgated pursuant to the Federal Water Pollution Control Act, as Amended (Clean Water Act). This law also requires protection of wetlands and other areas and may pertain in several ways to the remediation of mining sites located near wetlands or surface water bodies.

EPA's Storm Water Regulations (40 CFR Part 122) establish requirements for storm water discharges associated with "industrial activity", including inactive mining operations that discharge storm water contaminated by contact with, or that has come into contact with, any overburden, raw material, or waste products located on the site of such operations (inactive mining sites are mining sites that are not being actively mined, but which have an identifiable owner/operator) (40 CFR 122.26(b)(14)). See Appendix E for a further discussion of the implications of this ARAR to mining Superfund sites.

Other federal environmental statutes and regulations that include ecologically relevant ARARs are summarized below:

Endangered Species Act of 1973, as reauthorized in 1988. This Act requires federal agencies to ensure that their actions will not jeopardize the continued existence of any endangered or threatened species. Many mining sites are located in otherwise pristine areas that have historically supported a variety of wild flora and fauna, and the ecological assessment should determine if there is a possibility of endangered or threatened species in the vicinity of the site. If there is, EPA must consult with the FWS.

Fish and Wildlife Conservation Act of 1980. This Act requires states to identify significant habitats and develop conservation plans for these areas. The OSC or RPM should consult the responsible state agency to determine whether the mining site is located in one of these significant habitats.

Wild and Scenic Rivers Act of 1972. 0 This Act declares that certain rivers should be preserved. The ecological assessment should determine whether there are any designated Wild or Scenic rivers near the mining site.

[11] Environmental Protection Agency (EPA). 1989. *Risk Assessment Guidance for Superfund: Volume 2 - Environmental Evaluation Manual*. Interim Final. Office of Solid Waste, Office of Emergency and Remedial Response, Washington, DC. EPA/540/1-89/001A.

Fish and Wildlife Coordination Act, as amended in 1965. This Act states that the FWS must be consulted when bodies of water are diverted or modified by another federal agency.

The Migratory Bird Treaty Act of 1972. This statute protects almost all native bird species in the U.S. from unregulated "taking", which can include poisoning at hazardous waste sites. This Act would probably apply at many mining sites.

The Surface Mine Control and Reclamation Act of 1977. This Act requires that excavated surface mines be filled in with the overburden stripped from the mines, returning the area approximately to its original contour.

In addition to federal regulations, other state and local requirements also may be applicable or relevant and appropriate. Consult the *CERCLA Compliance With Other Laws Manual*[12] for more detailed information on ARARs and their relevance to Superfund cleanups of mining sites. Also, consult with the BTAG.

F.9 Identify Initial Data Quality Objectives (DQOs)

Chapter 7, Sampling and Analysis, discusses DQOs. The field data for site characterization must be accurate and amenable to statistical analysis. Consequently, DQO's reflect the statistical design of the study and the level of significance needed to support any conclusion that might be drawn from the study (see also *ECO Update*, Volume 1, Number 4[13]). In particular, the RPM should ensure that minimum sample sizes to allow statistically valid analyses are specified for each type of study or each study area. In general, the more variable the attribute being measured, the more samples will be required to demonstrate significant differences between control and test groups or between reference and study areas. Data quality objectives also should address sampling completeness, comparability, representativeness, precision, and accuracy, as described below.

Completeness. To ensure a complete data set for statistical analysis with acceptable confidence limits, minimum sampling requirements should be described and contingency plans established for problems that might occur and affect the completeness of the field data. For example, some sample locations may be inaccessible, some samples might not be analyzed for certain substances due to matrix interference, and other samples might be invalid due to holding time violations. It also is important to identify the environmental data that need to be collected concurrently with biological or chemical samples (e.g., water temperature, pH, dissolved oxygen, water hardness).

Representativeness. It is important that the sampling locations be representative of the media, habitats, and exposure areas at the site, i.e., that the locations are typical or characteristic of the media/habitat, and not unusual in some way that might bias the results.

Comparability. Combining results from several analytic techniques and sampling events usually is necessary for the baseline risk assessment. When toxicity tests or community surveys are conducted on samples from the site, analytic chemistry should be performed on samples taken from *the same location at the same time*. If sampling is conducted in more than one phase and data from different phases of the study are to be combined, special attention to

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[12] Environmental Protection Agency (EPA). 1988. *CERCLA Compliance with Other Laws Manual, Part 1.* Office of Emergency and Remedial Response, Washington, DC. OSWER Directive 9234.1-01.

[13] Op. Cit. 3.

factors that could affect sample comparability is needed (e.g., detection limits, sample preparation procedures, season or other time-variable attributes that might affect results).

Precision and Accuracy. The contractor's work plan should establish quality control procedures to ensure precision and accuracy for field work and laboratory analyses for activities including sample handling, controls for tests, and numbers of replicate analyses. Use of standardized methods, when appropriate, facilitates quality control; standardized protocols can be found in EPA manuals and are utilized by the contract laboratories that routinely conduct tests for EPA. As described in *ECO Update*, Volume 1, Number 4[14], some laboratories have established standard quality control procedures for aquatic toxicity tests conducted under the National Pollutant Discharge Elimination System (NPDES) (e.g., with fathead minnows, *Daphnia*, algae). Many states have certification programs for these laboratories' tests. For less standardized procedures, appropriate quality control measures need to be specified. For example, an independent taxonomist could enumerate and classify the organisms found in a randomly selected set of benthic invertebrate samples.

F.10 Prepare Statement of Work for the Site Characterization Phase

The project requirements for the RI/FS should be identified and documented in a statement of work (SOW) developed by EPA. The contractor or PRP performing the field investigation then develops project plans including the work plan, sampling and analysis plan, and field sampling plans (Highlight F-6) that address the SOW. The project plans for the ecological assessment need to be developed in conjunction with the human health risk assessment team. The RPM should schedule a review of the contractor or PRP's work plan by the BTAG before field work begins. In several Regions, BTAGs have prepared example SOWs or other guidance materials for RPMs. *ECO Update*, Volume 1, Number 4[15] explains how to develop a SOW.

Overview. The SOW and project plans for the RI should define the objectives of the study, the proposed field or laboratory methods (with appropriate reference to Agency guidelines or other sources), expected sampling locations and sizes, the statistical methods to be used, and data quality objectives and control procedures. The success of a work plan for the RI site characterization and baseline risk assessment may be enhanced considerably by developing preliminary hypotheses regarding:

- Contaminant sources and migration pathways;
- The nature and extent of existing contamination at the site;
- The potential for future releases and further contamination at the site; and
- The number and types of habitats that might be contaminated now or in the future.

These preliminary hypotheses, in turn, will assist in identifying or determining:

- Specific areas at the site and in the surrounding area that need to be sampled or surveyed; and
- The number of chemical samples (and sampling locations) that will be required to adequately characterize the existing or potential future contamination.

The SOW and work plan also should discuss how decisions will be made about the need for additional studies.

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[14] Ibid.

[15] Op. Cit. 3.

Specific tasks. The remainder of this section outlines specific tasks associated with developing initial hypotheses about existing and potential future contamination. As a general rule, it is helpful to focus first on areas of known contamination and sources that have released contaminants, develop hypotheses regarding the magnitude and areal extent of known contamination, and then develop hypotheses regarding the potential for future contamination.

Task 1: Coordinate with human health assessment team

Usually, the ecological assessors identify areas and types of samples that are needed in addition to those identified by the human health team. If the human health assessment team has the lead in developing the field sampling plan, the ecological assessment team must review the plan to determine if additional samples are required for the ecological assessment.

Task 2: Coordinate with natural resource trustees and the BTAG

The success and efficiency of the site sampling effort will be enhanced considerably by close coordination with the natural resource trustees and the BTAG. At a minimum, trustees should be involved in review of the initial and final sampling plans. Because trustees are required to quantify natural resource injury and damage, they might need to conduct sampling beyond what EPA needs for a baseline risk assessment. For example, the trustee may need to demonstrate the areal extent of resource injury, while EPA may need only to demonstrate risk to those resources. Because BTAGs generally include representatives from natural resource trustees as well as provide technical assistance for conducting ecological risk assessments, the BTAG also can help determine which types of samples are likely to be the responsibility of the trustees and which should be collected by EPA.

Task 3: Delineate potential assessment areas

Often, large mining sites are subdivided into several operable units. The conceptual model of the site should provide an overview of the relationship among operable units and the entire watershed. To develop field sampling plans, however, it can be helpful to subdivide the site or operable units into areas that may require different sampling strategies. Using the site map developed with the conceptual model of the site, delineate areas on the map that may require different investigation strategies. Usually, separate "assessment areas" should be delineated *for each combination* of the following factors:

- Type of medium being sampled (e.g., sediment, water, fish tissues);
- Habitat or ecological receptor;
- Contaminants of concern;
- Level of contamination (e.g., close to a source, more distant, deposition area in a stream);
- Type of remediation likely, and
- Expected response (either in terms of speed or type of response, e.g., reduced contaminant concentrations) to potential remedial actions.

Within each assessment area, determine whether any sampling location within the area could be considered representative of the area or if a gradient of contamination is expected. To maximize the efficiency of possible sampling designs, delineate assessment areas that are as large as possible. Potential assessment areas may be refined based on site visits and as hypotheses are accepted or new hypotheses are developed.

If more than one medium is to be sampled in a given type of habitat, the size of the assessment areas may be different for each medium. For example, a set of sediment samples may be considered representative of only a small portion of the length and width of a river, whereas a set of tissue residue levels taken from fish captured at the same locations may be considered representative of a larger section of the river.

The 1989 Record of Decision for Commencement Bay (Washington state), the Near-shore/Tideflats operable unit, although not a mining site, provides an example of how assessment areas (or segments) can assist in data analysis and identifying areas in need of remediation at large sites. At this site, the waterways leading to Commencement Bay were subdivided into segments based on proximity of sources, length of the waterway, and changes in the waterways' configuration. For each segment, three to ten sampling stations were established to represent the segment. Measures taken at most sampling stations included contaminant concentrations in sediments, sediment toxicity bioassays, and benthic infauna abundances. It was assumed that a segment would require no action unless at least one of the indicators of contamination, toxicity, or biological effects was significantly elevated above reference conditions.

Task 4: Develop specific hypotheses to be tested about the nature and extent of contamination

In order to design an RI sampling plan that will allow attribution of observed contamination to site sources, it is important to develop hypotheses concerning how the contaminants might have migrated from the sources. Use of the site map developed for the conceptual model is helpful in this step. For example, one hypothesis might be that observed contamination in a wetland is the result of runoff or leachate from a mining waste pile. Information required to evaluate the hypothesis might include groundwater and soil samples upgradient of the waste pile and between the waste pile and the wetland, groundwater and soil samples at other points upgradient of the wetland (to determine whether other sources may have contributed to the observed contamination), and the presence of other physical signs of contamination between the waste pile and the wetland (and/or between the wetland and other potential sources).

Task 5: Identify specific data needs for chemical sampling in abiotic media

For each proposed assessment area, identify the specific information that will be provided by chemical and/or other types of samples. Types of information that can be provided by chemical sampling include:

Verifying or delineating contaminant migration pathways;
Delineating areal extent of existing contamination;
Identifying hot spots (e.g., highly contaminated deposition areas);
Verifying known or suspected contamination at specific locations;
Determining background levels; and
Determining gradients of contamination in relation to known sources.

Task 6: Develop specific hypotheses about ecological exposures and effects

Using the site maps, one can overlay the location of various habitats with the expected pattern of contamination. The conceptual model then can be used to identify hypotheses about potential ecological impacts. For example, one hypothesis might be that the metals present in soils and sediments are not bioavailable, and therefore are not toxic to the potential receptor organisms. Another hypothesis might be that surface water toxicity to adult fish is less important than sediment toxicity to the eggs and fry in limiting the resident fish populations.

Task 7: Identify specific biological data needs

There are four general types of biological samples that may assist in testing hypotheses about ecological impacts: tissue residue samples, toxicity tests, biological field surveys, and biomarkers. We discuss circumstances under which each of the biological sampling methods might or might not be recommended for an ecological risk assessment below. *Note that EPA does not need to demonstrate conclusively that site contaminants caused existing impacts; EPA need only demonstrate a* ***risk*** *of these impacts now or in the future to justify remedial action.*

Tissue residue samples of fish, invertebrates, or other biota generally should be collected if there is reason to suspect that these biota have been exposed to contaminants that are likely to bioconcentrate (i.e., concentrate in tissues of aquatic organisms at levels higher than the surrounding water). If a contaminant is known or expected to bioaccumulate (i.e., is found at higher concentrations in organisms at each higher step in a food chain), samples should be taken from biota at two or more trophic levels (e.g., plant, herbivore, carnivore) along with the environmental media to which the biota are exposed. This is important because site-specific conditions influence the magnitude of bioaccumulation, and most estimates of bioaccumulation include a large range of uncertainty. Edible tissues (e.g., fillets) generally are sampled for human health risk assessments; however, whole-body samples are more appropriate for ecological risk assessments.

Toxicity tests evaluate the effects of contaminated media on the survival, growth, behavior, reproduction, and/or metabolism of test organisms. Toxicity tests conducted in the laboratory generally use standard laboratory organisms (e.g., *Daphnia*, fathead minnows). Toxicity tests conducted *in situ* (e.g., by caging test animals in the study area) can be used to evaluate toxicity or bioavailability to the particular organisms of interest at the site. Toxicity tests generally are recommended if:

> The bioavailability of contaminants in particular media (e.g., sediments) is unknown, which often is the case with contaminants at mining sites;
>
> The contaminants are toxic below quantitation limits;
>
> The toxicity of a particular site-specific mixture of contaminants in a given area cannot be estimated readily; and
>
> Supporting evidence for a hypothesized link between observed (or potential future) contamination and adverse impacts is needed to make a remedial decision.

Which specific toxicity tests are most appropriate depends on the assessment endpoints. EPA's *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference*[16] reviews aquatic, terrestrial, and microbial toxicity test methods, including both "off-the-shelf" methods and innovative procedures. Specific toxicity test protocols continue to be developed, and the BTAG should be consulted to ensure that the most up-to-date protocols are used.

Biological field surveys need not be extensive, although they do require matching surveys from an appropriate reference area for their interpretation. Field studies offer direct or

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[16] Environmental Protection Agency (EPA). 1989. *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference*. Office of Research and Development, Environmental Research Laboratory, Corvallis, OR. EPA/600/3-89/013.

corroborative evidence of a link between contamination and existing ecological impacts but are not required for most assessments. For example, field studies can be used to:

- Document or verify the absence or reduced abundance of key native species;
- Evaluate suitability of habitats for wildlife species of concern;
- Identify evidence of stress (e.g., stressed or dead vegetation, bare soil and erosion);
- Identify changes in community structure (e.g., reduced biodiversity, altered species composition);
- Illustrate an increased incidence of lesions, tumors, or other pathologies; and
- Document the presence or increased abundance of species associated primarily with contaminated habitats.

If wetlands exist on or near the site, a functional evaluation of wetlands (e.g., value as wildlife habitat, for pollution abatement, or flood control) might be appropriate. EPA's *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference*[17] includes a review of field survey methods for aquatic ecosystems and terrestrial vegetation, invertebrates, and vertebrates.

Biomarkers of exposure (e.g., enzyme activity) can be measured to verify that organisms inhabiting contaminated areas actually have been exposed to site contaminants. Given the propensity of some metals to bioaccumulate as well as the availability of sensitive and accurate techniques for routine detection of metals in biological samples, indirect indices for exposure to metals generally are not needed. Erythrocyte ALAD (delta-aminolevulinic acid deyhdratase, a cytosolic enzyme), an indicator of lead exposure, is an exception, because it can be measured in blood samples, which allows non-destructive sampling. The Field and Laboratory Reference[18] gives examples of ALAD's use as an indicator of lead exposure in fish, waterfowl, and mammals.

Highlight F-13 summarizes general types of chemical and biological studies that might be used at Superfund mining sites and the information provided by each type.

Task 8: Coordinate data collection efforts with natural resource trustees

At some sites, natural resource trustees might need to use biological surveys to document and quantify existing damages to trustee resources from site contaminants. It is very important to coordinate data collection activities with the natural resource trustees:

- To avoid duplication of effort;
- To maximize the usefulness of each type of data collected; and
- To maximize the efficiency of data collection.

EPA has developed a Superfund fact sheet that explains in more detail how to coordinate ecological data collection activities with natural resource trustees.

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[17] Ibid.

[18] Ibid.

Task 9: Develop initial field sampling plan

In conjunction with the human health assessment team, develop an initial field sampling plan for the site characterization phase of the RI. Sampling locations established in the initial sampling plan should address all relevant sources, existing contaminant migration pathways, potential future contaminant migration pathways, and habitats of concern. Using the conceptual model of the site as a guide, the initial field sampling plan should include at least the following:

- A list of specific hypotheses to be tested with sampling;
- For each hypothesis, the type of information that would support or reject the hypothesis;
- For each hypothesis, the type(s) of samples or observations that will provide the required information;
- A preliminary delineation of specific assessment areas to be sampled; and
- A listing of available sampling information for each assessment area.

For each proposed assessment area and type of sample (e.g., metals in soils), the field sampling plan should determine the number of samples to collect and the specific locations for each sample. This is one of the most difficult tasks in preparing the project plans. A trade-off exists between the number of samples taken (and hence degree of certainty) versus the time, effort, and expense involved in obtaining and analyzing each sample. Suggestions on how to select the location and number of surface water and sediment samples are contained in the appendices to EPA's *Oversight* document[19] and in EPA's *Standard Operating Procedure Manual*[20]. These documents provide basic rules of thumb for determining number of sampling locations for rivers, streams, and creeks (examples in Highlight F-14); for lakes and ponds (examples in Highlight F-15); for impoundments and lagoons; and for estuaries. Some general suggestions to help in developing a field sampling plan for each assessment area follow.

Hypotheses to test. Begin with the hypotheses identified in Tasks 4 and 6 about contaminant sources, migration pathways, extent of contamination, bioavailability, and other concerns. It may help to redefine some of the assessment areas in light of the hypotheses to be tested.

Sample locations. Within each assessment area, begin with the location where contaminant concentrations are expected to be greatest. These may include the point(s) at which contaminants are most likely to enter the assessment area (e.g., the point of groundwater discharge into surface water), the point(s) in the assessment area closest to key sources, and points where soils, sediments, tailings, or other debris are likely to accumulate (e.g., bends in rivers where sediments accumulate). Second, estimate the potential extent of contamination. Sampling information obtained for HRS scoring and evidence visible in aerial photographs (e.g., tailings, sediment deposits) might help determine tentative sampling distance limits. Third, select sampling locations between the sources and the expected sampling distance limits and just beyond those limits. Where appropriate, use rules of thumb as shown in Highlights F-14 and F-15. If during the field sampling, contamination attributable to the site is found beyond the tentative sampling distance limit, it may be necessary to collect more distant samples to determine the full extent of contamination.

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[19] Environmental Protection Agency (EPA). 1991. *Guidance on Oversight of Potentially Responsible Party Remedial Investigations and Feasibility Studies, Volume 2, Appendices.* Office of Solid Waste and Emergency Response, Washington, DC. OSWER Directive 9835.1 (c). EPA/540/G-91/010b.

[20] Environmental Protection Agency (EPA). 1986. *Engineering Support Branch, Standard Operating Procedures and Quality Assurance Manual*. Region IV, Environmental Services Division.

Highlight F-13:
General Types of Studies and the Information They Provide

Type of Study	Information Provided
Samples of abiotic environmental media (e.g., surface water, soils, sediments)	Concentrations of specific contaminants in environmental media at sampling point Elevated concentrations demonstrate that contaminants have reached sampling point Concentrations can be compared to ecological benchmark levels to assess risk
Tissue residue samples of fish, invertebrates, or other biota (e.g., edible tissues, specific tissues such as liver, whole body)	Concentrations of specific contaminants in specific tissues and/or whole body of organism Elevated concentrations demonstrate that organism has been exposed to contaminants Concentrations can be compared to predicted levels to calibrate bioaccumulation and exposure models Concentrations can be used to directly estimate dietary exposures at the next trophic level
Toxicity tests (laboratory or *in situ*) using soils, sediments, or surface water from the site	Bioavailability of contaminants in environmental medium or media Toxicity of specific mixture of contaminants in environmental medium or media May provide supporting evidence for a link between contamination and adverse impacts
Biological surveys of population abundance or community structure	Documentation or verification of altered populations or communities Absence, abundance, or density of particular species Community structure (e.g., species diversity, species composition)
Biomarkers of exposure or effects (e.g., biochemical or physiological markers; lesions, tumors, or other morphological abnormalities)	Specific biochemical or physiological changes may demonstrate that organism has been exposed to particular contaminants Increased incidence of gross pathologies or morphological changes demonstrates that organisms are experiencing adverse impacts May provide supporting evidence for a link between contamination and adverse impacts.

Task 10: Determine location and number of required samples

Highlight F-14:
Example Rules of Thumb for Sample Collection in Rivers, Streams, and Creeks

To ensure representativeness, samples should be taken immediately downstream of a turbulent area, or downstream of any marked physical change in the stream channel.
At least three locations between any two points of major change in a stream (such as waste discharge or tributary) should be sampled to adequately represent the stream.
Typically, sediment deposits in streams collect most heavily in river bends, downstream of islands, and downstream of obstructions in the water.
Samples should not be taken immediately upstream or downstream from the confluence of two streams or rivers because of the possibility of backflow and inadequate mixing.

Highlight F-15:
Example Rules of Thumb for Sample Collection in Lakes and Ponds

If stratification is present in a lake or pond, each layer of the stratified water column should be sampled separately. Stratification can be determined with temperature, specific conductance, pH, or dissolved oxygen vertical profiles.
In ponds, a single vertical composite at the deepest point may be representative. In naturally formed ponds, the deepest point is usually near the center.
In lakes, several vertical composites should be taken along a transect or grid in order to ensure that the samples are representative.
Sediment samples in lakes, ponds, or reservoirs should be collected approximately at the center of the water mass where contaminated fine-grained materials are most likely to collect.

Sample number. EPA's *Oversight* document[21] and *Standard Operating Procedure Manual*[22] provide some rules of thumb for determining a minimum number of samples to obtain (example in Highlight F-14). The variability in contaminant concentrations among samples will influence the number of samples required to characterize an area within specified statistical confidence limits. Estimate the expected variability among samples. Sampling results from other Superfund mining waste sites might be helpful in determining how much variability may be expected and how many samples are needed per unit area.

Sampling times. Determine the times of year or conditional events (e.g., snow melt) when samples should be collected. It is best to collect media samples during periods when environmental conditions favor the concentration of chemicals in environmental media (e.g., avoid high-flow conditions unless immediately following a storm event that might increase contaminant concentrations in the surface water via runoff).

Reference area. Finally, reference samples should be taken from an appropriate reference area (see section F.5, Task 7) to determine background levels of contamination.

Iterative process. It can be helpful to determine the number and locations of samples iteratively, starting with an initial, general plan for each assessment area, and refining these

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[21] Op. Cit. 19.

[22] Op. Cit. 20.

plans based on the specific sampling requirements for the area and how these relate to the requirements for other areas. *ECO Update* Volume 1, Number 4[23], explains this phased approach in more details.

Sampling plan. Once the number of samples that are needed for each assessment area is determined, expected sampling locations (including detailed maps) and sampling dates should be specified (and time of day if important).

Task 11: If needed, plan further site visit(s) to characterize potential ecological receptors

If any questions remain concerning the potential ecological receptors of concern (e.g., species present, habitat characteristics), another site visit with a trained ecologist/biologist(s) should be planned (see section H.5, Tasks 7 and 8). If a Preliminary Natural Resource Survey (PNRS) is needed and has not yet been conducted, the natural resource trustees should be encouraged to conduct the preliminary PNRS at this time.

F.11 Ecological Risk Assessment Guidance

After the initial sampling and studies for the RI are completed, the data are evaluated to determine if the baseline ecological assessment can be completed based on the data. This section describes the steps of the ecological assessment by which this determination is made. Section H.12 describes the objectives and rationale of the ecological assessment. The remaining sections describe the assessment in terms of the three components of ecological risk assessment: exposure assessment (section H.13), ecological effects assessment (section H.14), and risk characterization (section H.15).

F.12 Objectives and Rationale

As described in section H.4, the baseline ecological risk assessment should provide the information to answer key questions:

> Is there a potential for an adverse effect on ecological receptors; and
> If there is, what type of remedy would be needed to be protective?

In addition, the ecological risk assessment should:

> Describe the observed or potential magnitude of adverse ecological effects at the site and the primary cause of the effects; and
> Characterize the ecological consequences of the "no further action" remedial alternative;
> Determine if special measures need to be taken during remediation to protect habitats; and
> Determine what monitoring will be needed to ensure protection of ecological receptors during and after remediation.

During the ecological assessment, the data obtained during the initial RI site studies are used to refine information on the extent and magnitude of existing contamination of soils, other surface

23 Op. Cit. 3.

substrates, surface waters, and sediments; to determine whether nearby habitats are contaminated; and to determine whether levels of contamination are sufficiently high to pose a reasonable likelihood of ecological risk now or in the future. For enforcement lead sites, a key purpose of the ecological assessment is to determine whether information is sufficient to establish and to defend an endangerment finding. It is not necessary to *prove* that impacts *are occurring* as a result of site contaminants, however (see Highlight F-16).

Highlight F-16:
Objectives of the Baseline Ecological Risk Assessment

The baseline ecological risk assessment summarizes information on contamination and observed impacts to determine whether existing contamination is likely to result in significant risk, and to determine whether additional information is required to identify remedial alternatives and goals that are protective of ecological receptors. For this assessment, it is not necessary to conduct detailed studies to demonstrate a definitive causal link between existing contamination and observed impacts. The ecological risk assessment does not have to prove that impacts are occurring as a result of contamination; instead, the risk assessment need only demonstrate that the release poses a risk of impacts.

Although EPA's remedial measures must eliminate, reduce, or control risks to the environment, it is not necessary for these measures to *restore or replace* affected natural resources. Restoration or replacement generally is the responsibility of the natural resource trustees unless the remedy itself results in injury to natural resources. For example, EPA may need to replace a wetland that is capped to prevent further contaminant migration, but EPA may not need to restore a contaminated wetland if the remedy prevents further migration of contaminants to that wetland.

It can be easier to demonstrate that a community (e.g., aquatic community, soil invertebrate community, terrestrial plant community) is at risk of adverse effects than to demonstrate that a given wildlife population is at risk. If one can delineate areas of a habitat that are contaminated at levels that might harm a proportion of the community or a key community species (e.g., the dominant species of vegetation), one can predict that the portion of the community present within these areas is at risk of adverse effects. Questions for a community-level assessment might include:

> Are the hot spots at the site sufficiently contaminated to impair the community? What proportion of the community is contaminated at levels that could result in chronic adverse effects?

For a population-level (species-specific) assessment, one needs to ask different questions:

> If an animal were to obtain a single prey or a single day's worth of food from a hot spot at the site, would it be at risk of acute poisoning?
>
> If an animal is not at risk of acute poisoning, is a large enough proportion of the home range of a single animal contaminated at sufficient levels that the animal might suffer chronic effects from longer-term exposures?
>
> How many individuals of a species might be exposed above acute and/or chronic toxicity benchmarks?

The remainder of this section outlines specific tasks associated with analyzing the field data to complete the ecological risk assessment (i.e., exposure assessment, ecological effects assessment, and risk characterization), distinguishing community-level from population-level considerations.

F.13 Exposure Assessment

The exposure assessment quantifies the magnitude and type of actual or potential exposures of ecological receptors to site contaminants. It includes four key elements:

Documenting contaminant release, migration, and fate;
Characterizing receptors;
Measuring or estimating exposure concentrations; and
Analyzing uncertainty.

Quantifying release, migration, and fate For detailed guidance on quantifying contaminant release, migration, and fate, consult EPA's *Risk Assessment Guidance for Superfund: Volumes* 1[24] and 2[25] and the *Exposure Assessment Guidelines*[26]. In addition, the Exposure Factors Handbook, Office of Research and Development (ORD), EPA 1996, should be considered as a source.` Parameters critical for determining the environmental behavior of contaminants, including transport through the environment (e.g., through air or the food chain), include physical transformation (e.g., volatilization, absorption, precipitation), chemical transformation (e.g., photolysis, hydrolysis, oxidation, reduction), biological transformation (e.g., biodegradation), persistence, and bioaccumulation.

Characterizing receptors Although assessment endpoints and receptors were selected during the scoping phase of the RI, new information from the field investigation should be evaluated to determine whether there may be populations, species, or communities exposed other than those that were identified initially. Any gaps in information needed to characterize receptors should be identified. Receptor characterization differs for community-level and population-level assessments, as described below.

Community-level assessments. If terrestrial, wetland, or aquatic communities are components of the assessment endpoint, key attributes of the communities that help define the measurement endpoints need to be characterized (e.g., dominant vegetation; species composition of a cold-water fishery).

Population-level assessments. If populations of selected species (e.g., an endangered species) have been designated as receptors for evaluation, determine the potential relationship that the animals' foraging, drinking, and other activities have to the spatial extent of contamination at the site. If contaminants are known or expected to bioaccumulate, identify the trophic level of the species of concern (i.e., the approximate number of steps in the food chain from primary producers to the animal in question). Initially, it would be appropriate to assume the highest trophic level consistent with a species' dietary habits. EPA's *Great Lakes Water Quality*

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[24] Environmental Protection Agency (EPA). 1989. *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual*. Interim Final. Office of Solid Waste, Office of Emergency and Remedial Response, Washington, DC. EPA/540/1-89/002.

[25] Op. Cit. 11.

[26] Environmental Protection Agency (EPA). 1992. *Guidelines for Exposure Assessment.* Science Advisory Board, Washington, DC.

Initiative[27] has assumed that mink, kingfishers, and ospreys feed at trophic level 3, that otters obtain half of their diet at trophic level 3 and half at trophic level 4, and that bald eagles feed at trophic level 4. EPA has not yet developed guidance for determining trophic levels. Consult with the BTAG for advice.

Measuring or estimating exposure concentrations EPA's *Framework for Ecological Risk Assessment*[28] defines exposure as the co-occurrence of or contact between a stressor and an ecological component. The receptors of concern dictate how one evaluates patterns of contamination in time and space to predict potential impacts. In this section, we describe approaches to defining exposure concentrations for community-level and population-level assessments.

Community-level assessments. Most community assessments require comparison of chemical concentrations in key media (e.g., surface water, sediments, or soil) to benchmark levels for these media above which adverse community-level effects might be expected. It may be useful to overlay a map of the communities of concern at the site with a map of the contamination pattern found during the field investigation.

The values measured during the initial field sampling of the RI can be used to estimate current exposure levels. Fate-and-transport models are needed to predict the movement of contaminants in the future. In some cases, it may be difficult to measure existing contamination during site visits (e.g., some areas may be flooded, streams may be in high flow, certain locations may be physically inaccessible or too dangerous to sample). In these cases, modeling and estimation techniques can be used in place of field sampling results.

There are two basic options for evaluating current or future environmental concentrations:

> Estimating environmental concentrations only at the point of maximum predicted concentration in each assessment area (or community) to allow a point estimate of risk; and
>
> Estimating the areal extent of contaminant concentrations in each assessment area or community to allow an areal estimate of potential impacts (e.g., 10 stream miles or 5 acres exposed above benchmark levels).

The basic information provided by the point estimate of risk is a quantitative estimate of the number of habitats or areas likely to be contaminated above ecological benchmark levels. The basic information provided by the areal estimate of risk includes a quantitative estimate of the total amount (or proportion) of each habitat or area likely to be contaminated above ecological benchmark levels.

The first of these two options might serve as an initial step to identify assessment areas to which the second option might apply. The second option might be helpful in comparing relative risks. For example, chemical concentrations could be measured at the location(s) where contamination is predicted to be maximal (e.g., point where groundwater discharges into surface water). If these measured concentrations fall below ecological benchmarks, it is unlikely that further evaluation of the pathway(s) will be needed. In contrast, if the measured concentrations exceed ecological benchmarks, it may be useful to estimate the areal extent of the benchmark exceedance. If a benchmark for chronic exposures is exceeded over a small

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[27] Environmental Protection Agency (EPA). 1992. *Great Lakes Water Quality Initiative Procedure for Deriving Criteria for the Protection of Wildlife,* Draft. Office of Research and Development, Environmental Research Laboratory, Duluth, MN.

[28] Op. Cit. 1.

stream reach (e.g., 10 meters), few impacts on a local fish population might be expected. If, on the other hand, chronic benchmarks were exceeded for many miles, significant impacts on the fish population are possible.

Species-level assessments. If one or more species have been designated for evaluation, the home range size of these species should be used in determining the area over which to evaluate contaminant concentrations. When assessing risks to wildlife species exposed to chemicals, potential dose is often the metric used. Potential dose is described as the amount of chemical in food or water ingested, air inhaled, or material applied to the skin[29]. Potential dose is analogous to the administered dose in a toxicity test.

Equation for estimating potential dose. A general equation for estimating potential average daily dose (ADD_{pot}) for chronic exposures (i.e., at least a few weeks) is

$$ADD_{pot} = [C \times IR] / Wt \qquad \text{(equation 1)}$$

where

ADD_{pot} = potential average daily dose (e.g., mg contaminant/kg body weight-day),
C = contaminant concentration in the contacted medium (e.g., mg/kg in food or water),
IR = ingestion rate measured as mass (wet weight) ingested by an animal per unit time (e.g., kg/day), and
Wt = fresh body weight of the animal (e.g., in kg).

This simplified equation assumes that C and IR are constant over time, or averaged over the exposure duration. Highlight F-17 presents two wildlife oral exposure equations corresponding to two patterns of contamination of water or food:

(1) The animal obtains some of its water or food from a contaminated source and the remainder from uncontaminated sources; and

(2) The animal consumes water or food from several sources that are contaminated at different levels.

A frequency term (FR) has been added to the first equation to denote the fraction of time that an animal is exposed to contaminated media (e.g., is present on the site). The concentration (C) equals the mean value of the contaminant concentration in a single water or food source. The second equation can be used when different water or food sources are likely to be contaminated at different levels. In this case, consumption from different sources is weighted by the proportion (P_i) of the animal's total daily intake obtained from each source. FR and P_i in Highlight F-17 are functions of the degree of overlap of the contaminated resources and the animal's home range. EPA's *Wildlife Exposure Factors Handbook*[30] provides a more detailed discussion of these and other equations that can be used to calculate contaminant intakes for species that consume more than one type of food.

For substances that bioaccumulate (see Highlight F-18), if measures of contaminant concentrations in potential prey are unavailable, one should include a food-chain transfer model for receptor species that feed at the higher trophic levels. For piscivorous wildlife (e.g., osprey,

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[29] Op. Cit. 24.

[30] Environmental Protection Agency (EPA). 1992. *Wildlife Exposure Factors Handbook*. Prepared for the Office of Research and Development, Office of Emergency and Remedial Response, and Office of Water by ICF Incorporated.

bald eagle, mink, otter), the contaminant concentration in the prey is the concentration in the contacted medium in equation 1. For aquatic food chains,

$$C_{prey} = C_{SW} \times BAF_N \qquad \text{(equation 2)}$$

where

C_{prey} = contaminant concentration in the prey (e.g., in mg contaminant/kg wet weight of the prey),
C_{SW} = contaminant concentration in surface water (e.g., in mg/L), and
BAF_N = trophic level (N)-specific bioaccumulation factor (e.g., L/kg).

Thus, the potential dose can be calculated in one step as shown in Highlight F-19.

Highlight F-17:
Recommended Wildlife Exposure Equations for Oral Exposure

One Source of Contamination:

$$ADD_{pot} = [C \times IR \times FR] / Wt$$

Different Sources with Varying Levels of Contamination:

$$ADD_{pot} = [\sum_{i=1}^{n} (C_i \times P_i) \times IR] / Wt$$

ADD_{pot} = potential average daily dose (e.g., mg contaminant/kg body weight-day).
C = average contaminant concentration in a single water or food source (e.g., in mg/L or mg/kg).
IR = ingestion rate measured as mass (wet weight) ingested by an animal per unit time (e.g., kg/day).
FR = fraction of intake from contaminated material (unitless).
Wt = fresh body weight of the animal (e.g., in kg).
n = total number of sources.
C_i = contaminant concentration in the ith water or food source (e.g., in mg/L or mg/kg).
P_i = proportion of water or food consumed from the ith source (unitless).

Bioaccumulation potential is the measure of the tendency for chemicals to preferentially concentrate in the tissues of living organisms. There are two general measures: (1) the bioconcentration factor (BCF), i.e., the equilibrium ratio of the concentration of a chemical in the tissue and its concentration in ambient water, in situations where the organism is exposed through the water only; and (2) the bioaccumulation factor (BAF), i.e., the equilibrium ratio of the concentration of a chemical in the tissue to its concentration in an environmental medium where the organism and the food chain both are exposed.

The BAF_N can be estimated in one of three ways (listed in order of preference):

(1) Measured in the field for organisms at trophic level N;

(2) A BCF measured in the laboratory (preferably on a fish species) multiplied by an appropriate food chain multiplier; or

(3) A BCF estimated from the log of the octanol-water partition coefficient (K_{ow}) multiplied by an appropriate food chain multiplier. This method will not work for most metals because their propensity to bioaccumulate is not a function of the lipophilic properties of the compound.

Highlight F-18:
Metals That May Bioaccumulate

Metals for which measured log bioconcentration factors (BCFs) for one or more chemical species exceed 3:

Cadmium	Copper
Lead	Manganese
Mercury	Selenium
Zinc	

For most inorganic substances, BAFs equal BCFs, although bioaccumulation of some trace metals is substantially greater in internal organs than in muscle tissue in fish. For example, BCFs for rainbow trout liver and muscle exposed to cadmium for 178 days were about 325 and 1 respectively.[31] A food chain multiplier greater than one is applicable to most lipophilic organic chemicals with a log K_{ow} of four or more.

BAFs and BCFs can be found in EPA water quality criteria documents, published papers, the AQUIRE data base, and other reliable sources. An uncertainty analysis is particularly important for food chain models because the results of the models are highly sensitive to the magnitude of the BAF used, which may or may not be appropriate for that particular site or prey. The uncertainty can be reduced substantially by measuring contaminant levels in the prey of the assessment species. Generally, whole body contaminant levels are needed, not just fillet contaminant levels as might be measured for the human health assessment.

F.14 Ecological Effects Assessment

Ecological effects assessment consists of quantifying the relationship between exposure concentrations and adverse effects in ecological receptors. Existing ARARs for the protection of aquatic life (i.e., state water quality standards, EPA's AWQC), published studies, biological field studies at the site, and/or toxicity testing can provide the 'dose-response' information. It usually is not necessary to quantify the full dose-response curve; determining what exposure level represents a threshold for an adverse effect can suffice. In this appendix, we refer to this threshold as a toxicity benchmark.

In the remainder of this section, we first discuss both community-level and species-level toxicity benchmarks. By comparing exposure levels with benchmark values developed from available literature, the site assessors can decide whether they need to proceed further with ecological effects investigations such as toxicity tests or field studies.

[31] Giles, M.A. 1988. Accumulation of cadmium by rainbow trout, *Salmo gairdneri*, during extended exposure. Canadian Journal of Aquatic Science 45:1045-1053.

Highlight F-19:
Recommended Wildlife Aquatic Food-Chain Exposure Equations

Prey from One Trophic Level:

$$ADD_{pot} = [C_{SW} \times BAF_N \times IR] / Wt$$

Prey from More than One Trophic Level

$$ADD_{pot} = [\sum_{I=1}^{n} (C_{SW} \times BAF_{Ni} \times P_i) \times IR] / Wt$$

ADD_{pot} =	average daily potential dose (e.g., mg/kg-day).
C_{SW} =	average contaminant concentration in surface water within the animal's home range (e.g., mg/L).
BAF_N =	trophic level (N)-specific bioaccumulation factor (e.g., L/kg).
IR =	ingestion rate measured as mass (wet weight) ingested by an animal per unit time (e.g., kg/day).
Wt =	fresh body weight of the animal (e.g., in kg).
n =	total number of trophic levels.
BAF_{Ni} =	trophic level (N)-specific bioaccumulation factor (e.g., L/kg) for the ith trophic level.
P_i =	proportion of prey at the ith trophic level (unitless).

Community-level benchmarks

Water quality standards and criteria for the protection of aquatic life. When available, state water quality standards for designated uses of surface waters are ARARs (see Section H.8). When state standards are not available, EPA ambient water quality criteria (AWQC) for the protection of aquatic life are ARARs. These water-concentration benchmarks for the protection of aquatic communities are available for most of the hazardous substances found at mining sites (e.g., metals, cyanide). Most of the state standards have been adopted from or modified from EPA AWQC. These ARARs are available for acute (1-hour) and chronic (4-day) exposures. Many of the criteria for metals depend on water hardness, and a few criteria depend on pH.

Other community-level benchmarks. Highlight F-20 provides examples of community-level benchmarks in addition to water quality ARARs. There is no EPA consensus at this time on use of these other benchmarks; consult with the BTAG to determine if any of these benchmarks are appropriate or if a different approach is needed (e.g., using toxicity tests).

Species-level benchmarks Highlight F-20 also provides examples of species-level benchmarks. It is important to remember that EPA's AWQC, and consequently most state standards, for the protection of aquatic communities are unlikely to be protective of piscivorous (i.e., fish-eating) wildlife if the substance bioaccumulates (e.g., mercury, selenium, cadmium). A food-chain model was *not* used to determine AWQC, even when toxicity to wildlife (e.g., PCB toxicity to mink) was considered in setting the criterion. If any piscivorous species are of concern in the area, consult with the BTAG for an update on available information and procedures.

EPA's Office of Water/Office of Science and Technology (OW/OST) is developing surface water criteria for the protection of terrestrial piscivorous wildlife. The criteria assume that the exposed species obtains all of its diet from the surface water body in question. EPA has not yet specified what temporal or spatial averaging requirements will apply to the wildlife surface water criteria. We therefore outline an approach consistent with OW/OST's methodology that can be used in the interim to develop surface water benchmarks for piscivorous wildlife. The benchmark is calculated on the basis of two values: (1) an animal's intake of the contaminant that can be attributed to the surface water contamination; and (2) a reference dose of contaminant above which adverse effects on the animal's growth, development, reproduction, or survival can be expected.

Section H.13 described how intakes of contaminants that can be attributed to surface water contamination can be calculated for piscivorous wildlife. For purposes of setting a screening-level benchmark, one can assume that the animal obtains all of its food from the contaminated surface water. The second value required to calculate a surface water benchmark protective of piscivorous wildlife is the reference dose, i.e., a chemical-specific reference toxicity value (TV), as described in the next paragraph.

Determining a reference toxicity value (TV). Toxicity values (TVs) should be developed by a terrestrial wildlife toxicologist. A TV can be estimated from a no-observed-adverse-effect level (NOAEL) multiplied by a species sensitivity factor (SSF), as described below.

From the available literature, a chronic NOAEL is identified. Peer-reviewed field studies of wildlife species are used when available. In the absence of field studies, laboratory studies with surrogate species (e.g., rat, northern bobwhite) can be used. EPA's *Great Lakes Initiative*[32] recommends the following data requirements for chronic studies:

> For laboratory mammals, at least one well-conducted subchronic study consisting of repeated oral exposure for 90 days or longer, or at least one well-conducted reproductive or developmental effects study consisting of repeated oral exposures.
>
> For laboratory birds, at least one well-conducted study of 28 days or greater designed to observe subchronic as well as reproductive or developmental effects.

If a NOAEL is unavailable, it can be extrapolated from a lowest-observed-adverse-effect level (LOAEL) by dividing the LOAEL value by a factor ranging from one to ten. If chronic data are unavailable, a subchronic value can be used, dividing by a factor of up to ten to extrapolate to the longer exposure duration. Finally, the NOAEL is converted to mg/kg-day (i.e., milligrams contaminant eaten per kilograms of consumer organism's body weight per day) basis if it is not already in these units.

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32 Op. Cit. 25.

Highlight F-20:
Types of Ecological Benchmark Values

Type of Benchmark	Examples or Approach
Surface water benchmarks for the protection of aquatic life (i.e., non-benthic aquatic communities)	State water quality standards[a/] EPA ambient water quality criteria (AWQC)[a/] EPA ambient aquatic life advisory concentrations (AALAC) Toxicity values/extrapolation factor(s)[b/]
Sediment benchmarks for the protection of benthic invertebrate communities	EPA interim sediment quality criteria[c/] Apparent effects threshold (AET) Sediment quality triad Screening-level concentration (SLC)
Surface water benchmarks for the protection of fish-eating wildlife species	EPA water quality criteria for the protection of terrestrial wildlife[d/]
Fish flesh benchmarks for the protection of fish-eating wildlife species	New York State fish flesh criteria[e/]
Soil benchmarks protective of plant communities	Toxicity values from PHYTOTOX data base
Soil benchmarks protective of soil invertebrate communities	Toxicity values for selected invertebrate species (e.g., earthworms, amphipods)
Soil benchmarks protective of terrestrial vertebrate species	Soil criteria derived from dietary toxicity values and specific exposure parameters for selected vertebrate species[f/]
Ambient air standards protective of terrestrial plant communities	Some secondary National Ambient Air Quality Standards (NAAQS)

a/ These ARARs are available for most of the contaminants found at mining sites.
b/ As an example, a chronic benchmark may be derived by dividing a LOAEL by a numeric factor to account for variation in species sensitivity (see text).
c/ EPA sediment benchmarks are not available for metals at present. For a review of approaches to developing sediment quality criteria, see Chapman[33]. The BTAG should be consulted to determine which approach(es) is most appropriate for a particular site.
d/ Back-calculate a benchmark surface water concentration from bioaccumulation factor values for aquatic food items and water consumption, aquatic food consumption, and toxicity for selected avian and mammalian species[34].
e/ Back-calculate a benchmark fish flesh concentration from fish consumption and toxicity data for selected avian and mammalian species[35].
f/ Back-calculate a benchmark soil concentration using body mass, dietary intake, bioaccumulation factors, and dietary toxicity values for representative birds and mammals assuming direct contact and food chain exposures[36]. Depending on how receptors and endpoints have been defined (see section 2.2, tasks 3 and 6), one or both of two types of assessments typically are useful: community-level assessments and population-level assessments.

Data rarely are available for the assessment species; therefore, an extrapolation factor to account for differences in species sensitivities to the substance usually is developed. A species sensitivity factor (SSF) typically falls between 1 and 0.01 depending on the amount and quality of data available on the toxicological, physicochemical, and toxicokinetic properties of the substance. An SSF of one is used if the data are from numerous species or if the data are from the only species of concern.

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[33] Chapman, P.M. 1989. Current approaches to developing sediment quality criteria. Environ. Toxicol. Chem. 8:589-599.

[34] Environmental Protection Agency (EPA). 1991. *Assessment and Control of Bioconcentratable Contaminants in Surface Waters*. June 1989 Draft prepared by EPA's National Effluent Toxicity Assessment Center, Environmental Research Laboratory - Duluth, MN; Office of Water Enforcement and Permits, Office of Water Regulations and Standards - Washington, DC; and Office of Health Effects Assessment - Cincinnati, OH

[35] New York State Department of Environmental Conservation (NY DEC). 1987. *Niagara River Biota Contamination Project: Fish Flesh Criteria for Piscivorous Wildlife*. Division of Fish and Wildlife, Bureau of Environmental Protection. DEC Publication, Technical Report 87-3.

[36] Op. Cit. 28.

Estimating a benchmark concentration for surface water (BC_{sw}) for the protection of piscivorous wildlife. The benchmark contaminant concentration in surface water (BC_{sw}) now can be estimated as described in equation 3.

$$Bc_{sw} = [TV \times Wt_A \times SSF] / [IR \times BAF_N] \quad \text{(equation 3)}$$

where

Bc_{sw} = benchmark contaminant concentration in surface water (e.g., mg/L).
TV = wildlife chronic toxicity reference value (e.g., mg/kg-day).
Wt_A = consumer animal's fresh body weight (e.g., kg).
SSF = species sensitivity factor as defined in text.
IR = food ingestion rate of consumer species (e.g., kg/day).
BAF_N = bioaccumulation factor (e.g., L/kg) for the Nth trophic level.

Toxicity tests Toxicity tests on media from the site, in combination with data on chemical concentrations and field studies, can provide important supporting evidence that observed effects are attributable to the presence of hazardous substances. Several factors need to be considered, however, in interpreting (and consequently planning) toxicity tests, as discussed briefly below.

Species sensitivity. Different species show varying sensitivities to different toxic substances. For a community-level assessment, it would be important to encompass the range of species sensitivities likely in the community of concern. There are several approaches to this problem. For some contaminants at some sites, the most sensitive resident species may already be known from previous work at the site. For aquatic communities, EPA's Office of Water has suggested a sliding scale of species-sensitivity extrapolation factors depending on the number of different genera tested.[37] Another approach is described in Highlight F-21. Consult the BTAG for the most appropriate approach for a site.

For a species-level assessment, the choice of number of test organisms and which test organisms to use depends upon how similar the available test species are to the assessment species, what is known about the contaminant's toxicity, and other factors. Again, consultation with the BTAG generally is necessary to ensure that appropriate procedures are applied to plan toxicity tests and interpret their results.

Duration of test. If chronic exposures are of concern, chronic bioassays should be used. To reduce the time and expense of testing, however, it may be possible to substitute one of the short-term (e.g., eight days) tests for estimating chronic toxicity of effluents and receiving waters (EPA 1985[38], 1988[39], 1989[40]). These tests are only suitable for substances that do not bioaccumulate, however. The species used in the short-term tests also may not be as appropriate as other available surrogate test species for a species-level assessment. Again,

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[37] Environmental Protection Agency (EPA). 1987. Guidelines for Deriving Ambient Aquatic Life Advisory Concentrations. Office of Water Regulations and Standards, Washington, DC.

[38] Environmental Protection Agency (EPA). 1985. *Short-term Methods for Estimating the Chronic Toxicity of Effluents in Receiving Waters to Freshwater Organisms.* Office of Research and Development, Office of Environmental Monitoring and Support Laboratory, Cincinnati, OH. EPA/600/4-85/014.

[39] Environmental Protection Agency (EPA). 1988. *Short-term Methods for Estimating the Chronic Toxicity of Effluents in Receiving Waters to Marine and Estuarine Organisms.* Office of Research and Development, Office of Environmental Monitoring and Support Laboratory, Cincinnati, OH. EPA/600/4-87/0928.

[40] Op. Cit. 16.

consult with the BTAG to ensure that appropriate procedures are applied to plan and interpret toxicity tests.

Highlight F-21:
One Approach to Accounting for Varying Species Sensitivities

Use multiple test species and an uncertainty factor. For example, in the context of EPA's National Pollutant Discharge Elimination System (NPDES) permits program, at least three test species (one fish, one invertebrate, and one plant) are required[41]. For toxicity tests on surface waters, analysis of species sensitivity ranges found in EPA AWQC documents indicates the following: If the fathead minnow, *Daphnia magna*, and the bluegill are used for freshwater, the results for the most sensitive of the three test species divided by a factor of 10 encompasses the value for the most sensitive animal species most of the time (i.e., for 71 out of 73 chemicals with data on 4 or more species; Kimerle[42]).

Biological field surveys Biological field surveys can provide direct or corroborative evidence of a link between contamination and ecological effects if an appropriate reference area is surveyed or if a gradient of contamination correlates with a gradient of impacts. The chemical and biological data need to have been collected simultaneously to determine if a correlation exists between contaminant concentrations and ecological effects. *These surveys usually are needed only if a detailed ecological assessment is necessary.*

F.15 Risk Characterization

Ecological risk characterization is primarily a process of comparing the results of the exposure assessment with the results of the ecological effects assessment. The purpose is to answer the following questions:

Are the ecological receptors of concern currently exposed to site contaminants at levels that can cause adverse effects or is future exposure at such levels likely?

If adverse ecological effects are observed or predicted, what are the types, extent, and severity of the effects?

What are the uncertainties associated with the risk characterization, and are they too large to allow decisions on remedial actions and goals?

All information available by the end of the initial sampling phase of the RI should be used to screen for potential ecological impacts at the site, both present and future. The potential for impacts can be evaluated on the basis of several types of information, considering the weight of evidence provided by each:

Historical information on impacts (e.g., fish kills following snow melts);
Comparing ecological benchmarks with contaminant concentrations in environmental media (e.g., surface waters, sediments, soils, plant and animal tissues);

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[41] Environmental Protection Agency (EPA). 1987. *Permit Writer's Guide to Water Quality-Based Permitting for Toxic Pollutants.* Office of Water Regulations and Standards, Washington, DC. EPA 440/4-87-005.

[42] Kimerle, R.A., Werner, A.F., and Adams, W.J. 1984. Aquatic hazard evaluation principles applied to the development of water quality criteria. In: Cardwell, R.D., Purdy, R., and Bahner, R.C. (eds.), *Aquatic Toxicology and Hazard Assessment; Seventh Symposium.* ASTM STP 854. Philadelphia, PA: American Society for Testing and Materials.

Evidence of bioaccumulation (e.g., tissue residue samples compared with exposure media);
Toxicity tests on environmental media;
Results of biological surveys of populations and communities compared with reference areas; and
Biomarkers of exposure or effects.

For any of these evaluations, it generally is helpful to delineate and map areas and habitats within which measured concentrations exceed ecological benchmarks or for which other evidence indicates the potential for adverse ecological impacts.

In the remainder of this section, we focus on the interpretation of exceedances of benchmark levels and species-specific risk estimates. These methods are appropriate for most assessments.

Exceedance of ecological benchmarks

Quotient method. As described earlier, ecological benchmarks are levels of contaminants in environmental media (i.e., surface waters, soils, sediments, or organisms at various trophic levels) that represent a threshold for adverse ecological effects. If an ecological benchmark concentration (BC) is available for the medium sampled (e.g., surface water), one can compare measured or estimated environmental concentrations (EC) with that BC. This approach, also known as the quotient method, assumes that adverse effects are unlikely if the EC is lower than the BC (i.e., $EC/BC < 1$) and likely if the EC is greater than or equal to the BC (i.e., if $EC/BC \geq 1$)[43].

Hazard index (HI). A more common situation, however, is for organisms to be exposed to more than one contaminant simultaneously. In this situation, EPA's *Guidelines for the Health Effects Risk Assessment of Chemical Mixtures* can be applied[44]. In this approach, the sum of the quotients developed for individual constituents, is compared with 1. If the sum, known as the hazard index (i.e., $HI = \quad EC_i/BC_i$), is less than 1, one assumes that ecological impacts are unlikely. If the hazard index is greater than 1, it is reasonable to conclude that a potential for impacts exists, and further study may be required[45]. The HI approach is most appropriate for substances that exhibit the same mode of action and target the same organs; it can underestimate risk if two or more chemicals exert synergistic effects.

Concern level (CL). In applying the quotient or HI approaches, consider the degree of uncertainty associated with both the EC and the BC values and the consequences of falsely concluding there is no risk when, in actuality, adverse effects are likely. If both the EC and the BC have been established using conservative procedures (e.g., upper confidence limits on average values, to encompass a "true" value 95% of the time), then comparing the EC/BC or HI values to 1 might be appropriate (i.e., there is a very small chance that an actual impact would be missed). If, however, both the EC and the BC have been established using "average" values, then the risk assessor must appreciate that the EC/BC or HI could be slightly less than 1 when in fact there is a good chance (e.g., 50%) that adverse effects would occur. In this

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[43] Environmental Protection Agency (EPA). 1988. *Review of Ecological Risk Assessment Methods*. Office of Policy, Planning and Evaluation, Washington, DC. EPA/230-10-88-041.

[44] Environmental Protection Agency (EPA). 1986. *Guidelines for the Health Risk Assessment of Chemical Mixtures*. Office of Health and Environmental Assessment, Washington, DC. EPA/600/8-87/045.

[45] Environmental Protection Agency (EPA). 1989. *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual*. Interim Final. Office of Solid Waste, Office of Emergency and Remedial Response, Washington, DC. EPA/540/1-89/002.

case, the risk assessor should establish a concern level lower than 1 based on (1) the degree of uncertainty and potential biases in the EC and BC estimates and (2) the consequences of falsely concluding that there are no impacts likely. Given the lack of guidelines on this topic, it is important to consult with the BTAG when setting a CL.

Exceedance of wildlife toxicity reference values In those cases where species of concern can be exposed to contaminants from more than one environmental medium (e.g., contaminated soils and surface waters) or can be exposed to different levels of contamination in different parts of their range, it might be appropriate to estimate a daily average contaminant intake from all sources rather than attempt to develop benchmarks for the environmental media. Section EPA/540/1-89/002. H.14 described how average potential daily intakes (ADD_{pot}) can be estimated for wildlife species of concern, and section H.15 described the development of wildlife toxicity values (TVs). The quotient and hazard index approaches can be used to compare ADD_{pot}s to TVs. The same considerations apply to determining a concern level (CL) as described above.

Interpretation of exceedances It is important to consider both the spatial and temporal applicability of the benchmark when attempting to compare exposure values to toxicity benchmarks. For example, EPA's AWQC and similar state water quality standards are intended to protect aquatic communities, rather than a specified aquatic population. Thus, if either an acute or chronic water quality benchmark is exceeded at any point in a surface water body, the aquatic community at that point can be considered at risk of adverse effects. If often is possible, therefore, to quantify the areal extent of the surface water bodies for which aquatic communities are likely to be impacted (i.e., areal extent of the criterion exceedance) either for acute or chronic exposures. Both the degree of exceedance (i.e., potential severity of the effects) and the areal extent of exceedances are important considerations for evaluating the significance of the estimated effects.

If any portion of a river exceeds an acute water quality criterion for the protection of aquatic life, there is some chance that the mobile members of the aquatic community (e.g., larger fish) will be adversely affected over an area that is larger than the area of exceedance of the criterion. For example, if a portion of a river regularly exceeds acute criteria, it may not be possible for fish to traverse the area without suffering adverse effects. This might divide and isolate the fish populations on either side of the area of exceedance. If anadromous fish used the river, they might be blocked from successfully reaching their spawning grounds upstream.

The RPM should consult with the BTAG if there are questions on how to interpret benchmark exceedances.

F.16 Is Additional Assessment Necessary?

F.16.1 Rationale. When the initial assessment is complete, the RPM needs to evaluate whether the goals of the ecological assessment for the site characterization phase of the RI/FS have been met, or if further site evaluation is warranted. The operative concern is whether ecological risks at the site are understood sufficiently to be adequately considered in selecting a remedial alternative or in establishing remedial goals. At enforcement-lead sites, EPA needs to be able to defend an endangerment finding.

F.16.2 Factors to Consider. Usually, the initial ecological assessment will be sufficient. Sometimes, however, there are problems that require further evaluation. This section identifies and describes several factors that may influence whether further site evaluation is warranted.

ARARs, other statutory requirements, and public concerns. Remedial actions must ensure that all ARARs and other statutory requirements are met or waived. This may require that risks to certain types of environments (e.g., wetlands) or organisms (e.g., endangered species) be eliminated, reduced, or controlled. Public concern also may be high for particular environments or species (e.g., local residents, states, or Native American Tribes may be concerned about trout streams, eagle populations, unique habitats, or other components of nearby ecosystems). Additional site investigation may be warranted if it is not clear how ARARs, other statutory requirements, or public concerns will be addressed by each proposed remedial alternative or cleanup goal.

Ability to link adverse effects to contaminants. EPA must provide sufficient information to reasonably conclude whether or not adverse effects are likely as a result of releases of contaminants from the site. However, EPA need not demonstrate a cause-and-effect linkage between *observed impacts* and site contaminants. Demonstrating a reasonable likelihood of risks to sensitive and other environments generally requires:

> Sufficient understanding of all contaminant migration pathways (i.e., the steps, rates, and processes involved in the migration of contaminants from sources through environmental media to sensitive or other nearby environments);
>
> Reasonably confident measures or estimates of representative environmental concentrations at each key point in all contaminant migration pathways; and
>
> Sufficient understanding of the types of adverse effects that may be associated with observed or estimated environmental concentrations.

For some assessment areas, it may be sufficient to demonstrate that releases can result (or have resulted) in concentrations above ecological benchmark levels, because there is sufficient information in the scientific literature linking such concentrations to adverse ecological effects. AWQC are examples of such ecological benchmark levels. For other assessment areas, toxicity tests and/or other additional investigations may be required to determine whether observed contaminant concentrations have the potential to result in adverse ecological effects. For example, ecological benchmark levels may be below analytic quantitation limits, or contaminants might not be bioavailable.

Most likely remedial alternatives, cleanup goals, or constraints. Additional information may or may not be needed to select a remedy or to evaluate its effectiveness. For example, it may be sufficient to demonstrate that a release has resulted in concentrations above AWQC at the point that contaminants discharge to a surface water body if all of the reasonable remedial alternatives will prevent future releases to that surface water body. In contrast, more complete information on the areal extent of contamination above benchmark levels (or above effect levels in toxicity tests) may be required when remedial alternatives involve removal, treatment, or capping of contaminated media such as soil or sediment that serve as non-point sources of contamination (i.e., it may be necessary to delineate the area that needs to be remediated).

Intended post-remediation uses for assessment areas. The level of information that the ecological risk assessment must provide may depend partially on the intended post-remediation uses for each assessment area. For example, little or no information on ecological risk may be required for areas that are to be capped and revegetated for reasons unrelated to ecological risk (e.g., because of human health risk or other intended use of the land area).

F.16.3 Consultation with the BTAG. The RPM should provide the BTAG with the results of the ecological risk assessment. The BTAG, in turn, should be able to determine if additional field investigations are necessary, and, if so, what investigations are required.

Highlight F-22:
List of Acronyms

ACRs	Acute-to-chronic Ratios
AQUIRE	AQUatic Toxicity Information REtrieval
ARARs	Applicable or Relevant and Appropriate Requirements
AWQC	Ambient Water Quality Criteria
BLM	Bureau of Land Management
BTAG	Biological Technical Assistance Group
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Program
DOI	Department of Interior
DQOs	Data Quality Objectives
EPA	Environmental Protection Agency
FS	Feasibility Study
FWS	US Fish and Wildlife Service
HRS	Hazard Ranking System
LOAEL	Lowest-observed-adverse-effect level
NCP	National Oil and Hazardous Substances Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No-observed-adverse-effect level
NPDES	National Pollutant Discharge Elimination System
NPL	National Priority List
OSC	On-scene Coordinator
PA	Preliminary Assessment
PNRS	Preliminary Natural Resource Survey
PRP	Potentially Responsible Party
QA/QC	Quality Assurance/Quality Control
QSAR	Quantitative Structure Activity Relationships
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
ROD	Record of Decision
RPM	Remedial Project Manager
SI	Site Investigation
SOW	Statement of Work
SSF	Species Sensitivity Factor
TRIS	Toxics Release Inventory System
TV	Toxicity Value

Glossary:

Bioaccumulation potential

A measure of the tendency for chemicals to preferentially concentrate in the tissues of living organisms; two general measures are the bioconcentration factor (BCF), the equilibrium ratio of the concentration of a chemical in the tissue and its concentration in ambient water, in situations where the organism is exposed through the water only; and the bioaccumulation factor (BAF), the equilibrium ratio of the concentration of a chemical in the tissue to its concentration in an environmental medium where the organism and the food chain both are exposed.

Contaminant migration pathway

The pathway through which a chemical or non-chemical stressor travels from a source to a specified habitat, environment, or ecological receptor; the contaminant migration pathway includes a source, the environmental medium or media through which the stressor moves, and one or more receptor(s).

Ecological benchmark level

Concentrations in environmental media (e.g., surface water, sediment, soils) above which potentially significant adverse effects to ecological receptors are expected to occur; usually derived from toxicity values (e.g., no-adverse-effect levels, lowest-adverse-effect levels, LC_{50}s) for either acute or chronic exposures.

Ecological receptor

An individual organism, population, community, ecosystem, or ecoregion that may be affected by site contaminants or other stressors.

Environmental medium

A component of the environment through which contaminants can move; includes both abiotic components (i.e., soil, groundwater, surface water, air, sediment) and biotic components (e.g., fish, shellfish, plants).

Hazard index (HI)

The sum of the ratios of the estimated environmental concentration of each contaminant (EC) to its ecological benchmark level (EB), calculated using the following formula:

$$HI = EC_i/EB_i,$$

where

EC_i = the concentration for the i^{th} contaminant

EB_i = the benchmark concentration for the i^{th} contaminant

This approach can also be applied to the ratio of average daily intake of an animal (ADD_{pot}) to a wildlife reference toxicity value (TV) for more than one contaminant.

Nearby habitat	A terrestrial, surface water, or wetland habitat that is actually or potentially exposed to site contaminants; nearby environments may be located anywhere from on site to several tens of miles from the site.
Primary consumers	Organisms that feed primarily on the primary producers (e.g., plants) at the base of a food chain.
Primary producers	Organisms (e.g., green plants and some bacteria) that are autotrophic (i.e., fix energy from the sun or use inorganic compounds for food) and form the base of a food chain or web.
Reference environment	A terrestrial, surface water, or wetland environment that closely resembles the environment of concern in terms of its biotic and abiotic composition and structure and is known not to be exposed to contaminants from the site.
Secondary consumers	Organisms (e.g., carnivores, insectivores) that feed primarily on primary consumers.
Sensitive environment	Environments or habitats that are rare, unique, relic, or otherwise have state, regional, and/or Federal significance or special statutory protection.
Stressor	Any substance that causes an adverse effect (e.g., skin lesions, lethality, decreased growth rate, prenatal mortality) on ecological receptors; stressors may be chemical (e.g., metals) or non-chemical (e.g., pH, turbidity, temperature) and may be natural or anthropogenic.
Trophic level	Any of the feeding levels through which the passage of energy through an ecosystem proceeds. For freshwater aquatic systems, this document assumes that zooplankton are trophic level 2, small fish trophic level 3, top carnivorous fish trophic level 4.

APPENDIX G

DETAILED INFORMATION ON MINE REMEDIATION TECHNOLOGIES

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Table of Contents

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Appendix G:
Detailed Information on Remediation Technologies

The following appendix contains information about the effectiveness, feasibility and cost of remediation at mine sites. Information on capping and surface reclamation comes largely from EPA's draft *RCRA Guidance Document for Landfill Design-Liner Systems and Final Cover* (1982); information on treatment of contaminated water and solid wastes comes from EPA's Handbook, *Remedial Action at Waste Disposal Sites* (1985), and the U.S. Army Engineers' *Handbook for Stabilization/Solidification of Hazardous Wastes* (1986).

Note that the information presented here on remediation technologies is dated. As new technologies are developed and the current technologies are refined the information presented here, effectiveness, feasibility, and costs, may change. Whenever possible, current sources should be utilized.

G.1 Engineering Controls

G.1.1 Capping and Surface Reclamation.

The <u>*effectiveness*</u> of capping as a disposal alternative at mine waste sites will depend on several site-specific factors, such as the materials and number of layers used, the mobility of the covered waste, the size and topography of the site. Considerations related to evaluation of caps against the nine criteria may include the following:

- Capping, in the absence of treatment, does not reduce toxicity or volume of the waste.

- Excessive settlement and subsidence of the cap, caused by consolidation of the waste, can reduce the effectiveness of the cap, including:

  -- Ponding of surface water on the cap;
  -- Disruption of gas collection pipe systems;
  -- Fracturing of low permeability infiltration layers; and
  -- Failure of geomembranes.

  Failure of the cap may result in release of the buried waste, such as leaching or the escape of fugitive dust.

- Freeze-thaw effects may, depending on climate, result in the development of microfractures or other failures that can increase the hydraulic conductivity of clays by as much as one order of magnitude.

- Infiltration layers may be subject to drying depending on the climate and soil-water retention in the erosion layer.

- Fracture and volumetric shrinking of the clay due to water loss may increase the hydraulic conductivity of the infiltration layer.

Considerations when determining the <u>*feasibility*</u> of capping may include the following:

- Capping can normally be accomplished with conventional construction equipment and, in some cases, on-site soils. However, the large areas of mine sites may pose substantial problems.

- The slope angle, slope length and overlying soil load may limit the stability of component interfaces, such as between the geomembrane with the soil. If the design slope is steeper than the effective friction angles between the material, sliding instability may occur.

- Capping and revegetation, if used, generally can be accomplished in less time relative to other alternatives. Capping may be widely available, therefore, to prevent the near-term spread of contamination.

- Treatability tests and research may be required to fully characterize the practicability of capping at the site, prolonging the remedial action. This is particularly true for revegetation of capped areas, where extensive research and testing may be required to find effective, long-term solutions.

<u>*Costs*</u> associated with capping can vary, depending on the materials and size of the cap, as well as the ancillary equipment (e.g., monitoring wells) that may be required. Some general considerations may include:

- Capping may have low capital cost in comparison with other alternatives addressing similar volumes of waste, such as excavation and offsite removal.

- Capping may entail long-term O&M expenses for monitoring and maintenance, including:

  -- Inspection of the cap for ponding, failure of the cap, or deterioration of the vegetation;
  -- If run-on or run-off systems are used, inspection and emptying of containment systems;
  -- Upkeep of the upper vegetative cover (e.g., replacement of eroded soils or vegetation);
  -- Periodic application of special surface treatments needed to prolong the life and effectiveness of asphalt or concrete liners (e.g., top soil to replaced eroded soil);
  -- Sampling of nearby monitoring wells, if used, to detect any leaching; and
  -- Institutional controls preventing unauthorized access that could affect long-term effectiveness.

The use of surface vegetation is recommended for both single- and multi-layered soil caps to provide for stabilization and erosion control, and improve aesthetics. Careful consideration and research of site-specific factors should be done to determine the types of vegetation chosen for revegetation. Depending on site conditions, this may include the following activities:

- Search for potentially suitable vegetation, and sampling and analysis of the site conditions affecting growth in the area to be reclaimed. The following parameters may be relevant to consider:

  -- **Climate.** Seasonal ambient temperatures can affect the plant's photosynthesis, respiration, and absorption of minerals. Strong or consistent prevailing winds can, in certain instances, lead to sandblasting and dislodging of plants and erosion and dehydration of surface tailings material. Heavy winter snowfalls and heavy spring rains can delay access to tailings for planting.
  -- **Moisture supply.** Certain soils, particularly fine soils like sands and sandy loams, normally exhibit lower moisture-retention than less fine soils, like loams and clays. The moisture needs of the plants should be compared to the moisture-retention characteristics of the soil.
  -- **Soil reaction.** pH levels may affect the ability of the vegetation to take up essential nutrients from the soil, such as phosphates in acid soils. Highly acidic soils can potentially be high in concentrations of aluminum, manganese, and iron. Excessively high concentrations can be phytotoxic for certain kinds of plants.
  -- **Nutrient levels.** Nutrient levels in the native soils should be compared with recommended levels for potential vegetation. If native soils do not provide adequate nutrients, consider soil treatment or importing non-native soil.

- Conduct bench scale or pilot programs of potentially suitable vegetation. For new vegetation or sites with unfamiliar contaminants, it may be advisable to test the selected vegetation in a lab or to cultivate the plants on a small scale at the site to simulate actual revegetation. Results of the program may help determine the suitability of the tested plants and the necessary conditions for optimal plant growth.

- Select vegetation. Preferably, selection should be based on observation of similar plants growing in the area under natural conditions. The species selected also should be highly adaptable to site-specific conditions and be self-supportive to the greatest extent possible.

For example, the following plants have been shown to be particularly well-suited for the revegetation of sulphide tailings areas.[1]

- Red or Tall Fescue
- Bromegrass
- Red Top

[1] Brooks, B.W., T.H. Peters and J.E. Winch. 1989. *Manual of Methods Used in the Revegetation of Reactive Sulphide Tailings Basins.* Canada Center for Mineral and Energy Technology, Energy, Mines and Resources Canada.

G.1.2 Collection, Diversion, and Containment

Examples of CDC methods are the following:

- **Prevention of run-on:** Examples of diversion technologies for surface water include interceptor trenches, channels, and drains, channel protection, dikes, and terraces. These technologies divert surface water so that it does not contact or infiltrate through sources of contamination.

- **Control of erosion:** Erosion control technologies reduce sediment loading to surface waters and help stabilize the land surface, ultimately reducing the spread of contaminants. Technologies that control erosion include dikes, terraces, diversion channels, and surface reclamation techniques.

- **Collection of water and control of run-off:** Collection technologies may include a network of pipes, drains, channels, and trenches that direct water to a central location to aid proper water management. Collection technologies collect diverted or other surface and ground water so that it can be managed properly. Collected water is often treated in some manner before discharge, often to meet ARARs.

Determining the potential *effectiveness* of CDC methods may need to include the following considerations:

- CDC methods, as a rule, do not reduce the volume or toxicity of the wastes, but are often used in more comprehensive remediation approaches that are designed to address these concerns, such as on-site treatment or offsite removal. As such, CDC methods used for temporary storage may involve a relatively high risk of recontamination if failure occurs. Therefore, careful evaluation of effectiveness, including contingencies for failure, may need to be considered. Some of the risk of a release can be abated if the containment of waste is held to a minimum period of time and the CDC method is used in conjunction with treatment or removal.

- Most CDC methods are proven and well-documented. A new application of CDC methods may, however, warrant a treatability study to characterize their effectiveness in light of the site-specific conditions.

- CDC methods can be an effective option in minimizing the generation of acid mine drainage by diverting run-off from metal-sulfide minerals. For example, slurry retrenching may be used to form a barrier between an aquifer and tailings piles.

- The effectiveness of CDC methods can potentially be influenced by unforeseeable factors, such as climate (e.g., rainfall flooding), and as such, their effectiveness over time may be unpredictable and difficult to evaluate. It may be advisable to identify reasonable factors that might affect performance and assess the likelihood that effectiveness can be assured.

Implementability considerations for CDC methods may include the following:

- CDC methods can usually be implemented using readily available construction equipment and materials (e.g., backhoe, low-permeability soils). However, the site may need to be surveyed to ensure that implementation is possible given site-specific conditions.

- Some CDC methods (e.g., interceptor or diversion dikes and berms) can be constructed with minimal design requirements, and thus, can be set up quickly without specialized oversight. However, innovative or more advanced CDC methods may require extensive design and testing.

- CDC methods may not be feasible for addressing large areas, particularly areas with non-point source water contamination. For example, at Clear Creek Operable Unit No. 1, source control and containment were deemed infeasible because the source of discharge from the tunnels was from percolating ground water entering the mines through fractures, and intersecting veins, tunnels, shafts, and cross cuts, while little of the source was due to point source contributions (e.g., the intersection of adits with surface channels).

Cost considerations for CDC methods may involve the following:

- CDC methods are often simple to install (e.g., man-made trenches, earthen basins, dikes, or berms) and have low capital costs. These costs, however, can be unpredictable, and may vary with site-specific conditions. For example, the number of man-made or purchased structures required, local availability of soil and equipment, and effective design life of the systems may influence O&M costs.

- CDC methods normally entail monitoring and maintenance expenses over their operating life. Mulching and seeding, for example, is often necessary to prolong the useful life of certain earthen CDC methods like berms and dikes. Many of the methods also are subject to erosion forces and may be difficult to maintain without rip-rap or gravel to protect them. Other CDC methods, such as settling or seepage basins, require that debris be routinely removed and disposed of in order to enable optimum operation. The operating costs for CDC methods, however, still compare favorably to that of waste treatment technologies.

G.1.3 Treatment of Contaminated Water

Precipitation

- The *effectiveness* of chemical precipitation may be governed by the following factors:

  -- The solubility product of ionic species will influence the rate at which the metal can be precipitated. The solubility product can be controlled by the amount of lime added to the solution. Most metals have a particular pH

level at which precipitation is most effective. For waters containing multiple metals, it may be necessary to vary the pH level to ensure precipitation of all metals.
- -- High levels of total dissolved solids can interfere with precipitation and inhibit settling of solids.
- -- Oil and grease in the water can inhibit settling of solids by creating an emulsion that suspends particles.
- -- Metal complexes in the water have a relatively high solubility limit, and thus precipitation may be inhibited or infeasible.

- The *feasibility* of chemical precipitation may be influenced by the following parameters:

  - -- The amount of the precipitating agent affects the solubility of the metals and should be regulated closely to ensure a high degree of precipitation. Controlling dosage rates may be particularly difficult for waters with wide variations in flow rates and quantities of metals.
  - -- Precipitation is generally not feasible for very dilute waters. However, in addition to solar evaporation of solvents, there may be the possibility in a given situation of subjecting the water to very low temperatures. Such treatment, together with agitation, could cause a fine precipitate to form that could then be removed by gravity or filtration methods. In waste treatment processes, it would be expected that precipitation, especially with any crystal growth, would occur chiefly in lagoons or ponds subjected to solar evaporation.
  - -- The residence time should be closely regulated to ensure a high degree of precipitation.
  - -- Precipitation chambers that provide for mixing of the water will help to ensure that the precipitating agent makes contact with the metals and to promote the settling of the precipitate.

- *Primary capital purchases* for precipitation include a vessel capable of holding the water for the appropriate residence time, a means of directing the water into and out of the vessel, and a device to remove precipitated metals. The major variable cost in precipitation is the lime or other agent added to the solution to adjust pH and the electrical costs associated with mixing and removal. The disposal costs for sludges with higher concentrations of metals, or complex metals, may be higher, as more lime (or other reagent) is normally needed for effective precipitation.

Clarification

- Clarification can be *effective* in removing solids (i.e., large or coagulated solids). Dissolved pollutants and fine particles may not be conducive to clarification.

- The *feasibility* of clarification can be influenced by several factors, including the susceptibility of the pollutants to be coagulated and/or settled given a reasonable residence time, and the flow rate of the water through the settling chamber.

- The *major capital purchases* for clarification include a basin or container of sufficient capacity to hold the water to be treated, a means of directing water in and out of the settling chamber, and a device to remove settled particles (and, if applicable, a scum raker). Monitoring devices for residence times and feed rates may also be advisable. Power costs involved with clarification tend to be relatively low because it relies heavily on gravity to remove suspended particles. These settled particles may require treatment and offsite disposal (e.g., RCRA-characteristic sludges).

Chemical Oxidation

- Factors that may influence the *effectiveness* of chemical oxidation include:

  -- Concentration of oxidizable compounds other than the contaminants of concern may consume the oxidizing agent, inhibiting the effectiveness of the oxidizing agent at treating targeted contaminants.
  -- Metal salts may react with the oxidizing agent to form metal peroxides, chlorides, hypochlorites, and chlorates. These compounds can consume the oxidizing agent, potentially interfering with treatment of the targeted contaminants.
  -- Residence time should enable volatilization of organics. Batch feed or continuous flow systems should be monitored to allow for adequate residence times.

- The *feasibility* of chemical oxidation may be influenced by the following parameters:

  -- Amount of oxidant should enable volatilization of targeted contaminants. Other constituents in the water (e.g., metal salts) may be oxidized by the oxidizing agent and thereby reduce the amount of the agent available for the targeted contaminants. The danger of incomplete oxidation is that more toxic oxidation products could be formed, such as in the case of the high-strength, complex waste streams.[2]
  -- Mixing of the oxidizing agent and water is important in ensuring that contact is made between the oxidizing agent and contaminants.
  -- Optimal pH is important to efficient volatilization and the prevention of undesirable reaction byproducts.
  -- Varying the amount and type of catalysts can promote oxygen transfer and enhance oxidation.

- *Primary capital purchases* include contact vessels with agitators to provide suitable contact of the oxidant with the waste, storage vessels, chemical metering equipment, and monitoring equipment.

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[2] USEPA. Handbook. 1985. *Remedial Action at Waste Disposal Sites.* Office of Research and Development.

Neutralization

- Neutralization can be *effective* in adjusting the pH of most waters. An important consideration in its effectiveness is the amount of feed used to treat the water. Monitoring devices may be necessary to ensure that the appropriate amount of feed is added to the water to ensure effective neutralization.

- The *feasibility* of neutralization may be influenced by the quality of the water to be treated. Waters containing high concentrations of toxic chemicals may result in the production of toxic air emissions. Acidification of waters containing certain salts, such as sulfide, may also produce toxic emissions. These emissions can be controlled using covers on the reactor basins or mixers to disperse the heat from the reactions. Other considerations include:

  -- Lime must be added dry to the water; however, blockage of the feed system is a common problem associated with dry lime.
  -- Lime neutralization of sulfuric acid, or of acidic wastes with sulfates or sulfites, may produce calcium sulfate or sulfite, which have limited solubilities.

- The *primary capital purchases* for neutralization include compartmentalized reaction basins, mixers, and a baffle system to regulate inflow and outflow of the water. The major variable costs include lime or other agent added to the solution to adjust pH. Disposal costs for sludges resulting from neutralization are normally higher for more heavily contaminated waters, as more of the neutralizing reagent is normally needed.

G.1.4 Extraction and Removal of Waste

Factors to consider when removing wastes include:

- **Recontamination.** The RPM must ensure that the extraction and removal action does not unintentionally recontaminate other areas of the site (e.g., via environmental transport routes). Fugitive dust in the soil, for example, can easily be churned into the air through use of heavy construction equipment during extraction and removal, potentially recontaminating downwind areas or posing an immediate threat to worker safety.

- **Capabilities of extraction equipment.** An important consideration in extraction of mining waste is using the appropriate equipment given site-specific conditions. Certain types of source problems (e.g., inaccessible mines like pit mines and underground mines, large piles) may make use of conventional construction equipment, such as backhoes and dozers, infeasible.

- **The feasibility of extraction and on-site containment.** The RPM should weigh the costs and benefits associated with keeping the extracted waste on site using containment and diversion technologies as well as the use of off site treatment or disposal. In some cases, it may be more practicable to keep the extracted waste on site pending development of on-site treatment during subsequent stages of the site remediation. If the wastes are treated on site to meet all federal and state ARARs, RPMs could potentially avoid off-site transportation and disposal costs.

Extraction and off-site removal of mining wastes is often accomplished using casting and loading excavation, hauling excavation, or both. Loading and casting can be accomplished by a wide variety of conventional equipment and techniques, including the following:

- **Backhoes, draglines and crawlers** -- trenching and excavation of the waste. Draglines in particular are very suitable for excavating large areas with loosely compacted soil.

- **Cranes** -- to load and cast, or rehandle the waste.

- **Bulldozers and loaders** -- removal of miscellaneous fill or soil overburden, or relocating earth or compacted wastes from unstable surface areas to more accessible areas for lifting and loading operations.

Hauling operations are normally accomplished using the following equipment:

- **Scrapers** -- excavation for removal and hauling of surface cover material at large disposal sites or respreading and compacting of cover soils (e.g., as in capping of excavated area).

- **Haulers equipped with large rubber tires** -- transportation of excavated wastes and soil for on- or off-road hauling. The waste is normally loaded onto the hauler with backhoes, draglines, shovels, and loaders.

- **Pumps** -- extraction of liquids and sludges from ponds, lagoons, or underground mines. Pumped wastes are transported to waiting tanker trucks for transportation.

- **Dredges** -- extraction of contaminated sediment from streams, surge ponds, or other water bodies.

In addition, dust suppression measures may be necessary to protect human or environmental areas or to comply with ARARS (e.g., NESHAPs) during excavation and removal operations. Available dust suppression measures include:

- Watering of areas prior to and during excavation activities;
- Placement of tarps or covers over excavated materials;
- Use of tarps or covers over truck beds to reduce blowing dust and spillage during transportation to the waste repository; and
- Daily cleanup of all spilled or tracked soils from sidewalks and roadways.

The RPM should ensure that adequate design and operating plans are developed before commencement of extraction and offsite removal, including:

- **Operational plans** -- These plans should identify hot, transition, and cold zones for site workers, as well as other important areas for extracting and removing the waste, and include a site worker safety plan and associated contingent emergency procedures developed with the local hospital and police and fire departments.

- **Environmental controls** -- The lead agency should develop plans to ensure that the response action is implemented to mitigate any disturbance to the surrounding environment. Based on the lead agency's determination of attainable ARARs, for example, the response action may be required to meet certain location-specific or other ARARs requiring evaluation and mitigation of any disturbance to the surrounding environment. For example, the Surface Mining Control Act requires that the removal of contaminated soils use Best Available Technologies (BAT) to minimize disturbance to wildlife, fish, and the environment, and include measures to prevent subsequent erosion or air pollution.

- **Excavation and removal procedures** -- An overall strategy should be developed to ensure successful excavation and removal, such as the provision of air or soil monitoring equipment, specific procedures for excavation and removal, and identification of targeted hot spots.

Extraction and offsite removal may be an *effective* and permanent method of eliminating contamination at the site. If, however, the removal action is an interim response action and is intended to address only a specific area or kind of contaminant of concern (e.g., lead-based fugitive dust in residential soils), the action may not be a comprehensive solution to the site's contamination. In such cases, the removal action may need to be followed by a more comprehensive remedial approach, such as treatment. Extracted wastes also would pose a potential for contamination at the ultimate disposal site, unless treated beforehand.

The following considerations may be applicable in considering the *feasibility* of removal actions:

- Excavation and offsite removal is applicable to many mine conditions, but may be impracticable where site-specific features (e.g., remoteness of the contamination in an underground mine, size of source) make extraction and offsite removal cost-prohibitive.

- Because the extraction and offsite removal of waste can often be implemented quickly, the option is often appropriate for addressing immediate contamination during an interim response action, even before site characterization is complete.

- Most extraction and offsite removal options utilize conventional construction equipment and well-proven construction techniques (e.g., use of backhoes or dozers).

Cost considerations for removal actions may include the following:

- Extraction and offsite removal may reduce long-term O&M expenses (e.g., ground-water monitoring) by eliminating or reducing contamination at the site.

- The capital costs of excavation and removal may be less expensive than onsite treatment and disposal. However, as mentioned above, the RPM should consider storing the excavated waste onsite pending development of onsite treatment during the subsequent remediation phase, potentially avoiding offsite transportation and disposal costs.

- If the extracted waste is not regulated under RCRA Subtitle C, it may potentially be managed as a Subtitle D waste. If, however, the waste is subject to RCRA Subtitle C, it may require manifesting, more frequent transportation offsite under 40 CFR Part 262, and disposal in a Subtitle C disposal unit. For such waste, the costs of the extraction and offsite removal option may be higher.

- Large-scale excavation, or excavation of wastes in remote areas of a mine, can be cost-prohibitive.

- The proximity of a licensed landfill or available disposal site should be considered in evaluating transportation costs

G.1.5 Treatment of Solid Wastes

Vitrification

- Determining the *feasibility* of vitrification may involve the following considerations:

    -- Vitrification is generally not feasible for volatile metallic compounds or wastes containing high levels of constituents that may interfere with the vitrification process.
    -- High concentrations of chlorides and other halogen salts may interfere with the glass-making process and corrode equipment.
    -- Halogenated organics are not conducive to oxidation during vitrification. If halogenated organics are present in the waste, sodium chlorides may exist in the glass. Because sodium chlorides have a low solubility in glass, they may not be adequately immobilized.
    -- Certain constituents, such as carbon or other reducing agents, may interfere with vitrification. These agents tend to reduce the volatilization temperature of selenium and arsenates.
    -- The energy resources needed for vitrification may be difficult to establish at a mining site.

- The *major capital purchases* for vitrification include a vitrification furnace, feed systems, and air emission controls. Operating expenses include the large energy resources needed to operate the system.

Soil Vapor Extraction

- Variable conditions in the soil may influence the *implementability* of soil vapor extraction, including the following:

    -- Low permeability soils may hinder the movement of air through the soil, inhibiting the volatilization of organics. These and other variable conditions may cause unpredictable or inconsistent removal rates.

-- High moisture content of the soil may inhibit movement of air in the soil and thus interfere with volatilization of organics.

• *Major capital purchases* include extraction wells, an air/water separator, a blower, and a vapor treatment unit.

Distillation

• The *effectiveness* of distillation methods may vary depending on the technology used:

-- Batch distillation is particularly applicable to wastes with a high concentration of volatile organics.
-- Fractionation is applicable to wastes containing greater than approximately seven percent organics. Fractionation can be operated to produce multiple product streams for recovery of more than one organic constituent from a waste, while generating a relatively small amount of residue to be disposed.
-- Steam stripping is commonly used in wastewater treatment, but may also be applicable to sludges containing volatile organics.
-- Thin film evaporation is normally applicable to wastes with greater than 40 percent organics.
-- Thermal drying is typically effective at treating wastes with greater than 40 percent organics.

• The following factors should be considered when determining the *feasibility* of distillation:

-- The vapor-liquid ratio is an important indicator of the potential effectiveness of distillation. This ratio refers to the relative temperature at which different contaminants in the waste are distilled. For waste constituents with the same vapor-to-liquid temperatures, distillation would be impossible. Thus, greater vapor-to-liquid ratios indicate a more effective distillation.
-- The flow of heat through the waste volatilizes the organic constituents. Less conductive wastes will make distillation more problematic and may require additional mixing.
-- High concentrations of oil and grease may clog steam stripping and fractionation equipment, thereby reducing their effectiveness.

• The *primary capital equipment* for distillation will vary depending on the type of distillation used, but may include:

-- Batch distillation: a feed system and a batch distillation unit consisting of a steam-jacket vessel, a condenser, and a product receiver.
-- Fractionation: a reboiler, feed systems, a stripping and rectification column, and a condenser.
-- Steam stripping: a boiler, feed systems, stripping column, a condenser, and a collection tank.

-- Thin film evaporation: steam-jacketed cylindrical vessel, feed systems, and a condenser.
-- Thermal drying: batch or continuous dryers and feed systems.

Cyclonic Separation

- The following considerations may be applicable when determining the *feasibility* of cyclonic separation:

  -- Cyclones may be feasible for removing solid particles of over five microns diameter.
  -- Higher cyclone speeds may increase efficiencies, but may also result in higher operating costs.

- The *primary capital purchases* include feed systems and the cyclone separator.

Solidification, Stabilization, and Encapsulation

- These treatment technologies can be *effective* at treating contaminants in sludges, soils, and liquids containing inorganic constituents.

- Factors that may influence the *feasibility* of these options include:

  -- High organic content in the waste can interfere with the bonding of waste materials; an analysis of volatile and total organic carbon may therefore be necessary.
  -- Wastes that are low in solids (i.e., 15% solids) may require large volumes of cement or other agent, increasing operating costs and the weight of the end product.
  -- Oil and grease in the waste should be less than ten percent since these constituents may weaken the bonds between particles and cement by coating the particles.
  -- Sulfates may retard settling and cause swelling and sailing.

- The *primary capital purchases* include mix tanks, feed systems, monitoring systems, and leachate collection systems, if applicable.

G.2 Constructed Wetlands

- The *feasibility* of wetland treatment may depend in part on the compatibility of the organic matter with the contaminants. Phytotoxic contaminants may limit the kinds of vegetation applicable for use. Depending on the flow rate and residence time for treatment, an adequate area of land must be available for establishment of the wetland.

- Construction of the wetland may be accomplished with conventional equipment. Potential O&M *costs* may include site monitoring (e.g., ground-water monitoring) and removal and replacement of the organic matter used to absorb the contaminants. Depending on the contaminants, the organic matter removed from the wetland may require treatment and disposal under RCRA Subtitle C or D.

Wetland treatment technology is still evolving. Site managers are encouraged to consult the latest literature to find out more about current projects.

G.3 Bioremediation and Bioreclamation

- Factors that may influence the *effectiveness* of biological treatment include:

    -- The ratio of biological oxygen demand to the total organic carbon content. Waters with low BOD to TOC ratios may not be feasible for biological treatment.
    -- High concentration of surfactants on organic matter may create a barrier between the microbes and organic matter, precluding effective metabolism.
    -- Temperature, pH, and residence time must be carefully monitored to ensure optimal conditions for microbial activity.

- Determining the *implementability* of biological treatment methods could potentially depend on the following considerations:

    -- A minimal quantity of nitrogen and phosphorus are essential for the synthesis of new cells, while trace amounts of several other elements such as potassium and calcium, are also needed to satisfy requirements for microbial metabolism.
    -- Waters containing toxic organic matter may require considerably more care than nontoxic waters. Toxic organics containing chlorine may, for example, significantly reduce microbial populations and make biological treatment virtually infeasible. The microorganisms used in biological treatment can easily be destroyed by shock loading or rapid increases in the amount of toxic material fed to the process. In such cases, a considerable period of time may be needed to reestablish an adequate population of microorganisms to treat the waste.

- *Capital costs* for biological treatment will vary depending on the specific technology selected. Common capital equipment may include aeration basins, air supply equipment, piping, and a blower building.

APPENDIX H

INNOVATIVE TECHNOLOGIES

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Table of Contents

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Appendix H
Innovative Technologies

H.1 Introduction

Much progress has been made in recent years in the development and application of innovative technologies in remediating environmental damage. This appendix provides a description of the following types of technologies concluding with some selected technologies that may be applicable to mine site cleanups. EPA does not make any representation of these technologies but has included them as example of available technology. Selected technologies that are available include:

Soil and Water Treatment Technologies.

- Bioremediation
- Chemical Treatment
- Soil Washing/Flushing
- Solidification and Stabilization
- Solvent/Chemical Extraction
- Thermal Desorption and Thermal Destruction
- Vapor Extraction

Remediation Management Practices

- Application of Mining and Beneficiation Techniques
- Constructed Wetland Remediation
- Reclamation
- Contamination Prevention
- Monitoring and measurement

Several sources are available to gather information about current technologies available. First among these are EPA's Technology Innovation Office (TIO). Most of the information TIO generates resides on the Agency's Clean-Up Information (CLU-IN) home page at **http://clu-in.com.**

H.2 EPA's Technology Innovation Office and Website

The U.S. Environmental Protection Agency, Technology Innovation Office (TIO) was created in 1990 to act as an advocate for new technologies. TIO's mission is to advance the use of new technologies for characterization and remediation. To accomplish this mission, TIO works in concert with states, other federal agencies, professional associations and private companies to create a marketplace with a rich diversity of cost-effective solutions for the Nation's remediation needs. TIO produces numerous one-time and periodic publications and electronic information on technologies and markets for soil and ground water remediation. TIO strives to provide information that is relevant to technology developers, academics, consulting engineers, technology users, and state and federal regulators.

CLU-IN is intended as a forum for all stakeholders in waste remediation and contains information on policies, programs, organizations, publications and databases useful to regulators, consulting engineers, technology developers, researchers, and remediation contractors. The site contains technology descriptions and reports as well as current news on business aspects of waste site remediation and links to other sites important to managers interested in site characterization and soil and groundwater remediation technologies.

Information on the TIO Website **(http://www.epa.gov/swertio1/index.htm)** includes:

Site Remediation Technologies: Technologies Encyclopedia, Descriptions, Technology Selection Tools, Programs & Organizations, Publications

Site Characterization Technologies and Publications

Regulatory Information: Federal Registers, Regulatory Changes

Supply & Demand for Remediation Technologies: Supply of Technologies, Demand for Technologies, Marketing of Technologies, Publications

Publications and Software: Alphabetical list and an indexed list of publications and software organized by subject area.

Other Internet and Online Resource: Related WWW Sites, Other Environmental WWW Sites, Mailing Lists (Listservs), Electronic Bulletin Boards.

APPENDIX I

EPA MINING CONTACTS

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Table of Contents

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Appendix I
EPA Mining Contacts

I.1 Introduction

This appendix provides a list of contacts at the Environmental Protection Agency who may be able to provide assistance with concerns at abandoned mining and mineral processing sites. The first section provides a list of contacts within various EPA Headquarters Offices. The second section provides a list of contacts at the EPA Regional Offices. The final section provides a list of the members of the EPA Hardrock Mining Team.

This list of contacts was developed in 1998 and will change with time.

I.2 EPA Headquarters Offices			
Name	**Address**	**Phone**	**Fax**
Shahid Mahmud	Superfund Office US EPA 1235 Jefferson Davis Highway Arlington, VA 22202	703-603-8721 703-603-8755	703-603-9104
Joe Tieger	Superfund US EPA 401 M St. Washington, DC 20460	202-260-3104	202-260-9007
Steve Hoffman	Mining Coordinator Office of Solid Waste 2800 Crystal Drive Arlington, VA 22101	703-308-8413	703-308-8686
Clara Mickles	Indian Affairs US EPA 401 M St. Washington, DC 20460	202-260-7519	
Steve Silverman Steve Neugeboren	Office of General Counsel US EPA 401 M St. Washington, DC 20460	202-260-7629	202-260-7702
Keith Brown	Office of Compliance Manufacturing covering mining US EPA 401 M St. Washington, DC 20460	202-564-7124	
Jorge Rangel	NAFTA US EPA 401 M St. Washington, DC 20460	202-260-0259	202-260-9459
Elaine Suriano	Office of Federal Activities US EPA 401 M St. Washington, DC 20460	202-564-7162	202-260-0129

I.2 EPA Headquarters Offices			
Name	**Address**	**Phone**	**Fax**
Dan Weese	US EPA Office of Water - Nonpoint Source Branch 401 M St. Washington, DC 20460	202-260-6809	
Jennifer Sachar		202-260-1389	
Mary Kay Lynch	Office of Federal Facilities Compliance US EPA 401 M St. Washington, DC 20460	202-564-2581	

I.3 EPA Regional Contacts

Region	Name	Address	Phone	Fax
1	Dennis Huebner Superfund Branch	Waste Management Division 1 Congress Street Boston, MA 02114	617-918-1203	617-573-9662
2	Ray Basso New Jersey Superfund Branch	Emergency and Remedial Response Division 290 Broadway New York, NY 10007-1866	212-637-4109	212-637-4439
	John LaPadula New York/Carribbean Superfund Branch		212-637-4262	
3	Abraham Ferdas Superfund Office	Hazardous Waste Management Division 1650 Arch Street Philadelphia, PA 19107	215-814-3143	215-597-9890
	Maria Parisi Vickers RCRA Programs Office		215-814-3149	215-597-3150
4	Richard Green Superfund and Emergency Response Office	Waste Management Division 61 Forsyth Street Atlanta, GA 30303-3415	404-562-8651	404-347-0076
	Alan Farmer RCRA Permit and Compliance Branch		404-562-8295	
5	Jody Traub Superfund Division	Waste Management Division 77 West Jackson Blvd. Chicago, IL 60604-3507	312-353-2147	312-353-9306
	Norm Niedergang RCRA Division		312-886-7435	312-353-4788
6	Carl Edlund Superfund Programs Branch	Hazardous Waste Management Division Fountain Place 1445 Ross Avenue Suite 1200 Dallas, TX 75202	214-665-8126	214-665-6660
	Arnold Ondarzo RCRA Programs Branch		214-665-6790	214-665-7263
7	Robert Morby Superfund Branch	Waste Management Division 726 Minnesota Avenue Kansas City, KS 66101	913-551-7682	913-551-7060

I.3 EPA Regional Contacts

Region	Name	Address	Phone	Fax
8	Paul Arell Superfund Management Branch	Hazardous Waste Management Division 999 18th Street Suite 500 Denver, CO 80202-2405	303-312-6649	303-293-1230
	Jim Dunn		303-312-6573	
	Carol Russell		303-312-6310	
	Orville Kiehn		303-312-6540	
	Mike Bishop	US EPA Montana Field Office Helena, MT	406-441-1150	
9	Keith Takata - Director Superfund Program	Hazardous Waste Management Division 75 Hawthorne Street San Francisco, CA 94105	415-744-1730	415-744-1916
	John Hillenbrand		415-744-1912	
	Rich Vaille		415-744-2090	
10	Nick Ceto Regional Mining Coordinator	Hazardous Waste Division 1200 Sixth Avenue Seattle, WA 98101	206-553-1816	206-553-0124
	Chris Field Superfund Response and Investigations Branch - Emergency Planning		206-553-1674	
	Bill Riley Office of Water Mining Specialist		206-553-1412	206-553-1441
	Sylvia Kawabata Program Management - Unit Manager		206-553-1078	
	Cindi Godsey	Alaska Operation Office 222 West 7th Ave., #19 Anchorage, AK 99513-7588	907-271-6561	
	Dave Tomten	Idaho Operation Office 1435 North Orchard Street Boise, ID 83706	208-378-5763	

I.4 EPA Hardrock Mining Team				
Region	**Name**	**Address**	**Phone**	**Mail Drop**
Headquarters Contacts				
HQ	Ashley Allen	USEPA Headquarters 401 M Street, SW Washington, DC 20460	703-308-8419	5306W
HQ	Elaine P. Suriano		202-564-7162	2252A
HQ	Joseph Tieger		202-564-4276	2272A
Regional Contacts				
5	Daneil Cozza	Waste Management Division 77 Jackson Blvd. Chicago, IL 60604-3507	312-886-7252	WS-15J
6	Kathleen Aisling	Hazardous Waste Management Division Fountain Place 1445 Ross Avenue Dallas, TX 75202	214-665-8509	6SF-LP
7	Pat Costello	Waste Management Division 726 Minnesota Avenue Kansas City, KS 66101	913-551-7939	WWPD/RMB
8	James Dunn	Hazardous Waste Management Division 999 18th Street Suite 500 Denver, CO 80202-2405	303-312-6573	8EPR-EP
	Carol Russell		303-312-6310	8OC
9	John Hillenbrand	Hazardous Waste Management Division 75 Hawthorne Street San Francisco, CA 94105	415-744-1912	WTR-7
10	Nick Ceto	Hazardous Waste Division 1200 Sixth Avenue Seattle, WA 98101	206-553-1816	ECL-117

APPENDIX J

INTERNET RESOURCES

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Table of Contents

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APPENDIX J
INTERNET RESOURCES

J.1 Introduction

The purpose of this appendix is to provide the user with information useful to mine site cleanups. This includes accessing the Internet to locate data that may be relevant to mine site remediation activities, information on the technical resources at the Office of Water, and a list of documents relating to Corrective Action. There is a wealth of information on websites sponsored by the Environmental Protection Agency , other federal government agencies , various state governments, academic institutions, sites pertaining to groundwater, publications and journals, Institutes an Ogranizations, both public and private).

Each of the website sections presents the name, Internet address, and a short description of sites containing potentially useful information. The user should note that most of the sites contain a great deal of information that is not related to remediation but which may be of indirect interest. Note also that the following list of sites is not comprehensive, but is, rather, a sampling of the most accessible and useful sites available when this list was prepared.

J.2 Environmental Protection Agency Websites

The EPA homepage provides a map that guides the user to EPA generated information available on the Internet. Of particular interest to site managers will be the following areas within the EPA website.

(http://www.epa.gov)

J.2.1 The Office of Solid Waste and Emergency Response (OSWER)

OSWER homepage--provides links to the following offices within OSWER
(http://www.epa.gov/swerrims/index.htm)

Other Wastes - Mining and Oil and Gas Wastes Information about other solid wastes regulated under RCRA Mining Wastes, Ash and Oil and Gas.
(http://www.epa.gov/epaoswer/osw/other.htm)

Technology Information Office Information about innovative treatment technologies to the hazardous waste remediation community. Includes programs, organizations, publications and other tools for federal and state personnel, consulting engineers, technology developers and vendors, remediation contractors, researchers, community groups, and individual citizens.
(http://www.epa.gov/swertio1/index.htm)

Hazardous Waste - RCRA Subtitle C Information about the hazardous waste program including identification, generation, management and disposal of hazardous wastes.
(http://www.epa.gov/osw/)

Superfund Program - CERCLA Information concerning EPA's program to identify and clean up abandoned or uncontrolled hazardous waste sites and to recover costs for parties responsible for the contamination.
(http://www.epa.gov/superfund/)

Underground Storage Tanks Information concerning underground storage tanks containing petroleum products and other hazardous substances.

(http://www.epa.gov/swerust1/)

Rules and Regulations Federal Register notices concerning EPA's waste programs are posted daily. In addition, there is a list server available for receipt of these Federal Register notices daily. Also, links that contain the Code of Federal Regulations (CFR) and the United States Code (USC).

(http://www.epa.gov/swerrims/rules.htm)

J.2.2 EPA Remedial Technology Information

Technical Information Office/CLU-IN - The Hazardous Waste Clean-up Information Web Site provides information about innovative treatment technologies to the hazardous waste remediation community.

(http://clu-in.com/)

Alternative Treatment Technology Information Center (ATTIC) is a comprehensive computer database system providing up-to-date information on innovative treatment technologies. ATTIC v2.0 provides access to several independent databases as well as a mechanism for retrieving full-text documents of key literature. The system provides information needed to make effective decisions on hazardous waste clean-up alternatives. ATTIC can be accessed with a personal computer (PC) and modem 24 hours a day, and there are no user fees. Please note, ATTIC access requires the use of a modem or telnet application within a web browser program.

(http://www.epa.gov/attic)

Treatment and Destruction Branch - conducts bioremediation and thermal and physical/chemical treatment research. Bioremediation research is focused on using indigenous microorganisms to degrade hazardous organic chemical contaminants in soils and sediments. The thermal and physical/chemical treatment research involves the field-scale evaluation of in-situ and ex-situ vitrification, thermal desorption, soil vapor extraction, and air stripping.

(http://www.epa.gov/ORD/NRMRL/lrpcd/tdb/)

SITE (Superfund Innovative Technology Evaluation) Program - encourages the development and implementation of (1) innovative treatment technologies for hazardous waste site remediation and (2) monitoring and measurement In the SITE Demonstration Program, the technology is field-tested on hazardous waste materials. At the conclusion of a SITE demonstration, EPA prepares an Innovative Technology Evaluation Report, Technology Capsule, and Demonstration Bulletin. These reports evaluate all available information on the technology and analyze its overall applicability to other site characteristics, waste types, and waste matrices. Testing procedures, performance and cost data, and quality assurance and quality standards are also presented.

(http://www.epa.gov/ORD/SITE)

Office of Radiation & Indoor Air Radiation Protection Division Remediation Technology and Tools Center develops guidance for better, faster, and more cost-effective remedial actions, providing technical support to EPA's Superfund program, and developing, organizing, and executing Inter-Governmental projects which foster innovative, effective, and efficient treatment technologies. The Center's main focus areas include Technology Development, Technology Evaluation, Technology Transfer, and Partner Interaction. This website includes links to past project successes and public announcements. Access to publication information and other websites is also included.

(http://www.epa.gov/docs/rpdweb00)

J.2.3 Other EPA Offices and Data Sources

Office of Research and Development (ORD), is the scientific and technological arm of the U.S. Environmental Protection Agency (EPA). ORD is organized around a basic strategy of risk assessment and risk management to remediate environmental and human health problems. ORD focuses on the advancement of basic, peer-reviewed scientific research and the implementation of cost-effective, common sense technology.

(http://www.epa.gov/ORD/)

The **Office of Water** site provides links to a wide variety of information regarding the nation's surface and groundwater resources. Included in these links are sites related to: contaminated sediments; ecosystem protection; groundwater protection; monitoring, data and tools; nonpoint source pollution control; pollution prevention; water quality models; and watershed management programs.

(http://www.epa.gov/OW/)

EPA - Data Systems and Software provides access to numerous database systems available for use in understanding the environment. Some of the available systems include: Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS); Resource Conservation and Recovery Information System (RCRIS); Hazardous Waste Data; and the National GIS Program

(http://www.epa.gov/epahome/Data.html)

EPA National Library Network Program maintains a list of servers providing reference materials, research documents, and other information for use by RPMs. Sites include a sorted list of EPA libraries.

(http://www.epa.gov/natlibra/index.html)

The **Research Programs** site provides information on past, current, and future research efforts undertaken by the Agency and has links to most of the EPA documents available on-line.

(http://www.epa.gov/epahome/research.htm#programs)

J.2.4 SLATE (State, Local, and Tribal Environmental Networks)

(http://www.epa.gov/regional/statelocal/index.htm)

State Governments Home Page provides resources to State Governments involved in implementing environmental protection programs. This page provides a focal point for State governments to exchange information with EPA and each other.

(http://www.epa.gov/regional/statelocal/)

Local Governments Home Page provides resources to Local Governments involved in implementing environmental protection programs. This page provides a focal point for Local governments to exchange information with EPA and each other.

(http://www.epa.gov/regional/statelocal/)

The **American Indian Environmental Office (AIEO)** coordinates the Agency-wide effort to strengthen public health and environmental protection in Indian Country, with a special emphasis on building Tribal capacity to administer their own environmental programs.

(http://www.epa.gov/indian/)

Drinking Water and Health Fact Sheets: The U.S. EPA Office of Groundwater and Drinking Water has introduced fact sheets about chemicals that may be found in some public or private drinking water supplies. These chemicals may cause health problems if found in amounts greater that the health standard set by the U.S. EPA. The consumer version of the fact sheet describes the chemical and how it is used, why the chemical is being regulated, what the health effects are, how much is released into the environment, and several other important facts about the chemical, The technical version of the fact sheets contains similar information plus the chemical and physical properties, trade names for the chemical and other regulatory information. The versions currently available include consumer versions for inorganic chemicals and technical versions for synthetic organic chemicals.

(http://www.epa.gov/OGWDW/dwhintro.html)

J.3 Other Federal Agencies

J.3.1 U.S. Department of Energy

Environment, Safety and Health InfoCenter: Combining information technology and services, the Office of Information Management seeks to facilitate access to quality environment, safety and health information. Through the ES&H InfoCenter, an experienced research staff provides multi-media access to Federal, industry and international information sources.

(http://tis-hq.eh.doe.gov/)

Labs and Facilities Servers site provides a list of links to all the laboratories, sites, and facilities maintained by the Department of Energy.

(http://WWW.DOE.GOV/html/servers/labtitls.html)

J.3.2 U.S. Department of Defense

Defense Environmental Network & Information eXchange (DENIX):: Provides the general public with timely access to environmental legislative, compliance, restoration, cleanup, safety & occupational health, security, and DoD guidance information. Information on DENIX is updated daily and can be accessed through the series of menus, the site map, or via the DENIX full-text search engine.

(http://denix.cecer.army.mil/denix/Public/public.html)

Library: A shared library of environmental information covering compliance, restoration, pollution prevention, natural & cultural resources, occupational safety & health, pest management, environmental planning, etc.

(http://denix.cecer.army.mil/denix/Public/Library/library.html)

Environmental Security Programs: Environmental program information includes: international activities, pollution prevention, conservation, compliance, cleanup/installation restoration, education & training, safety & occupational health, and program integration.
(http://denix.cecer.army.mil/denix/Public/ES-Programs/env-sec.html)

J.3.3 U.S. Geological Survey

U.S. Geologic Survey Mine Drainage Interest Group. The mission of the U.S. Geological Survey (USGS) Mine Drainage Interest Group (MDIG) is to promote communication, cooperation, and collaboration among USGS scientists working on problems related to mining and the environment. The group is interdisciplinary and includes members from all three program divisions of the USGS: Water Resources, Geologic, Biological Resources, and National Mapping.
(http://water.wr.usgs.gov/mine/)

Natural Resources Theme Page: USGS activities in the natural resources theme area inventory the occurrence and assess the quantity and quality of natural resources. Activities also include monitoring changes to natural resources, understanding the processes that form and affect them, and forecasting the changes that may be expected in the future.
(http://www.usgs.gov/themes/resource.html)

Environment Theme Area: Information on this site includes studies of natural physical, chemical, and biological processes, and of the results of human actions. Activities include data collection, long-term assessments, ecosystem analysis, predictive modeling, and process research on the occurrence, distribution, transport, and fate of contaminants as well as the impacts of contaminants on biota.
(http://www.usgs.gov/themes/environ.html)

Publications and Data Products: Provides downloadable files, and links to other sites with information relevant to site remediation, restoration, and reclamation.
(http://www.usgs.gov/pubprod/)

J.3.4 Office of Surface Mining

Environmental Restoration: All functions that contribute to reclaiming lands affected by past coal mining practices are included under environmental restoration. The Office of Surface Mining is developing quantitative on-the-ground measures for performance in this area. When completed in 1998, statistics will be reported that compare on-the-ground performance with appropriated funding.
(http://www.osmre.gov/osm.htm)

Technology Development and Transfer: The Office of Surface Mining provides assistance to enhance the technical skills states and Indian tribes needed to operate regulatory and reclamation programs.
(http://www.osmre.gov/tech.htm)

J.3.5 Bureau of Land Management

Information on this site includes BLM state office, strategic plan, public contact, 98 fiscal budget and calender of events. It provides updated information concerning surface management regulations. **(http://www.blm.gov)**

J.3.6 U.S. Forest Service

This site contains information about all aspects of the U.S. Forest Service. Information in areas of software applications, databases, forest health, forest issues, and upcoming events are available on this site. A directory of contacts is also available.

(http://www.fs.fed.us)

J.4.0 State Websites

J.4.1 Colorado

Colorado Department of Public Health and Environment (CDPHE). This site provides information on Colorado hazardous waste regulations and programs, including research documents. Also contains a list of links to other sites of interest.

(http://www.state.co.us/gov_dir/cdphe_dir/hm/)

Division of Mining, Mine Safety, and Mined Land Reclamation: Contains links to the Colorado Mined Land Reclamation Board, Coal Regulatory Program Office of Active and Inactive Mines, and the Minerals Regulatory Program

(http://www.dnr.state.co.us/geology/)

J.4.2 Montana

Remediation Division, Montana DEQ: The Remediation Division is responsible for overseeing investigation and cleanup activities at state and federal Superfund sites; reclaiming abandoned mine lands; implementing corrective actions and overseeing groundwater remediation at sites where agricultural and industrial chemical spills have caused groundwater contamination. Contains links to the Mine Waste Remediation Bureau, and Hazardous Waste Remediation Bureau, were not functional at the time of publication. **(http://www.deq.mt.gov/rem/index.htm)**

Remediation Division - Information Systems: The Division maintains two information systems of potential interest to RPMs. The: Superfund Site Tracking System (SSTS) - contains information relating to the 278 Montana Superfund sites, including locational information, contaminant information, and agency action information. The Clark Fork Data Management System (CFDMS) serves as a point of assimilation for all chemical/physical/biological analytical information relating to the Upper Clark Fork River Basin. The CFDMS is closely associated with the Natural Resource Information System (NRIS) Geographic Information System (GIS), located at the Montana State Library.

(http://www.deq.mt.gov/rem/infosys.htm)

J.4.3 Nevada

Nevada Department of Environmental Protection, Department of Conservation and Natural Resoruces: This page is the homepage for the state agencies reponsible for mining regulation and reclamation.

(http://www.state.nv.us/ndep/)

The Nevada Division of Minerals: The Nevada Division of Minerals administers programs and activities to further the responsible development and production of Nevada's mineral resources: minerals produced from mines; geothermal; and oil and gas. The division regulates drilling operations of oil, gas, and geothermal wells; administers a program to identify, rank, and secure dangerous conditions at abandoned mines; and manages the state reclamation performance bond pool.

(http://www.state.nv.us/b&i/minerals/)

The Nevada Bureau of Mines and Geology (NBMG): The Nevada Bureau of Mines and Geology (NBMG) is a research and public service unit of the University of Nevada and is the state geological survey. NBMG is part of the Mackay School of Mines at the University of Nevada, Reno. NBMG scientists conduct research and publish reports on mineral resources, engineering geology, environmental geology, hydrogeology, and geologic mapping. Current activities in geologic mapping and mineral resources include detailed geologic mapping and stratigraphic studies in Nevada, comparative studies of bulk-mineable precious-metal deposits, geochemical investigations of mining districts, metallic and industrial mineral resource assessments, igneous petrologic studies, hydrothermal experiments, and research on the origin of mineral deposits.

(http://www.nbmg.unr.edu/)

J.4.4 New Mexico

Bureau of Mines and Mineral Resources: The Bureau is non-regulatory, and serves as the state geological survey to conduct studies and disseminate information on geology, mineral and energy resources, hydrology, geologic hazards, environmental problems, and extractive metallurgy.

(http://geoinfo.nmt.edu/)

Mining and Minerals Division: The Mining and Minerals Division is responsible for implementing the programs which regulate and support development of mining operations in New Mexico. The division also works on safeguarding abandoned mines which pose a danger to people or the environment. Publications are produced by the division which provide information on the mining industry and permitting requirements for development of mining in New Mexico.

(http://www.emnrd.state.nm.us/mining/)

J.4.5 Utah

Division of Environmental Response and Remediation contains information on Underground Storage Tanks, Superfund and Emergency Response.

(http://www.eq.state.ut.us/eqerr/errhmpg.htm)

Division of Water Quality provides information regarding the quality of Utah's lakes and rivers, water quality permitting and regulations.

(http://www.eq.state.ut.us/eqwq/dwq_home.ssi)

J.4.6 Washington

Washington State Department of Ecology: Links to information on site cleanup responses, standards, and regulations; watershed assessments; environmental reviews; hazardous waste sites; and State initiatives. Also contains links to other sites.

(http://www.wa.gov/ecology/)

J.4.7 Florida

Florida Department of Environmental Quality: The mission of Florida's DEQ protect public health and the environment through promotion of waste management practices that minimize waste generation, encourage reuse and recycling, ensure proper management of generated waste, prevent discharges of chemicals and petroleum products contained in storage tank systems, and ensure adequate and timely cleanup of the environment from contamination caused by discharges of hazardous substances and petroleum products.

(http://www2.dep.state.fl.us/waste/)

J.5 Academic Sites

Information on Laurentian University Mining and Environment Databases: It has been developed at Laurentian University Sudbury Ontario, and contains 13,000 journal articles, books and government reports on mining reclamation. Topics include abandoned mines and land use planning, land reclamation, acid mine drainage, leaching, sulphide-based tailings, design and costs, mine closure techniques, and a wide variety of other related topics.

(http://laurentian.ca/www/library/medlib.htm)

Remediation and Restoration at UCLA's Center for Clean Technology. The mission of the Center for Clean Technology's thrust in the area of remediation and restoration is to discover and develop efficient remediation technologies that can achieve acceptable levels of risk and cost for both mankind and the environment.

(http://cct.seas.ucla.edu/cct.rr.html)

Pacific Institute for Advanced Study. The Environmental Group of the PIAS has acquired a broad spectrum of technical capabilities in contaminant characterization, environmental management services, air pollution control using advanced technology biofiltration, innovative soil washing technologies, design and construction of biopiles and biofilters, site and ground water bioremediation, environmental policy and planning, and computer simulation of area migration of contaminants including free phase light hydrocarbons, multicomponent organic liquids, dissolved transport in unconfined aquifers and estimating hydrocarbon recovery by in situ vacuum extraction. The Institute's linkages with a large network of researchers assure that solutions can be quickly and efficiently found to difficult and/or unusual problems that have resisted solutions by traditional means.

(http://www.sway.com/~pacific)

Water Resources Research - Environmental Information Systems Laboratory @ McMaster University. Hydrodynamic Pollutant Transport Simulation ~ Education and Training, Air / Water Interaction ~ GIS and Remote Sensing ~ Municipal Hydraulics, Surface and Groundwater flow. Includes extensive book lists and bibliographical lists with abstracts.

(http://water.eng.mcmaster.ca/home.htm)

Arizona State University's Center for Environmental Studies. The Center conducts research on risk assessment focusing on hazardous materials transportation, contamination and mitigation; social impact assessments; vegetation research focusing in riparian plant ecology, restoration, and effects of anthropogenic disturbances on native plant communities; hazard studies focusing hazardous waste facilities, nuclear waste policy, solid and hazardous waste management, emergency management, and public perception. The site is searchable.
(http://www.asu.edu/ces/)

University of Nevada, The Mackay School of Mines. Provides information and expertise in earth science and engineering. Site provides links to research libraries, Academic departments, and a number of laboratories and research facilities focused on Nevada mines and mining issues.
(http://www.seismo.unr.edu/ftp/pub/unr/board.html)

Colorado School of Mines: Colorado School of Mines is a public university devoted to engineering and applied science related to resources. It is one of a very few institutions in the world having broad expertise in resource exploration, extraction, production and utilization which can be brought to bear on the world's pressing resource-related problems. As such, it occupies a unique position among the world's institutions of higher education. **(http://www.mines.colorado.edu/)**

EH Library Bulletin, University of Washington. The online EH Library Current Contents Bulletin includes new EH Library acquisitions, on-line information, general environmental health news, grant information, and news items that review Web sites, USENET and email groups, and more.
(http://weber.u.washington.edu /~dehlib/textindex.html)

The Research Center for Groundwater Remediation Design, or (RCGRD). The Center conducts research to reduce the costs, risks, and uncertainties associated with groundwater systems. Soils, water-saturated aquifers, the unsaturated zone, and DNAPL are all within the scope of RCGRD's conceptual, computational, and mathematical research activities. Site is under construction, so data may or may not be available. **(http://www.rcgrd. uvm.edu/)**

University of Alabama, Hydrogeology Group. The Hydrogeology Program is actively engaged in research on a wide range of issues of both scientific and practical implications on the nation's groundwater resources. Current Research Topics include: multi-species contaminant fate and transport modeling, simulation-optimization framework for remediation design, global optimization approach for parameter identification; influence of aquifer heterogeneity on groundwater remediation; numerical simulation of tracer tests at the MADE site; and abnormal fluid pressures in sedimentary basins. **(http://hydro.geo.ua.edu/)**

Surfactants Virtual Library at MIT. This site contains links to interesting surfactant and detergent related web sites, with information on surfactant phenomena such as foaming, detergency, micelles, surface tension, emulsions, microemulsions, as well as surfactant applications such as cleaning, cosmetics, environmental remediation, etc. The library is broken down into the following categories: companies, publishers, professional societies, conferences, universities and research centers with interfacial phenomena or surfactant research programs, people involved in surfactant research, surfactant related articles and abstracts published on the Internet, and surfactant applications.
(http://www.surfactants.net)

The Hydrogeology program, Stanford University. This site provides limited access to research on groundwater remediation and research. Current Research Topics include: aquifer heterogeneity; coupled inversion; geologic simulation; in-well VOC removal; optimal aquifer remediation; and rate-limited mass transfer. Contacts and links to other sites are provided.

(http://pangea.stanford.edu/hydro/)

UIC Thermodynamics Research Laboratory. This site provides abstracts of presentations and bibliography for the following topics: statistical mechanics, equations of state, phase equilibria and non-equilibria, asymmetric mixtures characterization, surface and interfacial properties, solubilities in liquids and supercritical gases.

(http://www.uic.edu/~mansoori/TRL_html)

J.6 Groundwater Sites

THE GROUNDWATER REMEDIATION TECHNOLOGIES ONLINE RESOURCE GUIDE. The purpose of this guide is to present a selection of online resources that describe the methods, designs, and effectiveness of various groundwater remediation technologies. Although that is the emphasis of the guide, many of the resources mentioned herein will be useful for researching other matters peripheral to groundwater remediation. Resources include references to web sites; electronic bulletin boards, file servers, subscriber services, and newsgroups.

(http://gwrp.cciw.ca/Internet/online.html)

Mine Environmental Neutral Drainage Program (MEND): Acidic drainage is the largest single environmental problem facing the Canadian mining industry today. Technologies to prevent or substantially reduce acidic drainage from occurring in waste rock piles and tailings sites, and on walls of open pits, need to be developed and proven. These new technologies will substantially reduce the long term financial liabilities facing public agencies at abandoned mine waste sites. In response to this need, in 1989, the Mine Environment Neutral Drainage (MEND) program was established in Canada to initiate and co-ordinate research efforts. Because of special technical needs concerning large waste rock piles, a compatible research program was established in British Columbia, the BC Acid Mine Drainage Task Force.

(http://www.nrcan.gc.ca/mets/mend/)

The Water Librarians' Home Page. This page contains links to resources that developed by a librarian in a California water agency. Topics include: water agencies, water reference databases, comprehensive water pages, water mailing lists; science and technology: earth sciences, engineering, environmental science; and law and government agencies.

(http://www.wco.com/~rteeter/waterlib.html)

J.7 Publications/Journals Sites

Journal of Soil Contamination. This journal provides access to publications of the Association for the Environmental Health of Soils (AEHS). It provides a link between the association's membership and those disciplines concerned with the technical, regulatory, and legal challenges of contaminated soils. The journal will be a quarterly, internationally peer-reviewed publication focusing on scientific and technical information, data, and critical analysis in analytical chemistry, site assessment, environmental fate, environmental modeling, remediation techniques, risk assessment, risk management, regulatory issues, legal considerations a subscription is required to obtain copies of the journal. **(http://www.crcpress.com/jour/sss/soilhome.htm)**

The Northern Miner: a weekly newspaper covering the activities of North American-based mining companies wherever they are working. Content includes exploration results, onsite reports, company profiles, international projects, property acquisitions, mergers, joint ventures, mine development, stock market activity, complete mining stock table listings and more. Each week our editorial team reports on the latest North American and international developments from such mining hot spots as Chile, Argentina, Peru, Mexico, North America, Australia and Africa. Our reporters have experience in the mining business and know what's important for readers. Our team includes geologists, mining engineers and seasoned editors.
(http://www.northernminer.com)

The Mining Journal: The Mining Journal Ltd is one of the world's leading mining and related construction industry publishers. We have a wide range of publications, many of them leaders in their own particular field, a management consultancy division, and also one of the most comprehensive company and mining databases available. All of our products and services are written, edited and managed by experts from the mining, metallurgical, geological and construction industries.
(http://www.mining-journal.com/mj/)

EPP Publications specializes in the fields of land contamination and reclamation, property development, waste and recycling, and environmental law and policy. Reports must be ordered, and each report must be purchased. This site provides a short abstract of papers that can be ordered, and subscription information to the various journals they publish.
(http://www.btinternet.com/~epppublications/)

Soil and Groundwater Cleanup Online Magazine. This site provides back issues of their magazine. Items of interest include information on: bioremediation; groundwater; in-situ technologies; ex-situ technologies; mixed wastes; site assessment; innovations; industry links; and news on new state and federal regulations.
(http://www.sgcleanup.com/)

J.8 Institutes/Organizations

Eastern Oregon Mining Association: Eastern Oregon Mining Association (EOMA) is a nonprofit organization representing and advocating for the role of mining in the Pacific Northwest. Its membership is primarily made up of operators of small mines, prospectors, and others interested in mining. EOMA is dedicated as well to the preservation of American mineral independence and proper stewardship of the environment. Headquartered in Baker City, Oregon, it has membership from the Cascades to the Rockies and from Washington to Nevada. It routinely provides assistance to Oregon state agencies in mining matters, and is in the forefront of policy making and consultation on multiple use and environmental matters.
(http://www.oregontrail.net/~eoma/)

The Minerals, Metals & Materials Society: Headquartered in the United States but international in both its membership and activities, The Minerals, Metals & Materials Society (TMS) is a professional organization that encompasses the entire range of materials and engineering, from minerals processing and primary metals production to basic research and the advanced applications of materials. Included among its members are metallurgical and materials engineers, scientists, researchers, educators, and administrators from more than 70 countries on six continents.

(http://www.tms.org/)

The Institute of Mining and Metallurgy: The IMM, founded in 1892, is a professional/learned body for engineers in the minerals industry and has its headquarters in London, UK. The IMM is a member of the Council of Mining and Metallurgical Institutions and of Eurominerals, and is a nominated body of the Engineering Council. The aims of the IMM may be summarized as: To advance the science and practice of operations within the minerals industry; To acquire, preserve and communicate knowledge of the industry. The IMM supports the professions involved with most sectors of the industry and technical disciplines include exploration, engineering and mining geology, mining engineering, petroleum engineering, mineral processing and extractive metallurgy as well as health and safety, management and environmental aspects of the industry.

(http://www.imm.org.uk)

The National Mining Association: The National Mining Association (NMA) is the voice of one of America's great basic industries- mining. It was created in 1995 as a result of the merger of two major organizations representing the mining industry at the national level: the National Coal Association and the American Mining Congress. While NMA is a relatively new organization, its predecessor organizations have a long history and tradition. The National Coal Association was founded in 1917 and the American Mining Congress was founded in 1897.

(http://www.nma.org/)

The Gold Institute: The United States is the world's second largest gold producer, capable of meeting all of its domestic gold needs, while exporting 36% of its production. While gold is widely used in jewelry and as a store of value, its importance has increasingly derived from a combination of properties that makes it vital to some of our most advanced technologies.

(http://www.goldinstitute.com)

American Institute of Mining, Metallurgical and Petroleum Engineers: AIME was founded in 1871 by 22 mining engineers in Wilkes-Barre, PA. Just as when it was founded, the goal of AIME today is to advance the knowledge of engineering and the arts and sciences involved in the production and use of minerals, metals, materials and energy resources, while disseminating significant developments in these areas of technology.

(http://www.idis.com/aime/)

Northwest Mining Association: NWMA is a regional association representing our members throughout the United States and Canada. NWMA serves in the role of the state mining association for Oregon and Washington, working closely with sister organizations representing the aggregate industry. We also work closely with the National Mining Association, state mining associations in the western United States, as well as provincial and regional mining associations throughout Canada.

(http://www.nwma.org)

The Society for Mining, Metallurgy and Exploration, Inc.: a member society of AIME - is an international, nonprofit association of some 17,000 professionals working in the mineral industries. SME members have the technical expertise acquired through training and experience and the innovative ability to enhance their industry.

(http://www.smenet.org/)

Rocky Mountain Mineral Law Foundation: Organized in 1955, the Rocky Mountain Mineral Law Foundation is an educational organization which studies the legal issues surrounding mineral and water resources. The Foundation encourages the scholarly and practical study of the law relating to oil and gas, mining, water, public lands, mineral financing and taxation, land use, environmental protection, and related areas. Its programs include institutes, short courses, and workshops in various U.S. and Canadian locations; the development and publication of treatises, books, forms, substantive newsletters, and specialized multi-volume looseleaf services; the administration of scholarships and research grants; and programs for natural resources law teachers.

(http://www.rmmlf.org/)

Nevada Mining Association: This site contains a newsletter on materials in the mining industry.

(http://www.nevadamining.org)

American Academy of Environmental Engineers. This site provides information on most aspects of environmental engineering. Contains an online list of publications relating to site remediation, pollution control, pollution prevention, and other environmental engineering topics.

(http://www.enviro-engrs.org/)

J.9 Other Websites

Waste Prevention World: The California Integrated Waste Management Board's Waste Prevention World site focuses on "doing more with less". It's about efficiency and rethinking daily activities. The site features specific tips on reducing waste at home, in the business place, and when landscaping. It also offers an online database for a topical search, as well as recycling coordination information.

(http://www.ciwmb.ca.gov/mrt/wpw/wpmain.htm)

Mining USA: The staff of Mining Internet Services, Inc. (MISI) is comprised of mining professionals with many years of engineering and industry experience. MISI was created solely to provide Internet services tailored to the mining community. We believe that the Internet is an exciting medium that can be developed into a platform to educate the public about mining. Our goal is to establish the premier mining home page that will set the standard for the industry. Therefore, we are offering extremely competitive rates to those companies and individuals that participate in achieving our goal.

(http://www.miningusa.com/)

INFO - MINE contains some of the most informative mining information on the Internet. Contents include: a daily news service; publications, technical information; company profiles; employment opportunities; and more. Some services require a subscription.

(http://www.info-mine.com/)

MINE-NET an information resource for the mining industry providing information on specific companies; products offered; scientific discoveries; sources of government, academic, professional publications. Contains some remediation data. The site is searchable and contains links to other sites.
(http://www.microserve.net/%7Edoug/index.html)

ENVIRO-LINK is a non-profit organization that is dedicated to providing you with the most comprehensive, up-to-date environmental resources available. Contains some site remediation information, and links to many other sites throughout the world.
(http://www.envirolink.org/)

The AI-GEOSTATS Homepage. Provides a searchable bibliography of geo-statistical information, on-line list of references, and a large list of geo-science publications that deliver subscriber information and data via e-mail.
(http://curie.ei.jrc.it/biblio/index.html)

The Environmental Health Clearinghouse: The site provides an easily accessible, free source of information on environmental health effects. The purpose of the EHC is to help the public get answers to their questions about environmental health and related issues. The EHC can provide information on an assortment of environmental topics including worker exposure, hazardous waste sites, chemical spills and releases, information for schools and students and other environmental health topics. The Clearinghouse uses environmental health technical information specialists to handle inquiries and provide online computer searches, mailing NIEHS publications, conducting research on inquiries, and/or referring the public to appropriate governmental agencies or to private sector organizations.
(http://www.infoventures.com/e-hlth/)

Pacific Northwest Laboratory Protech Online: The Protech Online Web Site is an resource for researching innovative groundwater remediation technologies.
(http://texas.pnl.gov:2080/webtech/menu.html)

J.10 Office of Water, Technical Resources Bibliography

The U.S. Environmental Protection Agency's (EPA) Office of Water serves to protect the nations surface water, groundwater, and drinking water resources. As part of that mission, the Office of Water has prepared a large number of technical documents relating to the remediation of waters contaminated by mining wastes. A selection of these documents are provided below.

Two Internet web pages provide a great deal of information related to the protection of water resources. These include the USEPA Office of Water home page, at:
(http://www.epa.gov/ow)

and MineInfo, a privately operated resources for individuals interested in the mining industry, at
(http://www.info-mine.com)

APPENDIX K

LAND DISPOSAL RESTRICTIONS OVERVIEW AND BIBLIOGRAPHY

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Table of Contents

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Appendix K
Land Disposal Restrictions Overview and Bibliography

K.1 Introduction

The purpose of this appendix is to provide the user with an understanding of RCRA's Land Disposal Restrictions program and rulemakings and to present a bibliography of related documents that may assist the user in evaluating remediation options at Superfund mine sites.

K.2 History of the Land Disposal Restrictions

Hazardous waste managed under the auspices of RCRA are addressed by a two-part regulatory strategy. The first involves technical standards for management units and is intended to ensure that hazardous waste is contained within the units in which it is managed. Undermining this first part of the strategy, however, is the assumption that land-based units are incapable of long-term containment. The LDR program grew out of the second piece of the strategy, which is to treat the wastes going into these management disposal units to ensure that should containment fail the waste will have little impact on human health and the environment. In the 1984 Hazardous and Solid Waste Amendments (HSWA) to RCRA, Congress specified that land disposal of hazardous waste be prohibited unless the waste meets treatment standards established by EPA. HSWA requires that treatment standards substantially diminish the toxicity or mobility of the hazardous waste, so that short- and long-term threats to human health and the environment are minimized.

K.2.1 LDR Treatment Standards

A waste identified or listed as a RCRA hazardous waste becomes subject to LDR when the Agency establishes treatment levels that the waste must meet before it can be land disposed. RCRA Section 3004(g) requires that EPA prohibit hazardous wastes from land disposal within six months of promulgating a new listing or characteristic. Until the Agency does so, however, newly listed or identified wastes are not subject to LDR and they may continue to be land disposed. Once EPA promulgates final treatment levels for a waste, handlers must manage it in accordance with all the requirements of Part 268 and the waste cannot be land disposed until it meets the treatment level.

Technology-based Treatment Standards: HSWA requires EPA to promulgate treatment standards that reduce the toxicity or mobility of hazardous constituents so that short-and long-term threats to human health and the environment are minimized. To implement this mandate EPA chose to base treatment standards on technical practicability instead of risk assessment. To this end, EPA conducts extensive research into available treatment technologies. Of all the proven, available technologies, the one that best minimizes the mobility and/or toxicity of hazardous constituents is designated as the **Best Demonstrated Available Technology (BDAT)** for that waste. The Agency then establishes a waste code-specific treatment standard based on the performance of the BDAT. These LDR treatment standards are expressed as either concentration levels or required technologies.

> **Concentration levels--** When treatment standards are set as concentration levels, treatment is not limited to the BDAT used to establish the treatment standard; instead the Agency uses BDAT to determine what is the appropriate level of treatment for each hazardous constituent commonly found in the waste. The regulated community may then use any method or technology (except for impermissible dilution) to meet the treatment standard. After treatment, waste analysis or application of knowledge must

be used to determine if the applicable concentration-based standards in Section 268.40 have been met.

Required Technologies-- When a treatment standard is a required technology, that technology must be used, unless it can be demonstrated that an alternative method can achieve a level of performance equivalent to the required technology. Whenever possible, EPA prefers to use numeric treatment standards in order to stimulate innovation and development of alternative treatment technologies.

Since the physical and chemical composition of a waste significantly impacts the effectiveness of a given treatment technology, EPA divided the treatment standard for each waste code into two categories: wastewaters and non-wastewaters. The Agency defines these two categories based on the percentages of total organic carbon (TOC) and total suspended solids (TSS) present in a waste (Section 268.2), since these factors commonly impact the effectiveness of treatment methods.

Universal Treatment Standards: Use of BDATs to set treatment standards for hazardous wastes gave rise to an unintended consequence: the numeric treatment standard applied to an individual hazardous constituent, like benzene, could vary depending on the performance of the BDAT on each listed or characteristic wastestream that was evaluated (e.g., non-wastewater forms of the listed wastes F005 and U019 both require treatment for benzene; however, the treatment standard originally set for benzene in the spent solvent was 3.7 mg/kg, while the standard originally set for unused, discarded benzene was 36 mg/kg, an order of magnitude difference). To simplify the LDR program and eliminate this lack of consistency between standards, the Agency examined the range of numeric standards applied to each hazardous constituent found in restricted hazardous wastes. Based on the range, EPA assigned a single numeric value to each constituent and listed its two treatment standards (wastewater and non-wastewater) in Section 268.48. These standards are known as the Universal Treatment Standards (UTS). Applying these universal treatment standards has not changed the hazardous constituents that must be treated in a particular waste, as only the numeric standards were amended. As a result, a common constituent found in multiple, different wastes will nonetheless carry the same numeric treatment level (e.g., treatment standards for F005 and U019 non-wastewaters continue to address benzene, but the level for each has been adjusted to 10 mg/kg).

Creation of the UTS significantly simplifies the process of assigning treatment standards to wastes that are newly identified or listed in the future. When a new waste contains hazardous constituents that have already been addressed in the UTS, the Agency will be able to apply the existing BDAT-based numeric standards for those particular constituents. Constituents not already included in the UTS can be evaluated individually and then added to Section 268.48.

Hazardous Debris Standards: Section 268.45 contains alternate treatment standards for manufactured items and environmental media that are contaminated with hazardous waste. These alternative standards were developed because materials such as rocks, bricks, and industrial equipment (known generically as debris) contaminated with hazardous waste may not be amenable to the waste code-specific treatment standards in Section 268.40. Section 268.45 allows an owner/operator to choose among several types of treatment technologies, based on the type of debris and the waste with which it is contaminated. The alternative treatment standards for debris can be divided into three categories: extraction, destruction, and immobilization technologies. When using an alternate debris treatment standard, the waste handler must ensure that the treatment process meets the design and operating requirements established in Section 268.45. In order to be eligible for land disposal, the debris must meet the specified performance standards in Table 1 of Section 268.45. Once hazardous debris has been treated according to the specification of one of these technologies, it may be land disposed in a hazardous waste unit. If hazardous debris no longer exhibits any characteristic following treatment with an extraction (e.g., sandblasting) or destruction (e.g., incineration) technology, it is eligible for land disposal and can be disposed of as nonhazardous or simply returned to the environment (Section 261.3(f)).

K.2.2 LDR Rulemakings

Due to the large number of hazardous waste codes that existed prior to HSWA, LDR treatment standards were developed in stages. In HSWA, Congress set a time frame for the implementation of treatment standards for all wastes listed or identified as hazardous on or before November 8, 1984. Congress set specific prohibition dates for certain high-risk and high-volume wastes and established a three-part schedule with specific deadlines for EPA to develop treatment standards for the remaining listed and characteristic wastes. Wastes identified subsequent to HSWA are considered newly identified or listed; additional rulemakings, promulgated in "phases," have since begun to address these new wastes. This section highlights some especially pertinent parts of those rulemakings and identifies and explains certain complex areas.

Solvent and Dioxin-containing Waste: The solvent and dioxin-containing wastes were the first wastes EPA addressed under the LDR program. Congress set a statutory deadline for EPA to establish treatment standards for these wastes because they are generated either in high volumes (solvent wastes) or are considered highly toxic (dioxin- containing wastes). The final rule published November 7, 1986 (51 FR 40572) established treatment standards for F001-F005 solvent wastes and F020-F023 and F026-F028 dioxin- containing wastes. The rule also established the basic framework for the land disposal restrictions program.

California List Waste: A second group of hazardous wastes for which Congress set a specific LDR deadline is known as the California list as it was compiled from a California Department of Health Services' program. The California list, effective July 8, 1987, prohibited the land disposal of liquid hazardous wastes containing certain toxic constituents or exhibiting certain properties unless subjected to prior treatment (52 FR 25760). The targets of the list included cyanides, pH, polychlorinated biphenyls (PCBs), halogenated organic compounds (HOCs), and metals. Certain HOC-containing wastes were also prohibited even when in solid form. As waste code-specific treatment standards subsequently have been issued, the California list prohibitions have been superseded by treatment standards specific to the RCRA waste code addressing the constituent (or property) of concern.

Thirds: Congress required EPA to meet a schedule for establishing treatment standards for all hazardous wastes identified or listed prior to HSWA. EPA was required to rank the listed wastes from high to low priority, based on the wastes' intrinsic hazard and volume generated. High-volume, high-intrinsic hazard wastes were scheduled to be addressed first, while low-volume, lower-hazard wastes, including characteristic waste, were to have treatment standards established last. Wastes with treatment standards promulgated in the first portion of the three-part schedule are known as First-Third wastes (53 FR 31138; August 17, 1988),followed by the Second-Third wastes (54 FR 26594; June 23, 1989), and Third-Third wastes (55 FR 22520; June 1, 1990).

Treatment Standards for Newly-identified or Newly-listed Wastes: HSWA further requires EPA to establish treatment standards for all hazardous wastes listed or identified after November 8, 1984. EPA is developing treatment standards for these wastes in phases.

The Phase I rule, the first of these rulemakings, was published in the Federal Register on August 18, 1992 (57 FR 37194). In addition to promulgating restrictions for certain new wastes, Phase I finalized the alternative treatment standards for hazardous debris.

The Phase II rule was finalized in the Federal Register on September 19, 1994 (59 FR 47982). This final rule consolidated the existing treatment standards into Section 268.40, created the UTS, and promulgated treatment standards for toxicity characteristic organic wastes, coke by-products, and chlorotoluenes.

The Phase III rule was finalized in the Federal Register on April 8, 1996 (61 FR 15566 and 15660). These final rules modified treatment standards for reactive wastes and decharacterized wastewaters, and promulgated new treatment standards for carbamate wastes and spent aluminum potliners.

The Phase IV rule was published on May 26, 1998 and is important to remediation efforts at mine sites as it addresses the previously exempt Bevill wastes (i.e., wastes from mineral processing facilities that were not among the 20 wastestreams retained in the Bevill exemption) and adjusts the treatment standards applicable to wastes that exhibit the toxicity characteristic for a metal constituent.

K.3 Bibliography of Selected Documents

The following is a bibliography of selected documents published in the dockets supporting Land Disposal Restrictions (LDR) Best Demonstrated Available Technology (BDAT) Phase I through Phase IV Rulemakings that may provide information on how Universal Treatment Standards (UTS) can be met at Superfund Mining sites. For ease of reading, the bibliography has been divided into five sections for documents:

Specific to Toxicity Characteristic (TC) Metals,
Specific to Mineral Processing,
Specific to Treatment Technologies ,
Other BDAT Background Documents (Corrosive Wastes and General), and
Publications by Other EPA Office or Outside Groups Included in the LDR Dockets.

The bibliography also includes the docket-document number, which identifies the docket and is followed by the document number (i.e., for document number F-96-PH4A-S0054, F-96-PH4A is the docket for the first supplemental Phase IV proposed rule, and -S0054 is the document number). The rule and its status also is indicated, since information in proposed rule dockets may not be finalized or may change prior to promulgation.

A review of history helps in understanding the utility of the documents listed. EPA established treatment standards for Extraction Procedure (EP) metals in the LDR Third Third rule finalized in 1990. In 1992, EPA established treatment standards for hazardous waste contaminated debris, including inherently hazardous debris such as lead pipe. Some remedial wastes may be debris-like and may be subject to debris standards. In 1994, EPA finalized the Universal Treatment Standards and established standards for electric arc furnace dust (K061). In establishing the K061 standard and UTS for metals, EPA changed the basis of the BDAT for many metals to High Temperature Metals Recovery (HTMR). This has not necessarily resulted in a real change in actual waste treatment technologies used.

EPA staff confirmed that stabilization remains the most common treatment method for non-wastewater forms of metal-bearing wastes. Stabilization data appear in documents supporting the Third Third final rule and the Phase IV proposed and final rule. For wastewater forms of metal-bearing wastes, various technologies can be used. These are best described in the UTS background document for wastewaters and the Phase IV proposed rule background documents. Debris is addressed as a separate waste form with unique alternative treatment standards that apply.

None of the BDAT background documents listed in the bibliography are available online. However, in developing BDAT, EPA uses various sources of data, some of which are available to the public via the Internet. While not included in the bibliography, two databases are available through EPA's Alternative Treatment Technology Information Center (ATTIC): the Treatment Technology Database and the Treatability Study Database. ATTIC is available at http//:www.epa.gov/attic/accessattic.html. Other online sources of treatment technology and treatability data are available and have been accessed to support LDR rulemakings.

LAND DISPOSAL RESTRICTIONS (LDR)
BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)
APPLICATION BIBLIOGRAPHY

Document No.	Rule/Status	Title	Notes (Description of waste codes at end of table)
U.S. EPA/Office of Solid Waste LDR Publications			
Specific to TC Metals			
F-96-PH4A-S0054, F-95-PH4P-S0285	Phase IV First Supplemental, Phase IV Proposed	Proposed Best Demonstrated Available Technology (BDAT) Background Document for Toxicity Characteristic Metal Wastes D004-D011, U.S. EPA, with Attachments A and B	Provides waste characterization data and information on treatment technologies for developing BDAT standards for wastewater and nonwastewater forms of the eight TC metal wastes (D004 - D011)
F-95-PH4P-S0289	Phase IV Proposed	Metal Treatment Performance Data From Comments to the Phase III Proposed Rule (Excerpts from Public Comments), U.S. EPA, OSW, WTB, with Attachments A through G	Contains metals treatment performance data from commenters on the Phase III Proposed Rule.
F-94-CS2F-S0021	Phase II Final	Memorandum to Lisa Jones, U.S. EPA, Regarding Final Report of Treatment Data for Nickel-Containing Wastes, From Radian Corporation, with Attachments A through J	Provides a compilation of HTMR treatment performance data used to develop previously promulgated BDAT standards for nickel wastes including K061, F006, K048-K052 and F024.

Document No.	Rule/Status	Title	Notes (Description of waste codes at end of table)
F-94-CS2F-S0023	Phase II Final	Memorandum to Lisa Jones, U.S. EPA, Regarding Comparison of Chromium Data, From Radian Corporation	Contains a comparison of waste treatment data used to develop proposed UTSs for chromium waste with treatment data submitted by Occidental Corp. in their comment (CS2P-00143) to the Proposed Phase II LDR. Includes treatment technology information and performance data for nonwastewater chromium wastes (K061).
F-94-CS2F-S0024	Phase II Final	Memorandum to the Administrative Record for Universal Standards for Metals, Regarding the Report on Chromium Treatment and the Development/Derivation of the Universal Standard for Chromium, with Attachments A and B	Provides detailed discussion of the HTMR and stabilization technologies specifically for the K061 rulemaking.
F-95-PH4P-S0190 F-95-PH4P-S0275	Third Third Final	Final Best Demonstrated Available Technology (BDAT) Background Document for K031, K084, K101, K102, Characteristic Arsenic Wastes (D004), Characteristic Selenium Wastes (D010), and P and U Wastes Containing Arsenic and Selenium Listing Constituents, U.S. EPA [From Third Third]	Provides treatment technology information, performance data, and explains the determination of BDAT for arsenic- and selenium-containing wastes: K031, K084, K101, K102, D004, D010 and P and U wastes.

Document No.	Rule/Status	Title	Notes (Description of waste codes at end of table)
F-95-PH4P-S0274	Third Third Final	Final, Best Demonstrated Available Technology (BDAT) Background Documents for D006 Cadmium Wastes, U.S., EPA	Contains waste-specific information, treatment technology information, and performance data for cadmium-containing wastes (D006) .
F-95-PH4P-S0279	Third Third Final	Final, Best Demonstrated Available Technology (BDAT) Background Documents for Barium Wastes (D005 and P013), U.S. EPA	Contains treatment technology information and performance data for barium-containing wastes (D005). Also details the development of the treatment standards for barium cyanide wastes (P013).
F-95-PH4P-S0280	Third Third Final	Final, Best Demonstrated Available Technology (BDAT) Background Documents for Chromium Wastes D007 and U032, U.S. EPA, with Attachment A and B	Provides treatment technology information, performance data, and performance data analyses for chromium wastes (D007). Also details the development of the treatment standards for calcium chromate wastes (U032).

Document No.	Rule/Status	Title	Notes (Description of waste codes at end of table)
F-95-PH4P-S0281	Third Third Final	Final, Best Demonstrated Available Technology (BDAT) Background Documents for D008 and P and U Lead Wastes, U.S. EPA, with Attachments A and B	Provides treatment technology information, performance data, and performance data analyses for lead-containing wastes (D008). Also discusses lead-containing P- and U-code wastes and details the development of treatment standards for these wastes.
F-95-PH4P-S0282	Third Third Final	Final, Best Demonstrated Available Technology (BDAT) Background Document for Mercury-Containing Wastes D009, K106, P065, P092, and U151, U.S. EPA, With Attachments A and B	Provides treatment technology information, performance data, and performance data analyses for the mercury-containing wastes K106, K071 (nonwastewaters), P065, P092, U151, and mercury TC wastes (D009).
F-95-PH4P-S0283	Third Third Final	Final, Best Demonstrated Available Technology (BDAT) Background Document for Silver-Containing Wastes	Provides treatment technology information and performance data for silver-containing wastes (D011). Also discusses associated silver-containing P-code wastes and details development of treatment standards for these wastes.
Specific to Mineral Processing			

Document No.	Rule/Status	Title	Notes (Description of waste codes at end of table)
F-96-PH4A-S0036	Phase IV First Supplemental	Best Demonstrated Available Technology (BDAT) Background Document for Mineral Processing Wastes, U.S. EPA	Contains a review of several applicable treatment and recovery technologies, comparative analysis, and performance data for mineral processing wastes characteristic for corrosivity (D002) and/or reactivity (D003)
Specific to Treatment Technologies			
F-96-PH4A-S0033	Phase IV First Supplemental	Letter to Anita Cummings, U.S. EPA, Regarding the Preliminary Assessment of Available Data on Metal Recovery Performances, ICF Inc., including Appendix A: Metal Recovery Technology Performance Summaries	Presents performance data from recovery of the 14 BDAT metals from mineral processing wastes. Focuses on electric arc furnace dusts from steel production (K061). Describes what types of waste INMETCO's recovery processes can handle, i.e., K061, K062, F006, D002, D006, D007, D001 and other wastes.

Document No.	Rule/Status	Title	Notes (Description of waste codes at end of table)
F-96-PH4A-S0037	Phase IV First Supplemental	Profiles of Metal Recovery Technologies for Mineral Processing Wastes and Other Metal-Bearing Hazardous Wastes, U.S. EPA	Contains information on characteristics and performance of 30 metal recovery technologies. Provides a preliminary assessment of whether a particular technology is suited for a specific waste (focused on mineral processing waste).
F-96-PH4A-S0038	Phase IV First Supplemental	Review Sheets for Literature on Metal Recovery Technologies for Mineral Processing Wastes, U.S. EPA	Contains review sheets for articles related to mineral processing. Specific information provided includes: if article is applicable to mineral processing wastes; level of development of technology; type of waste; specific waste application; type of process; metals or other products recovered; and if the article contains generation or characterization data on a mineral processing waste.
F-95-PH4P-S0256	Phase IV Proposed	Treatment Technology Background Document, U.S. EPA, OSW, with Attachments A through E	Contains treatment performance data and treatment technology information that may be used to treat wastewaters and nonwastewaters subject to the LDR.

Document No.	Rule/Status	Title	Notes (Description of waste codes at end of table)
F-95-PH4P-S0259	Phase IV Proposed	Proposed Data Document for Characterization and Performance of High Temperature Metals Recovery Treatment and Stabilization for Metal-Bearing Nonwastewaters, U.S. EPA, with Attachments A through Q	Contains performance and characterization data of HTMR treatment and stabiliztion for metal-bearing nonwastewaters including K061, K062, F006, F024, K048-K052, K046, K002, K003, K004, K006, K031, D007, D009, and K106.
F-94-CS2F-S0025	Phase II Final	Memorandum to the Administrative Record for Universal Standards for Metals, Regarding the Report on High Temperature Metal Recovery Processes and Stabilization Considered in the Development of Land Disposal Restrictions for K061 Nonwastewaters, U.S. EPA, 1994	Provides detailed discussion of the HTMR and stabilization technologies specifically for the K061 rulemakings.
F-94-CS2F-S0027	Phase II Final	Final Data Document for Characterization and Performance of High Temperature Metals Recovery Treatment and Stabilization for Metal Bearing Nonwastewaters, U.S. EPA	Presents characterization data and treatment performance data for metals in the Universal Standards Final Rule.
F-94-CS2F-S0030	Phase II Final	Memorandum to the Record, Regarding HTMR versus Stabilization, U.S. EPA, 1994	Contains statement saying that stabilization of metals achieves levels slightly higher than recovery of metals via HTMR.

Document No.	Rule/Status	Title	Notes (Description of waste codes at end of table)
Other BDAT Background Documents (Corrosive Wastes and General)			
F-93-CS2P-S0156	Third Third Final	Final Best Demonstrated Available Technology (BDAT) Background Document for Characteristic Ignitable Wastes (D001), Characteristic Corrosive Wastes (D002), Characteristic Reactive Wastes (D003), and P and U Wastes Containing Reactive Listing Constituents, (Title Page Only)	Contains applicable treatment technologies, characterization, and performance data for ignitable wastes (D001), corrosive wastes (D002), reactive wastes (D003) and P- and U-code wastes containing reactive listing constituents.
F-94-CS2F-S0028	Phase II Final	Final Best Demonstrated Available Technology (BDAT), Background Document for Universal Standards, Volume A: Universal Standards for Nonwastewater Forms of Listed Hazardous Wastes, U.S. EPA, July 1994.	Provides rationale and technical support including treatment technology information and performance data for selecting constituents for regulation under UTS and for developing UTS for nonwastewater forms of listed hazardous waste.
F-94-CS2F-S0046	Phase II Final	Final, Best Demonstrated Available Technology (BDAT), Background Document for Universal Standards, Volume B: Universal Standards for Wastewater Forms of Listed Hazardous Wastes, U.S. EPA, July 1994.	Contains descriptive text and tables showing performance data for treatment of metals in wastewater.

Document No.	Rule/Status	Title	Notes (Description of waste codes at end of table)
F-95-PH4P-S0284	Phase IV Proposed	Draft, Compilation and Examination of Metal Information, U.S. EPA, with Attachment A through D	Discusses treatment technologies and alternative technologies for metal wastes (D004 - D011). Information is also presented for non-TC metals such as antimony, beryllium, nickel, thallium, vanadium and zinc.
F-92-CD2F-S0113	Phase I Final	Memorandum to Mark Mercer Regarding Information on Immobilization of Hazardous Debris and Highly Contaminated Debris, Radian Corporation, Including Attachments A through E regarding organics interferences.	Contains information on immobilization of hazardous debris and examples of highly contaminated hazardous debris.
F-92-CD2F-S0118	Phase I Final	Hazardous Debris Final Rule Technical Support Document, U.S. EPA, 1992, with Attachments A through C.	Contains detailed descriptions of each treatment technology listed as BDAT for hazardous debris and a description of the performance standards applicable to each technology.
Publications by Other EPA Offices or Outside Groups Included in LDR Dockets			
F-95-PH4P-S0026	Phase IV Proposed	Physical/Chemical Treatment Technology Resource Guide, EPA/542-B-94-008, U.S. EPA, TIO.	Provides sources of physical/chemical treatment technology information and technical assistance such as bulletin boards, catalogs, databases, dockets and hotlines.

Document No.	Rule/Status	Title	Notes (Description of waste codes at end of table)
F-95-PH4P-S0222	Phase IV Proposed	Superfund Innovative Technology Evaluation Program: Technology Profiles, Seventh Edition, U.S. EPA, ORD.	Provides descriptions of innovative technologies and what waste they treat (mostly organic but includes heavy metals).
F-92-CD2F-S0061	Phase I Final	Review of In-Place Treatment Techniques for contaminated Surface Soils, Volume 1: Technical Evaluation, U.S. EPA, OSWER, OERR, MERL, and ORD.	Presents information on *in-situ* treatment technologies applicable to contaminated soils less than 2 feet deep. Includes treatment of heavy metals.
F-92-CD2F-S0062	Phase I Final	Review of In-Place Treatment Techniques for Contaminated Surface Soils, Volume 2: Background Information for *In-Situ* Treatment, U.S. EPA, OSWER, OERR, MERL, and ORD.	Presents information on *in-situ* treatment of hazardous waste contaminated soils. Information presented on monitoring to determine treatment effectiveness.
F-92-CD2F-S0064	Phase I Final	Handbook on *In-situ* Treatment of Hazardous Waste-Contaminated Soils, U.S. EPA, ORD, RREL	Provides an analysis of *in-situ* treatment of hazardous waste contaminated soils.

Document No.	Rule/Status	Title	Notes (Description of waste codes at end of table)

Description of Waste Codes

D001 - Characteristic for ignitability
D002 - Characteristic for corrosivity
D003 - Characteristic for reactivity
D004 - Toxicity characteristic (TC) for arsenic
D005 - TC for barium
D006 - TC for cadmium
D007 - TC for chromium
D008 - TC for lead
D009 - TC for mercury
D010 - TC for selenium
D011 - TC for silver

F006 - Treatment sludge from electroplating operations
F024 - Process wastes including distillation residues, heavy ends, tars, and reactor clean-out wastes, from the production of certain chlorinated aliphatic hydrocarbons by free radical catalyzed processes.

K002 - Wastewater treatment sludge from production of chrome yellow and orange pigments.
K003 - Wastewater treatment sludge from production of molybdate orange pigments.
K004 - Wastewater treatment sludge from production of zinc yellow pigments.
K006 - Wastewater treatment sludge from production of chrome oxide green pigments (anhydrous and hydrated).
K031 - By-product salts generated in the production of MSMA and cacodylic acid.
K046 - Wastewater treatment sludge from manufacturing, formulation and loading of lead-based initiating compounds.
K048 - Dissolved air floatation (DAF) float from the petroleum refining industry.
K049 - Slop oil emulsion solids from the petroleum refining industry.
K050 - Heat exchanger bundle cleaning sludge from the petroleum refining industry.
K051 - API separator sludge from the petroleum refining industry.
K052 - Tank bottoms (leaded) from the petroleum refining industry.
K061 - Emission control dust/sludge from the primary production of steel in electric furnaces.
K062 - Spent pickle liquor generated by steel finishing operations of facilities within the iron and steel industry (SIC Codes 331 and 332).
K071 - Brine purification muds from the mercury cell process in chlorine production, where separately prepurified brine is not used.
K084 - Wastewater treatment sludge generated during the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds.
K101 - Distillation tar residues from distillation of aniline-based compounds in the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds.
K102 - Residue from the use of activated carbon for decolorization in the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds.
K106 - Wastewater treatment sludge from the mercury cell process in chlorine production.

P013 - Barium cyanide
P065 - Mercury fulminate (R,T)
P092 - Mercury, (aceto-o) phenyl-

U032 - Calcium chromate
U151 - Mercury

APPENDIX L

MINE WASTE TECHNOLOGY PROGRAM

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Table of Contents

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Appendix L
Mine Waste Technology Program (MWTP)

L.1 Introduction

The purpose of this appendix is to provide the user with information and contacts for the Mine Waste Technology Program (MWTP). This program was created to provide engineering solutions to national environmental issues resulting from the past practices of mining and smelting of metallic ores. The MWTP has developed and implemented a program that emphasizes treatment technology development, testing and evaluation at bench- and pilot-scale, and an education program emphasizing training and technology transfer. Evaluation of the treatment technologies focuses on reducing the mobility, toxicity, and volume of waste; implementability; short- and long-term effectiveness; protection of human health and the environment; community acceptance; and cost reduction.

This program was formed through an interagency agreement between the United States Environmental Protection Agency (EPA) and the Department of Energy (DOE). The program is being implemented by MSE Technology Applications, Inc. (MSE) of Butte, Montana. Montana Tech of the University of Montana (Montana Tech) also located in Butte, Montana, currently provides analytical and computer support to MSE.

L.2 Information Management

As part of MWTP, Montana Tech is documenting mine waste technical issues and innovative treatment technologies. These issues and technologies are then screened and prioritized in categories related to a specific mine waste problem. Technical issues of primary interests are:

Mobile toxic constituents in water, including acid generation issues;
Mobile toxic constituents in air;
Cyanide;
Nitrate;
Arsenic; and
Pyrite.

Waste forms related to these issues include point- and nonpoint-source acid drainage, abandoned mine acid drainage, stream-side tailings, impounded tailings, priority soils, and heap leach-cyanide/acid tailings.

In conjunction with the data collection, Montana Tech has prepared a generic quality assurance project plan that provides specific instructions on how data will be gathered, analyzed, and reported for all activities of the MWTP. Features of both the EPA and DOE quality requirements are incorporated into this plan. Project-specific quality assurance project plans are developed by MSE; in addition, MSE provides oversight for all quality assurance activities performed by Montana Tech.

L.3 Demonstration Projects

As of 1996, MSE had undertaken seven pilot-scale demonstrations of innovative technologies for remediation of mining waste. Brief descriptions of six of the seven pilot projects follow this introduction; Project 6, the Pollution Magnet project, was dropped from the MWTP for reasons related to its similarity with competing technologies that were more developed and had a use that was non-mining-specific. The demonstrations were chosen after a thorough investigation of the technical issue is performed, the specific waste form to be tested is identified, and a sound engineering and cost determination of the innovative technology is formulated.

In addition to the pilot scale programs conducted by MSE, Montana Tech is conducting bench- or small pilot-scale research on several innovative techniques that show promise for cost-effective remediation of mine waste. One major criteria for these projects is the potential for scaling to demonstration pilot plants. One example, the Berkeley Pit Innovative Technologies Project, was initiated to focus on bench-scale testing of remediation technologies to help assist in defining alternative remediation strategies for EPA's future cleanup objectives for the Berkeley Pit waters. The Berkeley Pit is an inactive, open-pit copper mine that has been filling with acidic water since pump dewatering of adjacent underground mines ceased in 1982.

Project 1: Remote Mine Site Demonstration

EPA asked MSE to develop a treatment facility to treat acidic metal-laden water. Due to the remote nature of some mine sites, this facility must operate for extended periods of time on water power alone, without operator assistance.

An example of a remote mine site with a point-source aqueous discharge is the Crystal Mine. Located seven miles north of Basin, Montana, the Crystal Mine was an ideal site for this demonstration. In addition, the site has been identified by the Montana State Water Quality Bureau as a significant contributor of both acid and metal pollution to Uncle Sam Creek, Cataract Creek, and the Boulder River.

The Remote Site Demonstration Project at the Crystal Mine was to be conducted in the field for a minimum of 1 year under all weather conditions. Acid mine drainage from the lower portal of the Crystal Mine began passing through the system on a full-time basis in early September 1994. Initial analytical data from the project showed a greater than 90% removal of toxic metals from the mine drainage. The system was operated and data was collected for 2 years.

Project 2: Clay-Based Grouting Demonstration

Surface and groundwater inflow into underground mine workings becomes a significant environmental problem when water contacts sulfide ores, forming acid drainage. Clay-based grouting has the ability to reduce or eliminate water inflow into mine workings by establishing an impervious clay curtain in the formation. Groundwater flow is the movement of water through fissures and cracks or intergranular spaces in the earth. With proper application, grout can inhibit or eliminate this flow. Grouting is accomplished by injecting fine-grained slurries or solutions into underground pathways where they form a groundwater barrier. The Ukrainian clay-based grouting technology was selected for testing and evaluation because it offered a potentially long-term solution to acid mine drainage problems.

The project was finalized at the Mike Horse Mine near Lincoln, Montana. This site was selected because of its geologic characteristics. A major factor in the selection was an identified point-source inflow from Mike Horse Creek into the mine causing acid drainage that could potentially be controlled using a grouting technology. Grout injection began September 20, 1994, and was completed November 1, 1994.

Approximately 1,600 cubic yards of grout were injected during the initial phase. A second phase of grout injection was planned for the summer of 1995; however, high water damned up within the mine caused extensive damage to the mine and to the monitoring stations for the demonstration. As a result, Phase Two was discontinued.

Project 3: Sulfate-Reducing Bacteria Demonstration

Acid generation typically accompanies sulfide-related mining activities and is a widespread problem. Acid is produced chemically, through pyritic mineral oxidation, and biologically, through bacterial metabolism. This project focuses on a source-control technology that has the potential to retard or prevent acid generation at affected mine sites. Biological sulfate reduction is being demonstrated at an abandoned hard-rock mine site where acid production is occurring with associated metal mobility.

For aqueous waste, the biological process is generally limited to the reduction of dissolved sulfate to hydrogen sulfide and the concomitant oxidation of organic nutrients to bicarbonate. The particular group of bacteria chosen for this demonstration, sulfate-reducing bacteria (SRB), require a reducing environment and cannot tolerate aerobic conditions for extended periods. These bacteria require a simple organic nutrient.

At the acid-generating mine site chosen for the technology demonstration, the Lilly/Orphan Boy Mine near Elliston, Montana, the aqueous waste contained in the shaft is being treated by using the mine as an in situ reactor. An organic nutrient comprised mainly of cow manure was added to promote growth of the organisms. This technology will also act as a source control by slowing or reversing acid production. Biological sulfate reduction is an anaerobic process that will reduce the quantity of dissolved oxygen in the mine water and increase the pH, thereby slowing or stopping acid production.

The shaft of the Lilly/Orphan Boy Mine was developed to a depth of 250 feet and is flooded to the 74-foot level. Acid mine water historically discharged from the portal associated with this level. Pilot-scale work at the Western Environmental Technology Office (WETO) in Butte was performed in 1994. The objective of these tests was to determine how well bacterial sulfate reduction lowers the concentration of metals in mine water at the shaft temperature (8°C) and pH (3.0).

During 1996, the field demonstration was again monitored on a regular basis. The data generally demonstrated a decrease in metals concentrations. An increase in metals was observed during spring runoff; however, the levels decreased when flow rates returned to normal. Monitoring of the field demonstration will continue for an additional year.

Project 4: Nitrate Removal Demonstration

The presence of nitrates in water can have detrimental effects on human health and the environment. As a result, regulatory agencies have limited the allowable concentration of nitrates in effluent water. Nitrates may be present in mine discharge water as a result of the following mining activities: residuals from ammonium nitrate and fuel oil (ANFO) used in blasting; cyanide breakdown from leaching; and leaching of ANFO contamination from waste rock. To comply with Federal and State water quality standards, mining companies have typically used ion exchange or reverse osmosis to remove nitrates from discharge water. Both, however, are expensive and generate a concentrated wastestream requiring disposal.

Of the 20 technologies screened, the following 3 showed the most promise in making nitrate removal more cost effective and environmentally responsible: ion exchange with nitrate-selective resin; biological denitrification; and electrochemical ion exchange (EIX).

The best solution to the nitrate problem may be some combination of the three technologies that balances capital costs with operating costs, reliability, and minimization of wastestreams requiring disposal. Each combination has advantages and disadvantages that will be addressed during the project. A test process train was developed that is flexible and optimizes equipment capital while acquiring value-added test data. The demonstration included the following innovative technologies: ion exchange combined with biological denitrification for destruction of the concentrated brine; ion exchange combined with EIX for destruction of the concentrated brine; biological denitrification as a stand-alone process; and EIX as a stand-alone process.

The Nitrate Removal Demonstration Project was conducted at the TVX Mineral Hill Mine near Gardiner, Montana, where a building to house the equipment was constructed. Conventional ion exchange was used to remove nitrates from the mine water and produce a concentrated brine for additional testing. Biological denitrification units and an EIX unit were used to process both mine water and concentrated nitrate brine. Of all the technology combinations tested, biological denitrification of concentrated nitrate brine was the most successful at meeting these goals.

Biological denitrification was performed on both mine water and concentrated brine. This removal rate met the project goals and was typically greater than 99%. Biological denitrification of the raw mine was less successful. A removal rate of approximately 50% was typically achieved.

Electrochemical ion exchange was able to remove nitrate from the raw mine water more effectively than from the brine. Nitrate was removed at first, however, fouling of the resin by dirty water occurred quickly and the process was rendered ineffective after one batch. Filters were installed to alleviate the problem, but the size and nature of the particles made filtration difficult.

Project 5: Biocyanide Demonstration

The primary use of cyanide in the mining industry is to extract precious metals from ores, and the use of cyanide has expanded in recent years due to increased recovery of gold using heap leach technologies. Most processes use chemicals to oxidize the cyanide and produce nontoxic levels of carbon dioxide and nitrogen compounds. These are relatively expensive to operate.

Biological destruction of cyanide compounds is a natural process that occurs in soils and dilute solutions. To take advantage of this natural destruction, a strain of bacteria was isolated by researchers at Pintail Systems, Inc. The bacteria has been tested on cyanide-contaminated mine waters and has shown degradation rates of over 50% in 15 minutes. The main goal of this project is to use a strain of bacteria to destroy cyanide associated with precious metal mining operations. Another project goal is to develop a reactor design that will best use the cyanide-degrading effects of the bacteria to destroy cyanide from mining wastewater.

The field demonstration portion of the project is located at the Echo Bay McCoy/Cove Mine, southwest of Battle Mountain, Nevada. The mining rate at the mine exceeds 160,000 tons of ore per day. Milling of high-grade and sulfide ores occurs simultaneously with the cyanide solution heap leaching of lower grade ores.

Actual cyanide mine water was processed through the reactors to study the kinetics of cyanide degradation. The results from the tests were then used to design the pilot-scale reactors to be used at the mine. The final process train consists of tanks where both aerobic and anaerobic cyanide-degrading organisms are grown in large quantities. The bacteria are then pumped to the reactors for reinoculation. The cyanide solution enters the aerobic first where aerobic organisms degrade a large portion of the cyanide. The solution then moves through a series of anaerobic units for further degradation. Finally, an aerobic polishing step removes the last traces. Since cyanide is known to degrade by mechanisms other than biological, a series of control reactors was installed to run concurrently with the biological reactors.

Project 6: Arsenic Oxidation

The Arsenic Oxidation Project was proposed to demonstrate and evaluate arsenic oxidation and removal technologies. The technology being demonstrated during this project was developed jointly by the Cooperative Research Center for Waste Management and Pollution Control Limited (CRC-WMPC) and the Australian Nuclear Science & Technology Organization (ANSTO) from Lucas Heights, New South Wales, Australia.

Arsenic contamination in water is often a by-product of mining and the extraction of metals such as copper, gold, lead, zinc, silver, and nickel. In most cases, it is not economical to recover the arsenic contained in process streams because there is little demand worldwide for arsenic.

The small-scale pilot project demonstrated a two-step process for removing arsenic from contaminated mine water. The first step and primary objective of this project was to evaluate the effectiveness of a photochemical oxidation process to convert dissolved arsenic(III) to arsenic(V) using dissolved oxygen as the oxidant. The technology provides a method for the oxidation of arsenic(III) in solution by supplying an oxidant, such as air or oxygen, and a nontoxic photo-absorber, which is capable of absorbing photons and increasing the rate of arsenic(III) oxidation to the solution. The photo-absorber used is economical and readily available. Ultraviolet oxidation using high-pressure mercury lamps and solar energy was tested. The second step of this project resulted in the removal of arsenic(V) from the solution by using an accepted EPA method, adsorption using ferric iron.

The photochemical oxidation process was very effective at oxidating arsenite to arsenate at optimum conditions in the batch mode for both the solar tests and the photoreactor tests. Design problems with the photoreactor unit in the continuous mode, however, would not allow ANSTO to achieve their claim of 90% oxidation of arsenite in solution. Channeling of the process waters in the photoreactor unit was the reason for poor oxidation of arsenite, and steps to correct the problem during the field demonstration were unsuccessful. Modifications to the baffle system are necessary to prevent further channeling.

For further information on any of these demonstration projects, contact:

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APPENDIX M

REMEDIATION REFERENCES

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Table of Contents

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Appendix M
Remediation References

M.1 Introduction

The purpose of this appendix is to provide the user with a list of references related to EPA's Groundwater Remediation Program, Cyanide Treatment, and EPA's Corrective Action Program.

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