DRAFT SOLID MINERALS HANDBOOK
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CHAPTER 1: INTRODUCTION

A. PURPOSE

The purpose of the Solid Minerals Reclamation Handbook is to provide consistent guidelines and performance standards for reclamation and closure of noncoal solid mineral activities on Federal and Indian Lands. The noncoal programs covered by the Handbook include non-energy leaseables, mineral materials and locatable minerals. The Handbook serves as a supplement to Manual 3042 which presented National Policy on Land Reclamation for BLM's noncoal programs.

B. RECLAMATION GOAL

BLM's long term reclamation goals are to shape, stabilize, revegetate, or otherwise treat disturbed areas in order to provide a self-sustaining and productive use of the land in conformance with the land-use plan. Short-term reclamation goals are to stabilize disturbed areas and protect both disturbed and adjacent areas from unnecessary or undue degradation.

C. AUTHORITIES

This handbook addresses reclamation for operations conducted under 43 CFR Group 3500 for the solid leasable minerals other than coal and oil shale; 43 CFR Group 3600 for mineral materials; and 43 CFR Parts 3802 and 3809 for locatable minerals. The authority for regulating surface coal mine reclamation was given to the Office of Surface Mining Reclamation and Enforcement when Congress enacted the Surface Mine Control and Reclamation Act of 1977.

The Federal Land Policy Management Act of 1976 (FLPMA) mandates that "the public lands be managed in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values." Multiple-use management is defined in FLPMA (43 U.S.C. 1702(c)) and in regulations (43 CFR 1601.0-5(f)) as, in part, the "harmonious and coordinated management of the various resources without permanent impairment of the productivity of the lands and the quality of the environment with consideration being given to the relative values of the resources and not necessarily to the combination of uses that will give the greatest economic return or the greatest unit output." In addition, FLPMA mandates that activities be conducted so as to prevent "unnecessary or undue degradation of the lands" (43 U.S.C. 1732(b)).

The Mining and Minerals Policy Act of 1970 (30 U.S.C. 21a) established the policy for the Federal Government relating to mining and mineral development. The Act states that it is policy to encourage the development of "economically sound and stable domestic mining, minerals, metal and mineral reclamation industries." The Act also states, however, that the Government should also promote the "development of methods for the disposal, control, and reclamation of mineral waste products, and the reclamation of mined land, so as to lessen any adverse impact of mineral extraction and processing upon the physical environment that may result from mining or mineral activities."

BLM exercises the authority to supervise exploration, mining, and reclamation activities on Indian lands pursuant to 25 U.S.C. 396d and 25 CFR Parts 211, 212, and 216. The standards developed for reclamation and closure on Federal lands will apply to operations conducted on Indian lands. The Government's trust responsibilities for the various Indian tribes and entities require that BLM ensure proper reclamation and closure practices. The regulations governing operations on Indian lands require that "adequate measures be taken to avoid, minimize, or correct damage to the environment--land, water, and air--and to avoid, minimize, or correct hazards to the public health and safety" (25 CFR 216.1).

CHAPTER 2. MINING OR EXPLORATION PLAN REVIEW AND RECLAMATION CRITERIA

A. INTRODUCTION

The reclamation plan shall guide both the operator and the BLM toward a planned future condition of the disturbed area. This requires early coordination with the operator to produce a comprehensive plan. The reclamation plan will serve as a binding agreement between the operator and the regulatory agencies for the expected reclamation condition of the disturbed lands and must be periodically reviewed and modified as necessary. Because this is a binding agreement between the operator and the regulatory agency it must be monitored on a regular bases to ensure the reclamation plan is current. New information concerning the ore body, use of different mining methods than originally planned, etc., will require the review of the previous NEPA analysis to determine whether additional environmental documentation is warranted.

Although the operator will usually develop the reclamation plan, appropriate pre-planning, data inventory, and involvement in the planning process by the regulatory agencies, is essential to determine the optimum reclamation proposal. Most determinations as to what is expected should be made before the reclamation plan is approved and implemented. However, the regulations provide that plans can be modified to adjust to changing conditions or to correct for an oversight. The operator should not conduct surface disturbing activities without an approved plan. For notice level activities, the notice must contain an agreement to adhere to the reclamation requirements of the regulations and a proposal comprehensive enough for the BLM to ensure that unnecessary or undue degradation will not result. A reclamation plan should provide the following:

1. A logical sequence of steps for completing the reclamation process.

2. The specifics of how reclamation standards will be achieved.

3. An estimate of specific costs of reclamation.

4. Sufficient information for development of a basis of inspection and enforcement of reclamation and criteria to be used to evaluate reclamation success and reclamation bond release.

5. Sufficient information to determine if the reclamation plan is in conformance with the applicable BLM land-use plans, activity plans, and/or coastal zone management plans as appropriate.

In preparing and reviewing reclamation plans, the BLM and the operator must set reasonable, achievable, and measurable reclamation goals which are not inconsistent with the established land-use plans. Achievable goals will ensure reclamation and encourage operators to conduct research on different aspects of reclamation for different environments. These goals should be based on available information and techniques, should offer incentives to both parties, and should, as a result, generate useful information for future use.

The purposes of the reclamation plan are as follows:

1. Reclamation plans provide detailed guidelines for the reclamation process and fulfill Federal, State, County and other local agencies requirements. They can be used by regulatory agencies in their oversight roles to ensure that the reclamation measures are implemented, are appropriate for the site, and are environmentally sound.

2. Reclamation plans will be used by the operator throughout the operational period of the project and subsequent to cessation of exploration, mining, and processing activities. In turn, responsible agencies, including the BLM, will use the reclamation plan as a basis to review and evaluate the success of the reclamation program.

3. Reclamation plans should provide direction and standards to assist in monitoring and compliance evaluations.

B. <u>SURFACE DISTURBING ACTIVITIES</u>

For the purposes of this Handbook, surface-disturbing activities will be separated into three broad categories.

<u>Prospecting</u> is the search for new deposits or mineral commodities. Prospecting activities may include: geophysical/ geochemical studies, and hand sampling of mineral specimens.

<u>Exploration</u> includes efforts to determine the presence of economic deposits of mineral commodities. Exploration activities may include: road-building, drilling, trenching, bulk sampling, as well as any of the activities cited for prospecting.

<u>Development and mining or mineral processing</u> is the process of extracting valuable minerals from the earth and removing impurities from these minerals. These activities may include: developmental drilling, road-building, underground mining (including shafts, portals, and adits), surface mining (including trenching, open pits, and strip mines), dredging, placer mining, construction of buildings and facilities, use of leaching solutions or other chemicals, and the creation of tailings disposal sites and waste dumps.

See Table II-1 for a summary of activities and mineral categories/mine status.

II-1

Summary of Activities and Mineral Categories/Mine Status.

SURFACE-DISTURBING ACTIVITY	LOCATABLE Mineral Category	SOLID LEASABLE Mineral Category	SALABLE Mineral Category	ABANDONED Mine Status
Prospecting	Generally casual use, no BLM authorization (43 CFR 3809.5)	Generally casual use, no BLM authorization.	Generally casual use, no BLM authorization.	Generally no reclamation is required.
Exploration	Exploration activities as defined in 43 CFR 3809.5 which cause 5 acres or less of surface disturbance. An approved Plan of Operations is required for exploration activities resulting in greater than 5 acres of disturbance or bulk sampling removing more than 1,000 tons. Financial guarantees are required for both Notices and Plans of Operations.	43 CFR Part 3590 covers Solid Minerals (other than coal) for exploration and mining operations. The Authorized Officer (AO) has to approve the exploration plans which include reclamation plans. Prospecting permits required to conduct exploration. Bonds are required for prospecting permits.	Sampling and testing performed pursuant to a letter of authorization from the authorized officer (43 CFR 3602.2)	If there is a release or a threat of a release of a hazardous substance that is a threat to human health and the environment then the National Contingency Plan (NCP)must be followed when reclaiming this type of disturbance.
Mining or Milling	A plan of operations is required for all mining operations greater than casual use on BLM administered lands. A financial guarantee is required for all new notices (43 CFR 3809.552), old notices extended under 43 CFR 3809.333 on or before January 20, 2003 and all plan of operations (whether under the new or old 3809 regulations).	43 CFR Part 3590 covers operations. The AO must approve ming plans which include reclamation plans. Leases are required. Activities require a bond.	Noncompetitive sales (43 CFR 3610.2), competitive sales (43 CFR 3610.3), free use (43 CFR 3620).	Same as Exploration. Reclamation of this type of disturbance must follow the NCP.

C. NATIONAL ENVIRONMENTAL POLICY ACT

In accordance with the NEPA (NEPA), an environmental document will be prepared for those mineral actions which propose surface disturbance and have not been categorically excluded for the purpose of identifying and mitigating the impacts to the environment.

Notices under 43 CFR 3809 are not Federal actions subject to the provisions of NEPA. The requirements and mitigation measures recommended in an Environmental Assessment (EA) or Environmental Impact Statement (EIS) shall be made a part of the reclamation plan.

D. REQUIREMENTS FOR RECLAMATION PLAN CONTENT

The reclamation plan should be a comprehensive document submitted with the plan of operations, notice, exploration plan, or mining plan. It is expected that there will be changes to planned reclamation procedures over the life of the project. Any changes will generally be limited to techniques and methodology needed to attain the goals set forth in the plan. These changes to the plan may result from oversights or omissions from the original reclamation plan, permitted alterations of project activities, procedural changes in planned reclamation as a result of information developed by on-site revegetation research undertaken by the operator, results of monitoring data which indicates a new concern at the site and studies performed elsewhere, and/or changes in Federal/State regulations. Specific requirements are given in Manual Section 3042.

E. BLM REVIEW OF THE RECLAMATION PLAN

When reviewing the reclamation plan, the AO should:

1. Immediately upon its receipt, conduct a completeness review to determine whether the reclamation plan is technically and administratively complete.

2. Review the plan for content, both in the office and on-site with the operator, as necessary.

3. Recommend revisions, if necessary, as a result of the on-site review, NEPA documentation, and consultation with appropriate BLM personnel and other SMA's.

4. Ensure that the plan conforms to applicable State and Federal requirements.

5. Approve or accept the reclamation plan within the appropriate timeframes.

6. Set a schedule for inspection of operations and reclamation activities. Inspections must be scheduled at key points in the reclamation process, as well as at regular intervals.

7. Establish criteria for evaluating the success of reclamation.

F. ADMINISTRATION OF THE RECLAMATION PLAN

When administering a reclamation plan, the AO should:

1. Conduct scheduled inspections and other inspections as necessary to ensure compliance with the reclamation plan. It is important to inspect work while it is in progress and before it is concealed by further work.

2. Document inspections in an established case file and discuss needed changes with the operator. These discussions with the operator should also be documented in the case file.

3. Ensure that required interim reclamation is current and in accordance with the plan.

4. Take appropriate action in the event of noncompliance.

5. Require revisions of the reclamation plan as necessary.

6. Monitor completed projects and evaluate the success of reclamation.

7. Accept final reclamation after a reasonable monitoring period and issue a decision. A reasonable monitoring period should not be less than 5 years for determining vegetation and erosion control success.

CHAPTER 3. INSPECTION AND ENFORCEMENT

A. INTRODUCTION

The requirements of the reclamation plan and the appropriate regulations are enforced through regular inspections of the operation ,prior to commencement of the operation, during the operation and as a part of post-operation reclamation and closure activities. The types of enforcement actions available to BLM vary depending upon the particular use authorization for the operation. This section details the procedures to be used.

B. INSPECTIONS

Inspections will be conducted in accordance with current BLM policy on both Federal and Indian lands where operations for exploration, development, production, preparation, reclamation, and handling of solid minerals are being conducted. Inspections are conducted to determine compliance with all applicable laws, regulations, terms and conditions of all leases, licenses, or permits and requirements of approved exploration plans, mining plans, plans of operation, reclamation plans, and orders or notices hereafter referred to as "the established requirements" as related to reclamation. BLM will determine whether unnecessary or undue degradation of the land is occurring and the AO will take appropriate enforcement action when such determination is made.

Field personnel will be designated by the AO to conduct inspections and take enforcement actions (I&E). The intent of this policy is to identify the personnel responsible for I&E, insure that adequate resources are dedicated to I&E, and insure that qualified personnel are used for I&E functions. A variety of disciplines may be needed to conduct inspections of reclamation activities, e.g., engineers, geologists, hydrologists, soil scientists, Law Enforcement etc. Therefore, the AO may designate several people in specific areas of responsibility or may designate one person as responsible for a specific operation and expect that person to obtain the appropriate assistance whenever necessary.

The reclamation-related aspects of inspections are:

1. Determination as to whether the operation is in compliance with the reclamation plan and other established requirements.

2. Determination as to if concurrent reclamation, as planned, is taking place.

3. Identify deficiencies in the reclamation plan and require the operator to make appropriate modifications to the plan.

4. Identify any and all incidents of noncompliance.

5. Take appropriate enforcement action when noncompliance is identified.

6. Monitor reclamation success and completion.

7. Provide complete documentation of the inspection record and updating of the SLMS data base for solid leasables or other appropriate ADP system.

Once the operation has ceased activities and has entered the reclamation and closure phase, in accordance with the approved plan, the operator will submit an update to the existing reclamation plan if necessary. This update must reflect any modifications of the reclamation plan which affect proper closure of the mine site. BLM will schedule joint inspections by State and Federal agencies, the BIA, Indian tribe, Native Corporation, and/or private surface land owners, as applicable. These events will be correlated with the plan and all parties will be notified of the schedule and their part in the oversight and final inspection functions.

BLM personnel will observe plugging of underground mine portals in front of the seals to assure that openings are properly plugged. Similar observation will be made of selected drill hole plugging by the responsible personnel.

A report of the completion of closure work will be prepared and included in the appropriate case file. The report will contain a statement, signed by the AO or his delegated representative, that reclamation is complete, adequate, meets all plan requirements, and releases the operator's bond and the operator from further liability for reclamation. A copy will be given to the operator in addition to the copy placed in the case file.

C. INSPECTION SAFETY

BLM personnel conducting or participating in inspections will be knowledgeable of and comply with MSHA and OSHA safety requirements; shall have the appropriate and mandatory safety and health training for personnel working in and around surface and underground mining operations; and will comply with any additional safety rules and regulations required by the operator. Personal protective equipment such as hard hat, steel toed boots, and safety glasses must be worn during inspections, as appropriate. Other protective clothing and equipment must be worn when necessary.

If possible, inspections will be in the company of a representative of the operator. Exception to this requirement may be granted by the AO if conditions warrant.

D. ENFORCEMENT

The types of enforcement actions for violations available to the authorized officer vary depending upon the authorizing regulations for a particular operation. Refer to the appropriate inspection and enforcement policy for the appropriate regulatory program to find a complete discussion of the available enforcement actions. In all cases, the first step in the enforcement process will be a consultation with the operator in an attempt to correct the violation. Other actions are discussed below.

1. Leasable Minerals. For leasable minerals, if the consultation with the operator has not resulted in the correction of the violation, a notice of noncompliance (NON)(needs acronym to identify) will be issued. If the violation remains uncorrected, or if there is an imminent threat to public health and safety or the environment, a cessation order will be issued by the authorized officer. A continuing violation will result in a collection against the bond in the amount necessary to correct the violation and protect public health and safety and the environment. If there is no action by the operator, the BLM will undertake proceedings to cancel the lease, license, or permit. Any required enforcement action involving Indian lands will be reported to the BIA for action. The Superintendent of the BIA must serve the NON pursuant to 25 CFR 216.10(b).

2. Locatable Minerals. For locatable minerals, a NON will be issued if the operator does not correct the violation after consultation. If the operator fails to take action following the NON, the AO will issue a Record of Noncompliance (RON) decision. If working under a notice, this will require the operator to submit a plan of operations for the ongoing operation and any future operations which would otherwise have been conducted under a notice. If the problem which caused the NON to be issued remains unresolved, it will be necessary to seek injunctive relief in an appropriate Court which orders the operator to correct the violation. The operator is liable for damages which result in unnecessary or undue degradation.

   An uncorrected violation involving reclamation will result in a collection against any existing bond in the amount required to correct the violation. There is no authority to cancel mining claims or an approved plan of operations for violations related to reclamation.

3. Salable Minerals. If the violation involves unauthorized activities, the authorized officer will issue a notice of trespass. If the violation involves a failure to reclaim or meet other stipulations, a NON will be issued. Failure to comply with the NON or trespass notice will result in a collection against the bond, if any, in the amount necessary to correct the violation. In the case of free use permits, the failure to comply with reclamation stipulations will result in a refusal by BLM to issue future permits to the violating permittee and billing of the permittee for the performance of reclamation.

4. Notice of Noncompliance: The AO shall serve a NON to the operator by delivery in person or by certified mail, return receipt requested, for failure to comply with any of the established requirements. Failure of the operator to take action within the specified time limits will be grounds for an order for cessation of operations issued by the AO. The AO may initiate action for cancellation of the Federal lease or license and forfeiture of the bond for failure to correct the NON. The BIA, Tribe, Native Corporation allottees, as applicable, will be notified or consulted, as circumstances warrant, prior to issuance of a cessation order on Indian lands. The Superintendent of the BIA must issue the NON and the cessation order.

   The NON must specify the violation or noncompliance and what actions must be taken to correct the noncompliance. Time limits for compliance must also be stated in the notice. The operator must notify the AO when the noncompliance has been corrected. The AO may direct a follow-up inspection or await the next scheduled inspection to verify correction of the NON, as appropriate. Once the operator has corrected the noncompliance, the BLM personnel will submit a written report to the AO. Upon concurrence by the authorized officer that the noncompliance has been corrected, the operator will be notified in writing.

5. Cessation of Operations: With the exception of locatable mineral operations, an order for immediate cessation of operations without prior notice of noncompliance may be issued if the authorized officer has determined that a noncompliance exists which may, among other things, result in any conditions which may cause severe injury or loss of life or that could affect mining operations conducted under the mining plan or threaten significant loss of recoverable reserves or damage to the mine, the environment, or other resources. For serious violations which involve locatable mineral operations, other enforcement mechanisms may be required. These may include injunctive relief granted by an appropriate court, other agency enforcement or criminal citation.

E. ENFORCEMENT INVOLVING FEE SURFACE AND LEASED FEDERAL MINERALS OR INDIAN LANDS

BLM policy regarding privately owned surface where the mineral estate is Federally-owned and regarding minerals under Indian lands is that protection of environmental values on private surface or Indian lands will be at least as stringent as would apply on federally-owned surface.

If the surface owner requests a variance from normal and complete reclamation of the surface (e.g. requests that a pond be left for watering or a road be left for access across the property), the operator must include such requests in the reclamation plan or modify the plan accordingly. A written agreement between the operator and the surface owner regarding such deviation must be provided to the authorized officer and must specify which party, the operator or surface owner, is responsible for all future reclamation liabilities.

In no case will the reclamation bond be released until future liability is established and an agreement signed by both the operator and the surface owner. The agreement and any related documents will be kept in the case file.

The Authorized Officer will make a joint inspection to determine whether all operations have been completed in accordance with the terms and conditions of all leases, permits, or licenses, the requirements of the approved operating plan, and any modifications or requests for deviation from total reclamation.

F. BONDING

The establishment of appropriate bond amounts will include a consideration of the costs associated with actual performance of required reclamation, long-term monitoring and treatment, and closure procedures. In many States, the regulatory agency responsible for mined land reclamation establishes a rate per disturbed acre for reclamation costs. The BLM has cooperative agreements with many of these State agencies regarding bonding for mining operations. Where acceptable, the costs developed by the State should be used in setting the bond amount. Where required, the bond amount must cover not only actual reclamation costs and reclamation administration costs, but also the rental and royalty.

Where the State or other surface management agency has not established reclamation costs, the appropriate BLM office should develop a bonding rate based on local costs. Specific costs for revegetation, water management, reshaping, and other requirements may vary but, unless there are unusually difficult circumstances, bonding must be equitably set with respect to local reclamation costs. Consultation with other BLM offices, the Office of Surface Mining, the Forest Service, local mining companies, and universities is an effective method to help determine the most appropriate rate for the area in question.

Since the threat of cessation of operations or cancellation of the lease or other use authorization becomes less effective toward the end of the mine's life, it is imperative to have adequate bond coverage in case the operator defaults on their reclamation or abandonment obligations. The bond amount required to ensure proper reclamation must be determined and the bond in place prior to approval of the exploration or mining plan.

If an operator fails to take appropriate action to complete required reclamation or closure work, it may be necessary to call for forfeiture of part or all of the bond. If BLM holds the bond, notices of forfeiture will be sent by the BLM to the party of record (lessee, licensee, permittee) and/or operator and to the party that issued the surety or bond. Such notification will be by certified mail, return receipt requested. If the State holds the bond, any action must be coordinated through the appropriate State agency.

Not less than 30 days prior to cessation or closure of operations, the operator shall submit to the AO a notice of his intention to cease or close operations, together with a statement of the exact number of acres affected by his operations, the extent and kind of reclamation accomplished, and a statement as to the structures and other facilities that are to be removed from or remain on the operation site, or the leased, permitted, or licensed lands.

Prior to release of the bond, a final inspection must be conducted to ensure that reclamation and closure have been conducted in accordance with the approved plan and that all procedures have been successful. The overriding considerations are that the operator has completed the reclamation in such a manner as to minimize the potential that the Government would incur subsequent costs or liabilities or suffer future damages to any resources at the site. Where the operator has complied with all such requirements, the AO will recommend that the appropriate period of bonded liability be terminated.

CHAPTER 4. RECLAMATION OF SITE ACCESS

A. INTRODUCTION

Virtually all phases of mineral activity require some type of vehicular overland access, either by trail, road, or other means. Access can often be one of the major surface impacts related to exploration and mining activity. Careful consideration of the access route(s) and reclamation requirements are essential to a thorough analysis of any proposal.

Determine during the planning phase if the access route(s) is to be permanent or temporary. The type of access and the construction method helps determine the amount of disturbance which needs to be eventually reclaimed or maintained. The Bureau should coordinate with other Federal and State agencies and the operator to identify suitable and stable access routes, determine construction guidelines, select and implement appropriate Best Management Practices (BMP's), define reclamation objectives and methods, and determine mitigation measures.

Consult Bureau Manual Section 9113 for construction guidelines for all roads, especially those which will be permanently incorporated into the Bureau road network.

The following are generic guidelines and recommendations. You are strongly encouraged to utilize the references and attachments at the end of the chapter for specific techniques, methodologies, and details. Other cooperating Federal and State agencies should be contacted for additional information.

B. ROAD LOCATION AND CONSTRUCTION GUIDELINES

1. Use existing access whenever possible to minimize new surface disturbance. Access routes should be planned for the minimum width needed for safe operations and equipment passage and should follow natural terrain and contours such as benches and ridges. Access should be planned so that construction does not adversely alter natural drainage.

2. Select access routes which are stable and dry. When wet areas cannot be avoided, consider the use of geotextile fabrics, mattes, planking, or rocks to improve the subbase and minimize rutting and erosion. When possible avoid areas where snow accumulates and may stay late into the spring. These areas may be unstable and difficult to reclaim.

3. Avoid sustained grades greater than 10 percent and side slopes greater than 45 percent. Avoid locating roads on steep slopes where shallow, course textured soils

exist. Short sections of steep grade may be preferable to long sections of low grade in some locations.

4. Most roads should be crowned with sloped roadbeds to prevent surface erosion. Cut and fill slopes should be constructed to ensure slope stability and erosion control. All construction shall be done in accordance with professional engineering standards and practices.

5. Topsoil should be salvaged during construction and stored uphill of the road cut, if possible. Woody material should be salvaged to construct slash filter windrows at the bottom of cut and fill slopes. Silt fencing material and weed-free straw bales should be utilized in the vicinity of any active stream channel or other wetland area. Design the project to withstand specific storm events as described in Chapter VII of this handbook and in accordance with other Federal and State guidelines.

6 Installation or construction of surface drainage and flow control structures such as culverts, flow deflectors, rolling dips, energy dissipators, sediment collection traps/barriers, diversion ditches, interceptor trenches, siltation berms, vegetated buffer strips, rocked dips, rock retaining walls, sediment settling ponds, and french drains may be necessary, depending on local conditions and requirements. Examples and illustrations are provided as attachments.

7. All cut and fill slopes and other disturbed areas should be seeded, fertilized, and mulched at the application rates and time frames mandated by the local Bureau office.

8. Mitigate the visual impacts whenever possible by reducing the cut slopes and introducing trees, shrubs, and other ground cover to the reclaimed road sites. Consider hydro-mulching to speed vegetation recovery.

C. <u>ROAD RECLAMATION GUIDELINES</u>

1. Determine the desired level of obliteration and reclamation. Determine if there are alternative short or long terms uses for roads.

2. Determine short and long term reclamation objectives and goals. Identify the monitoring methods to determine reclamation success or failure and possible mitigation.

3. Reclamation may include ripping and scarifying the surface, removal of culverts and other flow structures, rounding of the cut slope, reshaping the fill slope, or complete removal of the road and total recontouring to the original topographic profile.

4. Establish mitigation measures to remedy problems identified by monitoring.

D. RAILROADS

Railroads are sometimes used in large mining operations. The reclamation of railroads is similar to that for roads. Ties and rails should be removed. Remove ballast or reclaim with the ballast in place. Railroad beds should always be considered for appropriate secondary or alternative uses.

E. REFERENCES

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Cost Estimating Guide for Road Construction: U.S. Forest Service, Northern Region, 1995.

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McLean, A. C. and Gribble, C. D., 1992. Geology for Civil Engineers: Chapman and Hall, New York.

Montana Placer Mining Best Management Practices: Montana Bureau of Mines and Geology Special Publication 106.

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CHAPTER 5. SURFACE WATER MANAGEMENT

A. INTRODUCTION

All surface disturbance associated with the various phases of mineral exploration and development has the potential for increased erosion and sedimentation. The potential for erosion is highest immediately following the disturbance, but can remain high until final site stabilization and revegetation. Erosion is affected by a wide range of site-specific factors, including, but not limited to: climate, soils, slope angle, slope length, and slope aspect. Failure to adequately address erosion concerns during any phase of mineral operations can have serious adverse impacts. Comprehensive consideration of erosion and surface water management is one of the primary issues confronting mine planners.

The hydrology (surface water management) portion of the Plan of Operations, including the reclamation plan shall be designed and implemented in accordance with all federal, state and local water quality standards, especially those under the Clean Water Act, National Pollution Discharge Elimination System (NPDES) point source and non-point source programs.

All operations with the potential for disturbance that may impact surface waters should develop base line water quality and quantity information.

All Plans of Operations should include a detailed discussion of proposed surface water run-on and run–off and erosion controls for the entire life and scope of the project.

All Plans of Operations should also include a water-monitoring program to ensure compliance with the approved plan.

B. EROSION CONTROL

The first line of defense against erosion of disturbed areas is to take measures that can limit the availability of material that can potentially be eroded. Erosion can be caused by either water or wind and often measures that protect a surface for one may be at least partially effective for the other. Wind erosion will be covered in detail in Chapter XX.

The following measures can be effective in limiting erosion from disturbed sites:

The most obvious measure, which is absolutely effective in limiting erosion, is to keep disturbance to the minimum required to accomplish the exploration or development objective.

1. Another obvious means of limiting erosion is to limit the disturbance to the minimum time required to accomplish the project objectives. Conduct surface disturbing operations so that as little ground is possible is disturbed prior to the actual need for the disturbance and reseed or stabilize the area as soon as practicable. It may also be possible to time disturbance seasonally in some cases to limit the potential for erosion.

2. Limit the angle and slope of disturbed areas. With steeper slope angles, the higher the velocity and the silt carrying capacity of the run-off. Longer slopes lengths have greater potential for erosion due to channeling. Slope length can be effectively limited through the use of terraces, benches, "dozer gouges" or other slope breaks. Any terraces or benches should be designed to handle the expected peak flows and should be constructed wide enough to prevent overflowing during winter freeze-thaw episodes. It may also be helpful for the terraces be wide enough to provide for some form of access should repairs be needed. Benches or terraces should be designed to drain into natural drainages.

3. Modification of the surface can help inhibit water flow and erosion. Common techniques can include contour ripping, disking or furrowing, dozer gouges, addition of mulch, and sometimes including rock mulch. Slopes steeper than 2.5:1 (H:V) or 40% may require specialized reclamation equipment to traverse.

4. Steep slopes may need to stabilized using erosion control fabric. There are a wide variety of materials available for specialized uses. It will probably be helpful to refer to the information provided by the various manufacturers to determine which material might work best.

5. For sites where the disturbance is more than seasonal, some form of revegetation should be used. There are a variety of annual or perennial species that will be suitable for most sites.

6. For sites where there is the possibility of erosion caused by run-on from above the site it may be useful to consider diverting water around the disturbed site. Diversions are discussed below in this section.

C. <u>SHAPING WASTE EMBANKMENTS</u>

Consider both large-scale features of dumps as well as smaller scale surface manipulation features that can be useful in controlling surface water flows on dumps.

1. Dump slopes should be concave, like most native slopes, rather than convex.

2. Dump slopes should generally mimic the nearby native slopes, to the extent practicable. The use of GPS instruments on reclamation machinery can help achieve slopes and cover placement consistent with overall reclamation objectives.

3. Diversion structures should be sized for an appropriate storm interval and also be constructed so as to provide access for maintenance.

4. Where diversions connect or return to natural waters or watercourses, consider armoring the channel, and also providing for potential maintenance.

5. Smaller scale surface manipulations, such as “dozer gouges”, contour furrows, “cat tracking”, and scattering trees and litter can help limit the effective slope length and provide microsites for vegetation, helping to control erosion.

D. <u>SEDIMENT CONTROL</u>

In most cases it will not be possible to completely eliminate erosion and it will be necessary to develop some form of sediment control. Sediment control structures can range from simple to the complex. In general sediment control structures should be located as close to the source of the sediment as possible. Where the threat to downstream water quality is high, the plan should provide for total containment and treatment of surface run-off from the site.

1. Common forms of sediment control include:

   Sediment barriers which can include temporary and permanent structures such as dams, slash filter windrows, brush barriers, silt fences, ditches, straw bales,

   Sediment ponds or traps (siltation ponds/water retention ponds).

   Shaping waste embankments to reduce run-off velocities and provide depositional areas.

2. These sediment control structures are discussed in detail below:

a. Sediment Barriers

Sediment barriers are generally only effective for small volumes of water and sediment. They can be as simple as strategically placed and anchored straw bales, or as complex as carefully installed geotextile filter cloth. The specific type of barrier to use will depend on the suspended particulate size in the run-off, and the quantity and velocity of water.

Slash filter windrows or brush barriers can be a simple and inexpensive means of sediment control off small sites or areas. These are generally simply piled as brush piles at the lower margin or slope change of a disturbance. Brush barriers can also be effective placed in drainages above sediment ponds to help slow inflow and reduce sediment input into the pond. (See Figure 8).

Rock filters can be effectively used in trapping sediments and are simple to design and construct. Rock filters should be designed to handle the expected peak run-off flows in the area. Normally rock filters are constructed using smaller rocks in the core to serve as the filter and coarse rocks on the surface to protect the filter. (See Figure 9).

Silt fences are a common means of controlling minor amounts of sediment and can be used in conjunction with either rock filters or slash filter windrows. (See Figure 9).

b. Sediment Ponds:

Properly designed sediment ponds can be one of the most effective means to capture or detain surface run-off for the purpose of removing suspended sediment. The sediment trapping efficiency of a pond is related to the residence time of the water in the pond. Longer residence times increase a ponds efficiency. The trapping efficiency of the sediment pond is dependent upon:

The surface area and depth of the settling basin

The rate of inflow

The horizontal velocity of flow through the basin

Settling velocity of the particles

The flow pathway between the pond’s inflow and outflow

3. In order to prevent contaminated surface run-off from entering natural waterways the following guidance is recommended for the construction and maintenance of sediment pond.

    a. Divert natural water flow around disturbed areas or sediment ponds to prevent contamination.

    b. Where topography limits the size of ponds, baffles can be used to effectively lengthen the flow path and retention time. The pond should be deep enough to prevent hydraulic scouring and provide additional storage volume for storm events, and to limit the need for frequent clean out. The pond should be designed and maintained to ensure retention of the design storm event.

    c. Where the risk to natural resource values or facilities is high, the pond should be designed for total containment of project site run-off from the design storm event.

    d. The integrity of the pond must be ensured through the proper design, and construction of the pond dam, standpipe (if used) and emergency spillway. The emergency spillway must not be constructed in fill material and should be protected with coarse rock or structures designed to resist erosion during storm events. Where standpipes are used, anti-piping barriers and rock stilling basins should be constructed at the pipe discharge point. *See Figures VII-2, VII-3, and VII-4.*

    e. All sediment control structures, such as ponds, dikes, diversions etc. should be designed under the direction of and certified by a registered profession engineer. The design must be reviewed by the AO prior to construction. Design of these structures must address sediment capacity, design storm events and any other appropriate factors. Sediment control structures should be completed prior to upstream surface disturbance.

    f. Sediment ponds shall not be constructed in permanent stream channels or on unstable slopes without prior consent or approval of the AO. The operator must ensure that all structures are constructed and maintained according to the design, and are periodically maintained, and inspected.

    g. Sediment control structures shall be maintained until the lands disturbed have been reclaimed and the reclamation criteria met. Ponds can then be reclaimed in accordance with the reclamation plan.

4. Diversions:

All surface disturbing activities that involve more than short term disturbance will require diversions and constructed waterways as a means of transporting water off the site and avoiding storm water runoff problems. Diversions should intercept water above the disturbed area (run-on water) (see Figures 2 and 5) and transport it around and away from any disturbed areas. Water from within the disturbed area (run-off water) may need to be routed into a sediment pond as noted above to assure sediment is not transported into offsite waters. Long-term diversions of permanent streams should be avoided where possible. Long-term diversions of intermittent streams are more difficult to avoid for large operations, but again should be avoided if possible. Most of these diversions will require a "404" permit from the U.S, Army Corps of Engineers. There may be other applicable state and federal permit requirements as well.

a. When planning for diversions:

If possible, avoid live streams

Locate diversions as high as possible to limit water volume

Analyze risk of diversion failure to downstream structures/features

Design and construct diversions for appropriate storm events

Design diversions appropriate for duration of project

b. The following additional considerations can be important during the review, permitting, operations and final reclamation of projects:

Diversions transferring water from one drainage or watershed to another are complex and should be discouraged. Proposals involving this should be evaluated in close consultation with other state and federal regulatory agencies.

The longer a stream diversion remains in place, the higher the risk of failure or environmental damage. It is important to balance risk and the design storm with the planned *duration* of the diversion. Short-term diversions are more easily managed than long-term diversions. Long-term diversions are likely to require long-term maintenance.

Construction of the diversion should provide for stability of the streambed and banks; this might include heavy riprap or protective vegetation being established in the diversion channel. *(See Figure VII-10)*

The headgate or interception point where the natural drainage is intercepted should be engineered for the design storm event. Bear in mind water does not do right angle turns well. Abrupt changes to the natural channel will be maintenance problems.

The stream gradient of the diversion channel must be engineered to minimize streambed erosion and bedload potential. Abrupt changes in gradient will also be maintenance problems

The reclamation plan should specify how the diversion will be reclaimed. All pipes or culverts should be removed during reclamation. Maintenance for diversions that will remain in place should be evaluated, and if necessary, included in bond calculations.

Diversions that are no longer needed should be reclaimed.

c. Some important considerations for diversions include

Material used as rip rap and construction material for diversions should be coarse, durable and geochemically stable rock (non acid generating). (see Figure 2)

If large changes in slope are required, it may be necessary to use engineered drop structures to accomplish the change in slope. (see Figures 3 and 4)

Particularly vulnerable spots for diversions include: interception of natural waterways, returns to natural waterways, changes in gradient, and abrupt changes in the watercourse. (see Figure 1)

Ensure that diversion gradient and flow capacity is similar to native where the diversion returns to native watercourse.

Long term diversions will require at least some level of maintenance, so access of some sort will be required along diversions.

5. Stream Reconstruction

Stream reconstruction is some of the most costly reclamation possible. It is best to avoid disturbance to streams if at all possible. If disturbance to the stream is not possible to avoid, then it should be limited to the maximum extent possible, both in terms of time and area.

Stream rerouting and reconstruction poses complex permitting and reclamation challenges. Projects that propose rerouting and ultimate reconstruction of live stream channels should be closely evaluated to ensure there are no alternatives to the proposed disturbance.

Prior to disturbance of the stream it is necessary to thoroughly characterize the stream type, flows, water quality and riparian features in order to effectively plan either a diversion or ultimate reconstruction. Drainage areas, basin relief ratios, valley gradients, and drainage densities should closely approximate pre-disturbance values. Reclaimed drainages should have similar geomorphic and hydraulic characteristics. For geomorphic characteristics these should include: channel depth, top width, stream gradient, cross-sectional area, sinuosity and channel length. For hydraulic characteristics these should include: flow depth, water surface top width, cross-sectional area of flow, water surface slope, mean channel velocity, bendway shear stress, in-stream vegetal retardance or channel roughness.

a. In the case of actual stream reconstruction the following items are critical:

Reestablish a stable valley form

Reestablish an effective floodplain

Reestablish a streamcourse appropriate for the grade and volume as determined during characterization of the original stream.

Excavate channel

Place substrate material in the channel

Place Erosion control material along channel banks

Place rock in riffles

Place woody debris

Revegetate channel banks with willows or other vegetation as appropriate.

For diversions involving live streams it is not necessary to follow the exact same procedures, but they still must include a stable “valley” form and channel, grade and riprap suitable for the anticipated flow volumes and velocities and some form of erosion control.

Following completion of stream reclamation it will be necessary to monitor the stream to insure that the reclamation goals for the stream are being met. It is not uncommon for stream restoration projects to require fine tuning following the completion of the project.

6. Other Affected Bodies of Water

Mining and related operations can impact water quality and quantity in offsite bodies of water, including rivers streams and lakes. Potential offsite impacts must be evaluated closely in consultation with relevant state agencies, since degradation of water, either onsite or offsite may be violations of state water quality laws.

a. General Procedures:

During review of the preparation of baseline studies and subsequent submission of the Plan of Operations the area should be inspected for existing and potential water quantity and quality problems.

If actual or potential water quality problems are evident, the operator should plan and initiate measures that will avoid impacts that might violate state or federal water quality laws.

Post-closure resource values of the water should be consistent with pre-disturbance values and the land use plan.

Specific mitigation measures are highly site and problem specific.

Reclamation efforts directly affecting "waters of the United States" will require a US Army Corps of Engineers Section 404 permit or other state and federal permits.

7. Maintenance

In general reclamation and closure activities should not involve long-term maintenance requirements. In reality many mines are large-scale industrial disturbances and it is unrealistic to think there will be no long-term maintenance requirements. Where long-term maintenance will be necessary, some mechanism for funding this is required. Facilities requiring maintenance will likely prevent termination of the period of liability and release of the bond.

CHAPTER 6. GROUNDWATER

A. INTRODUCTION:

Appropriate management of surface and ground water during operations has a direct substantial effect on reclamation success. Water is used in most stages of mining and mineral processing. Minimizing and controlling the discharge of contaminated water is probably the most important mine reclamation challenge today. The States or the Environmental Protection Agency have ultimate responsibility for assuring that water quality standards are met. Adverse impacts to water can be caused primarily by two types of actions:

1. Introduction of substances (or certain forms of energy such as heat) into natural waters, causing physical and or chemical changes.

2. Interception or diversion of all or part of a water resource.

   The effects of these actions are as follows:

      The quality of the water may be adversely affected, making it less suitable, or unsuitable for human, animal, or plant consumption, or industrial use.

      There may be ecological damage altering the composition of the natural biological communities inhabiting the water or surroundings, and therefore decreasing biological diversity.

      Water may no longer be available in the required and accustomed quantities at the pre-mining points of use.

   Water percolating through contaminated material can become polluted. Therefore, control of infiltration requires that potentially toxic, acidic, or reactive waste be isolated from the water supply and that permeability be decreased. This is often achieved by a combination of methods which may include: the diversion of surface and ground water; capping and isolating toxic materials; selective placement of waste above the water table; installation of underdrains; regrading; covering; and revegetation.

B. WATER CONTROL:

The physical control of water use and routing is a major task for mining projects. This analysis includes the need to:

Minimize the quantity of water used in mining and processing

Prevent contamination and degradation of all water

Intercept water so that it does not come in contact with pollutant generating sources

Intercept polluted water and divert it to the appropriate treatment facility.

Control may be complicated by the fact that many sources of water pollution are nonpoint sources and the contaminated water is difficult to intercept.

C. PLANNING:

A baseline survey should identify all water which may be at risk from a proposed mine as well as selected control waters. All aspects of a mine which may cause pollution need to be investigated, so that every phase of the operation can be designed to avoid contamination. It is invariably better to avoid pollution rather than subsequently treat water.

D. MONITORING:

The purpose of a monitoring program is to determine the quantity and quality of all waters which will be affected by mining and processing. A properly designed monitoring program will assess the degree to which a mine reclamation project satisfies objectives of the plan. Specific objectives may include:

Establishment of baseline data prior to mining

Prediction of the effects of mining

On-going assessment of current conditions

Water use possibilities

Recently, a significant amount of research has been focused on pre-mine prediction of acid or other contaminated drainage. This analysis is becoming increasingly important to determine whether the quality of water draining from a mine site will meet regulatory standards. The results of this work can be used to plan mitigation activities to minimize the need for long-term or perpetual water treatment.

The selection of parameters to be measured in a monitoring program should be comprehensive and site-specific, particularly in the case of baseline studies. Analyze preliminary samples for all potential contaminants using a scan analysis. Some of the more important water quality parameters to be measured are shown below.

Physical

Temperature

Turbidity

Water flows

Chemical

Conductivity (Specific conductance)

Alkalinity/Acidity

pH

Hardness

Color

Dissolved Oxygen

Chemical Oxygen Demand

Biological Oxygen Demand

Nitrogen

Phosphorous

Metals

Total Solids

Total Dissolved Solids

Total Suspended Solids

Other Anions and Cations

Biological

Nektonic Organisms

Planktonic Organisms

Benthic organisms

Sampling procedures can be complex and often require specialized equipment and trained personnel, especially for biological sampling. The sampling plan should be designed to reflect seasonal variations, flow extremes, and other regulatory requirements. A process discharging a continuous stream of regular quality may require less frequent sampling than a highly variable effluent, which may be sampled hourly or even continuously.

Standardized analytical methods should be selected, and rigorously followed throughout the project. In some cases analyses can be performed at the sampling stations, either by fixed automatic or portable manual equipment.

Ground water investigations should be conducted for all mining projects which are expected to involve excavation below the water table or the impoundment of water.

Water contamination problems are seldom, if ever, attributable to any one specific contaminant. Rather, it is common for several pollutants to be found in any single waste water stream. The twelve groups of mining-related contamination include:

1	Organic Reagents	7	Dissolved Solids (Soluble Salts)
2	Oils	8	Anions and Cations
3	Cyanides	9	Suspended Solids
4	Acids and Alkalis	10	Turbidity
5	Base Metals	11	Thermal
6	Fluorides	12	Radioactivity

The possible combinations of the above pollutants comprise five major problems:

Acid mine drainage

Alkaline and saline mine drainage

Heavy metal pollution

Eutrophication

Deoxygenation

When faced with hardrock mining reclamation, including closure, the authorized officer must ensure decisions will not result in unnecessary or undue degradation of the public lands. All actions must comply with the appropriate federal and state laws.

Reclamation decisions need to be coordinated and made in collaboration with the State regulatory agencies responsible for the permitting and oversight of mine reclamation, including closure activities.

The BLM must ensure adequate financial guarantees are in-place for mining operations on public lands which will include reasonably foreseeable reclamation costs, including closure and monitoring, on BLM-administered lands.

The BLM field specialists and managers need to understand and consider all the technical issues associated with hardrock mine reclamation, including closure activities and the long term implications from closure, while ensuring that reclamation, including closure activities, are conducted in a timely and effective manner. Specific technical issues addressed in this guide are disposal and monitoring of heap detoxification waters, heap drain-down waters and process pond sludge.

All surface management activities, including reclamation, must comply with all pertinent Federal laws and regulations, and all applicable State environmental laws and regulations. The fundamental requirement, implemented in 43 CFR 3809, is that hardrock mining on the public lands must prevent unnecessary or undue degradation. The Plan of Operations and any modifications to the approved Plan of Operations must meet the requirement to prevent unnecessary or undue degradation. The requirement to prevent unnecessary or undue degradation does not authorize nor prohibit the authorized release of effluents into the environment. Authorization to allow the release of contaminated waters into the environment must be in compliance with the Clean Water Act, Safe Drinking Water Act, Endangered Species Act, other applicable Federal and State environmental laws, consistent with BLM's multiple use responsibilities under the Federal Land Policy and Management Act (FLPMA), and fully reviewed in the appropriate National Environmental Policy Act (NEPA) document.

The BLM should ensure reclamation issues, including closure, are adequately addressed as part of the initial Plan of Operations. However, it needs to be recognized that proposed reclamation activities found in the original Plan of Operations are subject to change and are likely to change. With mine development, more detailed hydrologic, geologic and chemical information and actual monitoring data becomes available that may warrant changes to the reclamation, including closure activities, described in the approved Plan of Operations. Where the operator proposes or the BLM requires modification to the proposed reclamation activities, including closure, the Plan of Operations must be modified.

The authorized officer is responsible for ensuring modifications to approved Plans of Operations, including mine closure decisions, are properly reviewed prior to approval. In assessing the need for additional NEPA documentation, the authorized officer should consider the significance of the proposed modification and the adequacy of the original NEPA documentation. Any Federal decision to approve a modification to an approved Plan of Operations must be in compliance with the requirements of NEPA. If the modification involves actions that have been evaluated under previous NEPA review, the authorized officer may issue a Documentation of NEPA Adequacy (DNA).

The following actions will usually be considered a significant modification of an approved Plan of Operations. These actions will be analyzed in an environmental assessment to determine if an environmental impact statement is required.

> The proposed modification involves disturbance or use of public land not covered in an approved Plan of Operations.
>
> The proposed modification is not fully covered in an existing NEPA document.
>
> The proposed modification has potential impacts not identified and analyzed during approval of the original Plan of Operations or subsequent modifications.

Any required NEPA documentation needs to consider the potential environmental impacts of the proposed modification, including impacts to resources associated with the unsaturated zone. (For the purpose of this guidance document, the unsaturated zone is the portion of the earth immediately below the land surface and above the water table. Within this zone the pores contain both water and air, but are not totally saturated with water.) At a minimum, zero discharge and fluid treatment alternatives need to be considered in the assessment for mine closure that are proposing discharge of fluids to the environment that do not meet applicable Federal and State water requirements. Environmental analyses will be conducted according to BLM's NEPA guidelines contained in H-1790-1.

E. <u>COORDINATION</u>:

Early, consistent cooperation and participation by all Federal, State, local and Tribal entities with review and approval responsibilities for hardrock mining, including closure decisions, is likely the single most effective way to reduce costs and delays in the current approval process. For hardrock mining on public lands, the BLM is the focal point and as such needs to take the responsibility to ensure the appropriate coordination takes place with all parties. In addition to the need to coordinate with other governmental entities, the BLM needs to ensure it meets its obligations under NEPA to provide the public an opportunity review and comment on decisions affecting public lands.

Coordinated Review of Technical Issues: To aid in the coordination with the State regulatory agencies, BLM personnel need to understand the State permit requirements and approval process. The agencies should concur on data adequacy and conclusions at the earliest possible time. Where appropriate, the BLM will utilize the State environmental regulatory requirements, guidance, standards and testing methods (including sludge) as the base for its analyses and reviews. This includes deferring to the State and the U.S. Environmental Protection Agency decisions pursuant to their authority under the Clean Water Act, Safe Drinking Water Act, Resource Conservation and Recovery Act, and other applicable Federal and State environmental laws where appropriate. Except for point source discharges to waters of the U.S., currently there are no numeric Federal standards for permitting discharges into the environment as part of mine closure. The overriding BLM standard is found in the 43 CFR 3809 regulations, specifically the requirement to prevent unnecessary or undue degradation.

G. TECHNICAL ISSUES:

This section of the guidance covers three technical issues: disposal of heap detoxification waters, disposal of heap drain-down waters, and disposal of process pond sludge. Each issue discussion contains methods and technical alternatives that should be evaluated under best management practices for water and sludge disposal.

1. Disposal of Heap Detoxification Waters: The following methods for the disposal of heap detoxification water should be evaluated in the NEPA document:

    - Water treatment and discharge (infiltration, leach field, injection).

    - Land application with or without water treatment (infiltration, leach field, injection).

    - Evaporation (zero discharge).

    - Combination of evaporation, treatment, or land application.

2. Disposal of Heap Drain-Down Waters: The following methods for the disposal of heap drain-down waters should be evaluated in the NEPA document:

    - Water treatment and discharge (infiltration, field leaching, injection).

- Land application with or without water treatment (infiltration, field leach, injection).

- Evaporation (zero discharge).

- Combination of evaporation, treatment, or land application.

3. Disposal for Both Heap Detoxification and Heap Drain-Down Waters:

   When infiltration is the method of water disposal for either heap detoxification or heap drain-down the following information needs to be collected and evaluated:

   - Chemical quality of the solution to be disposed.
   - Survey of surface waters (streams, creeks, etc.).
   - Depth to the shallowest water table or ground water aquifer.
   - Ground water quality.
   - Volume of disposal solutions.
   - Soils and subsurface lithology, to also include attenuation analysis.
   - Vegetative survey.
   - Ecological survey.
   - Predicted drain-down analysis.

   These analyses would be included but not limited to State analyses for potential degradation of waters of the State.

   When disposing of detoxification and heap drain-down waters utilizing land disposal of any type, the soils and sediments in the subsurface need to be tested for metal content. The test methods for metal content in earth materials should conform to those identified in EPA/SW-846 or ASTM.

4. Disposal Process Pond Sludge

   Process pond sludge associated with mining processes are exempted from hazardous classification under the Bevill amendment. Process pond sludge must be tested to determine metal content, pH, and water content prior to evaluating disposal alternatives. The test method utilized to test the sludge should be identified in either EPA/SW-846 or ASTM. In addition, the sludge should be dried to the greatest extent possible before disposal takes place, this can be completed by evaporating the water out of the sludge.

a. Ways to dispose of sludge:

Dry sludge and bury on site

Treat sludge and bury on site.

Remove sludge to off site facility.

b. If sludge(s) are disposed of on-site through burial, an appropriate cover and capping system should be designed to:

Provide erosional stability.

Provide optimum surface water run-off and routing.

Provide in-place physical stabilization.

Provide optimum evaporation (use of soil materials, vegetation, engineering design, etc.)

Minimize infiltration through sludge burial system with geosynthetic liners.

5. Risk Management:

When all reasonable and practical technologies have been expended in the efforts to reduce organic and inorganic constituents that may reside in soils, drain-down/effluent waters, and sludges, related to mine reclamation of heaps and impoundments then a risk management approach maybe initiated.

When contaminants of concern are identified in residual waters, soils or sludges during reclamation and these waters, soils or sludges are being proposed for land application a risk based management process can be utilized if appropriate. The risk management process that must be used is outlined in the Environmental Protection Agency Guidance for Risk Assessment, as well as, other guidance that are referenced in this policy, such as BLM Management Criteria for Metals at BLM Mining Sites, Technical Note 390, 1996, revised 1999.

a. The risk process should follow the EPA guidance that is:

Identify the type of contaminant present or contaminants and the threat that it poses to both human and ecological resources.

Assess through screening the waters, soils, and sludges to determine if site-specific contaminant levels are exceeding State, Federal and other appropriate standards.

If contaminant are exceeding State, Federal, or other appropriate standards then conduct risk assessment to determine associated risk to human and ecological resources.

The risk assessment will determine land application suitability and any additional treatment, redesign, mitigation necessary to ensure human and ecological health and safety.

The risk process will allow the BLM to make an informed decision on land application proposals with regard to reclamation plans.

b. BLM managers should adhere to the principles listed below when making human and ecological risk management decisions:

The goal is to reduce human and ecological risks to levels that will result in the health and maintenance of the land for multiple use objectives.

Use site specific human and ecological risk data to make informed decisions.

Characterize site risk.

Communicate risk to the public.

Remediate and mitigate unacceptable human and ecological risk.

6. Monitoring Water Disposal in the Unsaturated and Saturated Zones:

When land application is utilized to discharge and dispose of process and drain-down waters through an engineered system, the performance of the system must be monitored. The monitoring can be conducted by a monitoring point or series of monitoring points, specifically wells, piezometers and lysimeters.

The piezometers and lysimeters should be located within the soil or unsaturated lithology zone to collect and monitor the discharge process as it takes place for unsaturated zone characteristics. The piezometers and lysimeters should be placed at varying depths and distances around and away from the engineered system.

The well(s) should be located in the saturated zone (water table or aquifer) down-gradient of the engineered system and have enough coverage to account for spatial movement both horizontal and vertical. The well(s) should also be located in such a manner as to show system or natural conditions down-gradient from the discharge point(s) in distance increments. By placing well(s) in incremental distances down-gradient from the discharge points one will be able to observe the performance of the engineered system and confirm efficiency or effectiveness.

CHAPTER 7. PIT LAKES

A. Pit Lake Reclamation:

The sides of the pit should be graded so that they are less steep to reduce sloughing, slumping, and erosion. The potential for wave action to erode the pit walls should be considered. Aquatic and emergent vegetation may be introduced where water quality permits. If water is of sufficient quality and is projected to remain so over time, fisheries may be established in consultation with state agencies.

Where water quality is not projected to be of good quality, littoral zones may be reduced by planning water levels so that no ledges are near the surface, but over time these will probably reappear.

Pit lakes which are potentially toxic should not pass the permitting process, however, uncertainties in modeling and/or pre-existing lakes may still result in situations in which chemical reclamation is required.

For acidity, crushed limestone or other carbonates can be added on a trial and error basis to buffer acid. Hoppers have been used to dump the carbonates directly into the water. This may need for several years as pH is monitored. Metal contaminants associated with the water such as arsenic, manganese, iron, selenium, etc. will precipitate out with ferric oxide into a sludge at the base of the lake and thus be of less concern.

It is speculated that metals may also be precipitated through the addition of organics such as manure or straw, although actual experience is limited.

Large volumes of water may be treated by reverse osmosis, metal precipitators, or other recirculating treatment plants, although these are expensive and would require long-term or indefinite bonding to ensure their maintenance.

CHAPTER 8. WASTE DUMP DESIGN AND VISUAL RESOURCE MANAGEMENT

A. INTRODUCTION

Handling of the waste materials generated during mining has a direct and substantial effect on the success of reclamation. Materials which will comprise the waste should be sampled and characterized for acid generation potential, reactivity, and other parameters of concern. Final waste handling should consider the selective placement of the overburden, spoils, or waste materials, and shaping the waste disposal areas. Creating special subsurface features (rock drains), sealing toxic materials, and grading or leveling the waste dumps are all waste handling techniques for enhancing reclamation. Any problems with the placement of waste discovered after the final handling will be very costly to rectify. Therefore, the selective placement of wastes should be considered during the mine plan review process in order to mitigate potential problems. Waste materials generated during mining are either placed in external waste dumps, used to backfill mined out pits, or used to construct roads, pads, dikes etc.

The waste management practices design must be approved by BLM on BLM lands. On non-BLM lands design approval may be required by State, Tribal or Federal agencies.

B. WASTE DUMP DESIGN AND CONSTRUCTION

The most common types of waste dumps include: (1) Head of Valley Fills, (2) Cross Valley Fills, (3) Side Hill Dumps, and (4) Flat Land Pile Dumps. See Figure VIII-1. Large waste dump design must incorporate appropriate reclamation performance standards to achieve stability, drainage, and re-vegetation. Some guidance to consider during the mine plan review process includes the following:

1. Waste dumps should not be located within stream drainages or groundwater discharge areas unless engineered to provide adequate drainage to accommodate the expected maximum flow and exceed half a Probable Maximum Flood (PMF) event which is location specific.

2. Waste dumps will be graded or contoured and designed for mass stability. Design criteria should include a geotechnical failure analysis. It is also recommended that prior to the construction of large waste dumps, a foundation analysis and geophysical testing be conducted on the dump site to ensure basal stability, especially on side hill dump locations. The effects of local ground water conditions and other geohydrologic factors must be considered in the siting and designing of the dump.

3. Cross valley fills should provide for stream flow through the base of the dump. This is usually done using a rubble drain or french drain. At a minimum, the drain capacity should be capable of handling a design storm flow. To be effective, the drain must extend from the head of the upstream fill to the toe of the downstream face and should be constructed of course durable rock which will pass a standard slake test. Toxic or acid-producing materials should not be placed in valley fills.

4. Rock core chimney drains are sometimes appropriate for head of hollow fills.

5. Drainage should be diverted around or through head of valley and sidehill dumps.

6. Waste dumps will be graded or contoured and designed for mass stability. Design criteria should include a geotechnical failure analysis. It is also recommended that prior to the construction of large waste dumps, a foundation analysis and geophysical testing be conducted on the dump site to ensure basal stability, especially on side hill dump locations. The effects of local ground water conditions and other geohydrologic factors must be considered in the siting and designing of the dump.

7. Drainage should be diverted around or through head of valley and sidehill dumps.

8. Benches or Terraces should be designed to direct water into natural drainages.

9. Terraces should be wide enough to allow access if repairs are needed.

10. Fills must have no impoundments. Ephemeral ponding during major storms where water volume temporarily exceeds drainage ability is not an impoundment. However, the drainage ability of the dump design must be able to handle major storms and major storm runoff without water topping any portion of the dump crest.

11. Drains must be constructed of durable, nonslaking rock or gravel.

12. Topsoil or other suitable growth media should be removed from the proposed dump site and stockpiled for future use in reclamation.

13. Placement of coarse durable materials at the base and toe of the waste dump lowers the dump pore pressure and provides for additional internal hydrologic stability. An exception to this guidance would be in the case where the spoils materials exhibit high phytotoxic properties and the spoils must be sealed to prevent water percolation.

14. The finer textured waste materials which are more adaptable for use as a growing medium should be placed on the outside or mantle of the waste dump.

15. Berm dumps with available growth medium to prevent rockfall during final dump construction.

16. After the waste dump has been shaped, scarified, or otherwise treated to enhance reclamation, suitable topsoil or other growth medium should be spread over the surfaces of the dump (Refer to Section XVIII, Revegetation). Grading and scarification may be required.

17. Use of Cat mounted GPS units to cut slopes and contour gives more slope control and is cost effective.

18. The dump should be designed to provide for controlled water flow which minimizes erosion and enhances structural stability.

19. Control erosion on long face slopes by requiring some form of slope-break mitigation, such as benches to intercept the flow of water or rock/brush terraces to slow down the velocity of the run-off.

20. Waste dump benches should be bermed or sloped gently inward and constructed wide enough to handle the peak design flows and to prevent overflowing onto the face of the dump in the event of freezing conditions. Dump benches should be constructed to allow for mass settling of the dump.

21. See also Section VII, Erosion Control topic, Item 3 for additional discussion.

Consider appropriate performance guidelines for dynamic stability, drainage, and revegetation. Safety requirements must be calculated for large waste dumps or waste embankments.

Waste dump slope stability is expressed as a Factor of Safety (F).

$$F = \frac{\text{total force resisting sliding}}{\text{total force inducing sliding}}$$

When a slope is at the point of failure F=1.

1. Waste dumps generally fail in three ways: foundation slides, shallow flow slides, and rotational slides. See Figure VIII-2. A 1.5 minimum factor of safety for static conditions is adequate to avoid slope failure under most conditions (after Vandre) To protect for all types of dump failure an overall static factor of safety should not be less than 1.5. The psuedo-static factor of safety should be approximately 1.3 or greater

because it simulates non-static conditions. A 1.3 psuedo-static factor of safety approximates a 1.5 static factor of safety.

2. Factors of safety are calculated based on a number of conditions and considerations such as:

    Foundation slope and competency

    Dump slope angle and height

    Cohesion, density, and saturation of dumped material (Internal design, particularly drainage design, affects saturation)

    Compaction

    End use of surface (ie. range vs. highway)

    Seismic factors

3. Calculating a factor of safety can be a complicated process (see references in this chapter). Locally-accepted factors of safety should be used for construction within a given area. If the dump conditions vary from the standard, or are subject to climatic conditions listed in item 10, a factor of safety must be calculated by the operator, and submitted to BLM for further action.

4. In evaluating waste dump design, the following should be considered:

    a. The static factor of safety may be lower when dump heights are 60' or less where no cultural improvements such as; roads, buildings or power lines are present in areas of low seismic activity, as long as the dump will attain long term stability.

    b. Dumps may be single slope or benched. The combination of benches and slopes should collectively have an overall static safety factor of 1.5 or greater if item 4.a. above does not apply. Individual slope components of a benched slope with a static safety factor of 1.5 may have static safety factors below 1.5 (the forces resisting sliding should exceed forces causing sliding by 50% or greater). Single slope dumps must meet or exceed the same safety factor.

    c. From an engineering standpoint dumps must meet factor of safety standards. However, revegetation usually becomes effective on 3:1 or shallower slopes. Reclamation should be engineered to allow for successful reclamation at those slope angles. Slopes steeper than 3:1 are appropriate under the following conditions;

Where the operator can successfully demonstrate that it is environmentally advantageous or equivalent to reclaim with the steeper slope,

Where 3:1 or greater slopes would degrade human or ecosystem health and safety when reclamation at a steeper slope would lessen the impacts to surface resources.

Where dump material must be removed to attain a 3:1 slope, the only alternative dump sites are beyond a reasonable haulage distance and the mine plan has been approved by BLM prior to the issuance of the Reclamation Handbook.

Where dumped material is incapable of supporting revegetation and burial or encapsulation is not required in the mine plan. An example of this is salt wastes.

d. Benching or terracing slows runoff velocity on dump slopes. Long, uninterrupted dump slopes tend to develop erosion features quickly. Contour furrowing will minimize rilling and washouts on dump slopes and slow runoff velocity, but may be subject to breaching.

e. Waste dumps should be terraced to facilitate reshaping. The reshaping costs for terraced waste dumps are much less than for single-lift dumps of an equal height. The greater the number of terraces in the dump the less is the cost of reshaping because the dump will more closely approximate the final slope to be achieved during reclamation.

f. Depending on material characteristics, benching on waste dump slopes should be constructed using reliable engineering criteria. One example is the Richie criteria as modified in the 1992 Society of Mining Engineering (SME) Handbook which specifies a minimum bench width of 4.5' +(0.2 X change in elevation of the slope above the bench).

g. Benching should generally be sloped gently inward and designed to accommodate the drainage of surface water. Berming on benches is allowable, but not preferable because it often appears less natural.

   f. Adding waste material to the toe of existing dumps during final mining stages may save reshaping costs.

5. Setbacks should be required between the toe of the dump and:

   a. Streams or rivers

   b. Buildings

   c. Powerlines

   d. Roads and railroads

   e. Some rights-of-way

   f. Where other liability potential exists

6. Proposals for revegetating slopes steeper than 3: 1 should be carefully evaluated. Revegetation on steep slopes requires increased commitment by the operator and extensive monitoring to assure success. Most such revegetation is not successful.

7. When building or extending dumps, all vegetation and organic material must be first removed from the underlying natural ground.

8. When a dump is built on a natural downslope greater than 2.8:1 or static foundation failure factor of safety is less than 1.5, the structure must contain either a keyway cut to bedrock or a rock toe butress.

9. Operating revegetation equipment on dump slopes steeper than 3:1 may be dangerous to the equipment operator. Lesser slopes may also be dangerous under specific conditions (e.g. wet clays). Alternative activities should be discussed with the operator when these safety concerns are present.

10. Dumps should have adequate internal drainage structures when saturation could affect dump stability. Internal drainage structures should be capable of handling infiltration from the design flood event.

11. Dumps should be designed for local or regional factors which may include:

    a. High winds (when fines are present)

    b. Snow

   c. Flash flooding

   d. Earthquakes

   e. Poor foundation characteristics

12. Dumps with excessive fines in arid regions may be covered with coarse durable material to avoid release of windblown fines in the absence of vegetative cover.

13. Cracking and downslope movement indicate potential slope instability. When these conditions are apparent, the operator should immediately evaluate embankment conditions to determine type of movement and consequences of failure and report to the BLM Field Office.

Some References for Factor of Safety Calculations

Call, R. D., Slope Stability, SME Mining Engineering Handbook, Chapter 10.4, 1992

Coates, D. F., and Y. S. Yu, editors, Pit Slope Manual, CANMET, Ottawa, Canada, 1977.

Hoek, E., and J. W. Bray, Rock Slope Engineering, revised 2nd edition, Institute of Mining and Metallurgy, London, England, 1977.

Jaeger, J. C., and N. G. W. Cook, Fundamentals of Rock Mechanics, 2nd edition, Chapman and Hall, 1976.

Sweigard, R. J. Reclamation, SME Mining Engineering Handbook, Chapter 12.3, 1992

Vandre, B. C., Stability of Non-Water Impounding Mine Waste Embankments, U.S. Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah, 1980.

C. VISUAL RESOURCE MANAGEMENT (VRM) FOR WASTE DUMPS

There are five VRM categories. These relate to the scenic value of a locale.

VRM Categories 4 and 5 are the least scenic. They may be addressed by configuring waste dumps with regard to stable and revegetative conditions as described in the Waste Dump Design and Construction subchapter and applicable revegetation standards.

VRM Category 3 may be treated as VRM 4 and 5 when the site is remote and rarely visited. In all other instances VRM Categories 2 & 3 should be considered for some of the remediative techniques listed in this subchapter.

VRM Category 1 lands are the most scenic. These lands include national parks and monuments where mining is precluded. Mines producing locatable minerals can exist on Category 1 lands if the lands are not withdrawn from location. Any reclamation done on such lands could require extensive VRM remediative techniques.

Currently used common VRM techniques are as follows:

1. Slope Warping This is a dump slope design or configuration where the slope is sculpted to an undulating in and out plan perspective configuration. Warped slopes may remain at a constant angle, or may change.

2. Slope Rounding This is a design or configuration where dump slopes are altered to a convex slope shape, with the steepest portion at mid-slope. Such shape approximates hill shapes in non-glaciated non-arid lands. Rounding may increase surface area on a dump and may increase erosive effects in the steepest portions of a dump slope. Slopes may optionally be partially rounded.

3. Rough Slope Surfaces These are artificially roughened surfaces of a dump slope. Rough slope surfaces sometimes more closely approximates natural conditions than smooth slopes. Roughening increases water retention, slows runoff and may decrease erosiveness of a slope.

4. Non-Uniform Slopes These are slopes with changes in grade which may more closely approximate a natural condition. However, erosiveness may increase in the steeper sections of such slopes.

5. Reestablishment of Drainages The approximate establishment of original drainages, or simulation of natural drainages may increase sediment transport and erosion. The effects of drainage reestablishment is very design dependant because dumps have changed drainage and runoff characteristics.

6. Discontinuous Terracing These are dump slope terraces which have been broken into segments and partially overlap,.either upslope or downslope. This design works well as long as the segments overlap, since terracing is meant to interrupt and slow runoff. This design lessens the strong horizontal visual effect of terracing.

7. Artificial Talus Construction In dump areas near highwalls, and in portions of dump faces which are hard to revegetate armoring with cobble or larger sized rock approximates talus appearance. Artificial talus may also be used to visually break up a monotonous dump slope when talus naturally occurs in the vicinity. Such construction is not a substitute for revegetation over whole dump faces. In some cases artificial talus may be stained.

D. EUTROPHICATION

Lake eutrophication is a natural aging process due to accumulation of phosphate and nitrogen, increased biological productivity, and sedimentation. Mining activity can greatly accelerate the eutrophication of downstream bodies of water. There is no universal restoration technique for eutrophy. Procedures which enhance water quality in one lake may diminish it in another. Lakes are highly interactive systems. Altering one characteristic such as clarity or nutrient level will affect other aspects of the system.

The following are often eutrophication indicators:

Algal bloom and associated reduction in water clarity

Other aquatic plant growth

Sedimentation rate

Excessive fish kill from oxygen deficient water

To determine the extent of eutrophication the following information is necessary:

Total phosphorous sample

Total nitrogen analysis (nitrate and nitrite, ammonia total Kjeldahl (organic) nitrogen)

Sedimentation rate assessment

Lake flushing rate

Concentration of chlorophyll A

Other site specific analysis, as needed

Eutrophication causes may be:

Treated at the source

Treated between the source and the affected body of water, or

Mitigated in the body of water

Some treatments of eutrophication source material at minesite are:

Shaping, contouring, establishing topsoil, and revegetation to reduce siltation.

Establishing new wetlands to filter out undesirable nutrients, contaminants, and sediment.

Avoidance of over fertilizing for revegetation

Some treatments for locations between the mine and the affected body of water are:

Establishing new wetlands

Rock or sand bed filtration

Overland flow through vegetated areas with similar filtering as wetlands, such as meander loops

Use non chemical means for lake treatment first, if possible. Some treatments for lake site use are:

Addition of aluminum sulphate to lake to effect phosphorous inactivation thereby reducing algae (Treatment longevity is 2 to 10+ years. There are also some deleterious side effects.)

Addition of lime to lake as a buffer when pyrite is present in sediment derived from mines

Dredging to counteract siltation and undesirable nutrients and contaminants in the dredged material (Effective, expensive, serious negative impacts high, but short lived)

Flushing to dilute undesirable nutrients and contaminants (Very effective with 10 to 15% flushing rate per day. Seldom feasible)

Eliminate bottom browsing fish when browsing releases significant nutrients (Impacts lake interactive system)

Apply algicide, usually copper sulfate. (Very toxic to aquatic life)

E. DEOXYGENATION

Most aquatic organisms need dissolved oxygen to survive. Oxygen in water is replaced by plant photosynthesis and turbulent surface water effects. If water is deoxygenated assess the cause to determine if there is a remedy.

Deoxygenation is sometimes associated with eutrophication. Algae may cause some deoxygenation.

Oxygen supersaturation of surface water by day caused by algae

Oxygen depletion of surface water by night caused by algae

Oxygen depletion of deeper waters due to decomposition of plant and algal material

The above can occur simultaneously

Acid-forming materials in infilling sediments strip oxygen from water when reacting with other ions present.

Excessive fish kill may indicate deoxygenated conditions, however some summer and winter fish kill may be normal.

Some eutrophication treatments are appropriate for deoxygenation (see the previous section).

Algae reduction techniques

Flushing

Pyrite buffering

Possible elimination of bottom browsing fish

F. WATER TREATMENT

The complexities of surface and groundwater hydrology are such that it is often difficult to entirely prevent the formation of polluted water. Mine drainage is most commonly treated to remove those pollutants which present a threat to aquatic life. Water quality must meet State, local, and Federal water quality standards. Point source discharges will have to meet Federal and State NPDES effluent discharge requirements. In most cases, the effluent may have to be treated to drinking water standards if the drainage contributes to a potable water supply.

Treatment processes which have been used to treat mine effluents include: biological treatment, neutralization, adsorption on activated carbon, flocculation, ion exchange, precipitation, desalination, reduction, ultra-filtration, oxidation, cross-flow filtration, reverse osmosis, freezing, solvent extraction, evaporation, electrodialysis, and distillation.

K. <u>TAILINGS AND SLIME PONDS</u>

Tailings and slime ponds consist of impounded mill wastes. Slime ponds are tailings ponds with high percentages of silts and clays, which cause very slow sediment drying conditions. Slime ponds are commonly associated with phosphate and bauxite processing operations. Reclamation of slime ponds is complicated by the slow dewatering.

Tailings impoundments are typically placed behind dams. Dams and the impounded wastes may require sealing on a case-by-case basis to avoid seepage below the dam or contamination of the groundwater. This measure only may be done before emplacement of the wastes. Long-term stability of the structure must be assured in order to guarantee ultimate reclamation success. See Figure X-4.

Reclamation of tailings impoundments should involve the following steps:

1. Tailings characterization: The nature of the tailings to be impounded should be determined as early as possible during the development of any plan. Tailings exhibiting phytotoxic or other undesirable physical or chemical properties will require a more complex reclamation plan. Analysis should include a thorough review of groundwater flow patterns in the area and a discussion of potential groundwater impacts. An impermeable liner or clay layer may be required to avoid contamination of groundwater. Where tailings include cyanide, final reclamation may include either extensive groundwater monitoring or pumpback wells and water treatment facilities to assure (ensure) groundwater quality is protected. The presence of cyanide in the tailings will not normally complicate reclamation of the surface.

2. Dewatering: The first phase of actual reclamation will normally be the dewatering or drying of the impoundment so that equipment can gain access to the surface. This can range from simply letting the tailing material dry naturally to more complicated methods of trenching to allow water to escape from the tailings. This phase of

reclamation is often complicated by surface crusting of the tailings. This phase of reclamation can take up to several years.

Reclamation of slimes will typically require some form of trenching using either balloon-tired vehicles or cable trenching tools. Slimes reclamation can be greatly accelerated by creating surface drainage for initial stabilization using peripheral and feeder trenches. Feeder trenches which drain into the peripheral trench are typically 25' to 40' apart, and up to 2' deep. Once the surface of the tailings has dried, heavier equipment can be used. Farm equipment can usually operate when the solid content exceeds 60% in the top 6 feet.

Revegetation of the tailings after trenching can accelerate the drying process through evapotranspiration. Dust abatement may be required at this stage in order to avoid airborne particulates which may constitute a substantial environmental problem.

3. Reshaping: Depending upon the nature of the tailings, it may be necessary to modify the overall shape of the top of the impoundment to avoid the concentration of water on the impoundment and to improve visual quality. This can involve the addition of material to develop a "crown" on the impoundment and the construction of artificial drainages.

4. Surface Treatment: Depending upon the nature of the tailings materials, it may be necessary to construct a cover system to isolate the waste. Where the tailing itself is a suitable growth medium, or can be amended to provide a suitable growth medium, this will not be needed. Cover systems typically include: water exclusion layer, capillary break, and growth medium. In some cases, it may be impractical to revegetate the impoundment. Because dry tailings material is highly susceptible to wind erosion and subsequent dust problems, it is important to cap the tailings material with coarse durable rock.

5. Revegetation: If the growth medium is to be the tailings, it should be analyzed and evaluated. It is likely the physical and chemical characteristics will require some modification to ensure that the ultimate reclamation goals will be met. Common amendments include fertilizer, organic material, limestone (for control of acidity), acidifying agents (for control of alkalinity), and, in some cases, bactericides to help control the oxidation of sulfides during the initial stages of revegetation.

   Plant species selected for revegetation should be adapted to the site-specific conditions in order to fulfill the ultimate reclamation objectives. Factors to evaluate include: drought tolerance, rooting depth, hardiness, metals accumulation, palatability, seed availability, stabilization ability, ease of propagation, and longevity.

Field trials on test plots during the mine life are often required to evaluate which species will work best on a particular site.

Seedbed preparation is the next important phase of reclamation. Typically, this is performed by standard agricultural equipment and follows normal practices. Roughening of the surface to be planted should result in a firm but friable surface. In many cases, mulching and, occasionally, irrigation may be used to aid in establishment of vegetation. It is important to realize that dust must be controlled during the early stages of revegetation or it will scour and kill emerging vegetation. Following planting, the success of revegetation should be monitored to assure successful reclamation.

For a more thorough discussion of tailings reclamation, refer to the article by Richard C. Barth (1984) noted in the list of references.

L. HAZARDOUS MATERIALS

Most mines use some type of hazardous material during development or operation. These materials may include: toxic materials, such as cyanide; corrosive materials, such as acids or bases; flammable materials, such as organic solvents; reactive materials, such as oxidizing agents; and explosives. All of these materials must be used, stored, handled, transported, and disposed of in accordance with applicable Federal and State laws, including "right-to-know" laws.

A BLM Hazardous Materials Coordinator can provide advice on the details of proper disposal of such materials, and the statutory requirements that make the particular disposal techniques necessary. In general, disposal of hazardous wastes by pouring them on the ground or into streambeds, onsite burial of drums or other containers, or dumping of drums into tailings ponds, other ponds, or down mine shafts, does NOT constitute proper disposal.

If pipelines, vats, storage tanks, or other containers are to be removed at any time during the life of the mine, or as a part of the mine's closure and reclamation, they must be properly cleaned out. The materials used to clean such facilities and all other wastes must be disposed of in accordance with applicable waste laws.

Prior to final closure of the operation, the BLM should require that the operator certify that no hazardous materials or wastes have been left onsite unless specifically authorized by the AO with the concurrence of other Federal and State regulatory authorities. The appropriate Hazardous Materials Coordinator should be consulted as a part of the final closure of the operation.

CHAPTER 9. LEACHATES

A. ACID ROCK DRAINAGE

Mineralized areas are often characterized by the presence of the iron sulfide mineral, pyrite, FeS_2. Other sulfide minerals may also be present. The oxidation of sulfide minerals occurs naturally and was often used by early miners to identify favorable areas for exploration and development. The most common expression of this pyrite oxidation was the “iron cap” or gossan that characterized the surface expression of some of the early ore finds.

The chemistry of acid rock drainage can be quite complex, but the common reaction for pyrite is most often expressed as:

$$FeS_2 + 7/2\ H_2O \leftrightarrow Fe^{+2} + 2SO_4^{-2} + 2H^+$$

$$Fe^{+2} + 1/4\ O_2 + H^+ \leftrightarrow Fe^{+3} + \frac{1}{2}\ H_2O$$

$$Fe^{+3} + 3H_2O \leftrightarrow Fe(OH)_3 + 3H^+$$

$$FeS_2 + 14\ Fe^{+3} + 8H_2O \leftrightarrow 15\ Fe^{+2} + 2SO_4^{-2}$$

Water entering mineralized zones by infiltration, and oxygen entering by diffusion and convection, support bacteriologically catalyzed chemical oxidation of the pyritic material. This reaction series is a vigorous exothermic reaction and temperatures in a waste rock dump undergoing oxidation can easily reach 60 C. This reaction can produce sulfuric acid and dissolved metals at levels toxic to aquatic plant and animal life. Most metallic ions are increasingly soluble with decreasing pH. Thus, acid drainage may cause problems with high levels of dissolved metals in any produced leachate. Metals of concern vary extensively with different deposit types, but can include copper, lead, zinc, cadmium, mercury, and in some cases thallium or selenium. The semi-metal arsenic can also be liberated during the oxidation process. The chemistry of ARD waters can be quite complex, resulting in potentially more complex treatment requirements. Plans must include measures to prevent or control pollution of surface and ground water, to prevent damage to wildlife or their habitat, and other natural resources, as well as to protect public health and safety.

Any deposit containing iron sulfides, other sulfide minerals or their salts may be a potential source of ARD. There are a wide range of factors that can potentially affect the rate at which pyrite oxidizes. The oxidation of pyrite can occur at virtually all points of mining and beneficiation, including mining, stockpiling of ore and waste, run-off from disturbed areas and stockpiles, percolation through mined and reclaimed areas, leaching, and following initial success at reclamation.

11. Acidic drainage may be identified by any of the following:

    a. In many cases, beds of receiving waters will be coated with brightly colored yellow orange-red iron precipitate known as "yellow-boy" in the mining industry. Coloration of precipitates can grade from yellow-green to purple or black depending on other metals/minerals mobilized by the acid water and the state of oxidation. (See Figures 3 and 4)

    b. Acidic drainage is most often clear, thus clarity is not always an indicator of water quality (Figure1).

    c. The presence of ARD in arid settings is usually most apparent following a precipitation event and may be indicated by:

    d. Appearance of: mineral salt blooms in low places such as the toe of waste rock dumps and ore stockpiles (Figure 2)

    e. Irregular melting of snow over acid-generating materials; or accumulation of whitish gypsum slimes along drainages emanating from these sites under certain ambient temperature ranges.

    f. Fumaroles venting vapor along extensional cracks near dump margins.

    g. Acid generating waste may have no substantial vegetative cover and there may be a noticeable lack of insect or small mammal activity (Figure 3).

2. ARD can impact the receiving environment in the following manner:

    a. ARD may render receiving waters unsuitable for consumptive or industrial use depending on the concentration, total acid load, and nature of receiving waters, and their ability to dilute and possibly buffer ARD.

    b. Below pH 5.0, acid waters are corrosive to metal and concrete structures.

c. Low pH water can mobilize metals, increasing toxicity problems. High levels of dissolved metals are very common in ARD. Mitigation of high levels of dissolved metals is a critical factor in ARD treatment and usually involves fairly costly solutions as discussed below.

d. Elevated total acidity, sulfate levels, iron, and total sulfur can create a heavy demand for oxygen, which rapidly depletes its availability to biotic organisms

e. Sudden changes in pH can aggravate the problem of base metal toxicity.

f. Freshwater fish can usually survive in pH levels of 5.0 to 8.5, but waters below pH 4.0 are toxic. Often toxicity is linked to high levels of dissolved metals rather than pH alone.

3. Waste Characterization and Management: All operations proposing activities that may involve disturbance of sulfide bearing mineralization should be prepared to develop comprehensive waste characterization and management plans.

   Waste Characterization: Preliminary waste characterization by the operator or applicant involves the evaluation of waste rock units at the site. The general geologic relationships, waste rock lithology, mineralogy and alteration, sulfide morphology and distribution, distribution of rock units with the potential to neutralize acid production (e.g., carbonates), baseline hydrology, and physical waste rock and process material properties are all examples of information which is valuable at this stage for predicting potential development of ARD.

   Advanced waste characterization by the operator or applicant is necessary when the site characterization work has identified a potential ARD problem. Such an advanced waste characterization program may include a comprehensive and statistically valid program of static and/or kinetic testing.

   Static tests are a fairly quick and inexpensive preliminary determination of the potential for acid production. Typically, samples can be run in less than a week with costs from $20 to $150 per sample. All Notices or Plans of Operations covering mining activities in areas of known or suspected ARD potential should be evaluated by means of static testing.

   Kinetic tests are used as an attempt to duplicate in a laboratory how the waste will behave in the weathering environment. Kinetic tests are considerably more time consuming and expensive than static tests. Where static test results are uncertain, it is important to conduct kinetic tests in order to develop effective waste handling and reclamation procedures.

Because metal contamination is often associated with acid drainage problems, kinetic tests can also be useful indicators of potential drainage quality.

4. Waste Management or Handling Plans

Virtually all ARD control technologies involve prevention or control of the oxidation of sulfide minerals. If this is not possible, then the focus typically shifts to controlling the migration of any potential ARD and, as a last resort, treatment until applicable standards have been met. Treatment of ARD effluent is often a long-term commitment and should be considered the option of last resort. Oxidation of sulfides present in the waste can be reduced but not eliminated by one or a combination of the following source control methods:

a. The exclusion of water through the use of reclamation covers, seals, underdrains, and the diversion of run-on surface water away from the waste material. Proper location of waste facilities is an important consideration here. The "water balance" or "storage" cover is a popular cover design in the intermountain west and is discussed in more detail in the Cover chapter (Chapter XX)

b. The exclusion of oxygen through permanent subaqueous deposition or allowing underground workings to flood, if appropriate.

c. The selective handling of the ARD generating component of the mine wastes through isolation or removal. This can result in a concentration of sulfide rich waste material or minerals, which may then require consideration on their own.

d. The use of base additives to neutralize acid generating materials. This is often impractical for the volumes of waste typical of large mines.

e. The use of bactericides to inhibit bacteria, which tend to catalyze the oxidation reaction. The use of bactericides is generally temporary in nature and must be used in conjunction with other ARD abatement measures.

Concurrent reclamation can help minimize the exposure of acid generating waste to the weathering processes and is desirable for facilities with the potential to develop ARD. Such measures include selective materials handling and bottom-up waste rock repository construction, as discussed in Mine Waste Management and Pollution

Control, Chapter X.

Because the oxidation of sulfides cannot be completely prevented, any potential migration of ARD, whether on or off the site, must be controlled or prevented.

In some cases, it may be necessary to collect and treat ARD effluent. However, operations proposing long-term treatment and release of ARD should be evaluated closely by the BLM and other agencies for alternate measures. Long-term or perpetual treatment proposals are generally the least desirable reclamation or remediation alternatives. Operations with reclamation measures, which rely solely on active water treatment of ARD discharges without having first attempted both source and migration control, may not meet the BLM's mandates for multiple use, successful reclamation, or prevention of unnecessary or undue degradation. The cost of long term financial guarantee instruments may severely impact the financial viability of projects proposing long term treatment of ARD effluent.

Technologies to treat ARD impacted waters will be highly site specific but typically consist of facilities to add alkaline material to adjust the pH and precipitate out contained metals (Figure 3). Depending on the specific chemistry of the water, it may be necessary to re-acidify the water to reduce the pH to acceptable levels prior to releasing water to a receiving stream. An unavoidable impact of treating ARD impacted water is the production of large volumes of sludge material from the precipitate. This material itself will need to be tested to make sure it is not classified as a hazardous material due to contained metals, further complicating final disposal.

In some cases it may be possible to rely on the development of constructed wetlands as a final "polishing" phase of water treatment. There are important questions about the long-term effectiveness of constructed wetlands, so they should be evaluated carefully as an integral part of any ARD mitigation program.

All portions of the mine that have the potential for acid drainage problems will require detailed monitoring programs throughout the mine life and likely beyond.

B. <u>IN-SITU MINING</u>

Certain types of minerals can be produced by dissolving the mineral underground, bringing it up to the surface in solution, and then precipitating that solution to recover the mineral. This process is most widely used for uranium, and to a small extent copper, but is also used for soluble evaporite minerals such as trona, halite, and potash. A variation is to heat the water: sulfur can be produced by pumping heated water underground (the Frasch process) to melt the sulfur, which is then extracted from wells. There are two main distinctions between in-situ mining of uranium, and in-situ mining of evaporite minerals. First, uranium is typically associated with an aquifer, while evaporite layers are not aquifers. Second, no cavities are developed during in-situ uranium mining, and therefore there is no potential for subsidence; while dissolution of an evaporite deposit produces cavities which can result in subsidence unless controlled. In-situ mining of uranium and other metals is less invasive on the surface than open pit mining, but can result in underground excursions of mining fluid outside the mining area and contamination of aquifers unless properly controlled. Also, some areas may experience hazards caused by the proximity of solution mining to active conventional mines (Peters, 1978). Control of leachates in the reclamation process involves management of groundwater as well as surface water discharges. Federal regulations at 40 CFR 144 and 146 address the protection of groundwater from fluid injection activities, and are administered by the EPA under the Underground Injection Control (UIC) program of the Safe Drinking Water Act (P.L. 93-523). Individual states may have primacy for implementation of the UIC program and may have additional requirements for protection of water quality and water rights.

2. Uranium

   a. The in-situ leaching process: Many uranium deposits were formed in sandstone aquifers through which uranium bearing, oxygen-rich groundwater once flowed. When the groundwater flow crossed an oxidation/reduction interface, uranium and other dissolved metals (such as molybdenum, vanadium, selenium and arsenic) precipitated out in a lens- or crescent- shaped deposit known as a roll front (Pay Dirt, 1999). Some forms of uranium go from an oxidized (hexavalent) state in solution to a reduced (tetravalent) state as a precipitate (uranium ore may also be naturally present in a hexavalent state). In-situ leach (ISL) mining essentially reverses the reduction process by lowering the pH, oxidizing the uranium and returning it to the more soluble hexavalent state (Ahlness et al., 1992). To mobilize the uranium, injection wells (Figure XI.C.1) pump a leaching solution, or lixiviant, into the ore zone. In the western U.S., the lixiviant is water to which oxygen, and either carbon dioxide, sodium carbonate, and/or sodium bicarbonate (baking soda), have been added. The lixiviant oxidizes the uranium minerals, which then dissolve and are extracted through a series of pumping wells located inside the grid of injection wells (Hunter, 1996; Figure XI.C.2). The uranium-rich water is routed through a processing building, where the uranium is removed from the water by ion-exchange (IX) columns (Figure XI.C.3). The barren lixiviant is regenerated with oxygen and carbon dioxide and recirculated for continued leaching. The loaded IX resin is then processed to remove the uranium (elution). The eluted uranium is further processed into concentrated uranium slurry, and the slurry is then dried into yellowcake (U_3O_8). The yellowcake is packaged and shipped offsite for further processing. Capital and production costs for solution mining of uranium are much less than for open pit mining (Peters, 1978, p. 264) and in situ miners are exposed to less radon gas than underground miners (Ahlness et al., 1992, p. 1525). In addition, ISL operations have less surface disturbance, water demand, air quality degradation, and fewer employees, than comparable production from open pit mining. These factors help explain why ISL operations are the predominant type of uranium mine in the U.S. today.

Figure XI.C.1: Uranium ISL injection/production well field, Highland mine, Powder River Basin, Wyoming (Figure by Ed Heffern, BLM; used with permission of Power Resources, Inc.)

Figure XI.C.2: Typical pattern of injection, production, and monitoring wells at Highland ISL uranium mine, Wyoming (from Hunter, ; used with permission of Power Resources, Inc.)

Figure XI.C.3: Ion-exchange (IX) columns at Highland uranium mine, Wyoming. Truck trailer transports loaded IX resin to processing plant (Figure by Ed Heffern, BLM; used with permission of Power Resources, Inc.)

b. Groundwater control: In-situ mining produces slightly more water than is reinjected. This net withdrawal (or 'bleed') produces a cone of depression, which tends to confine the fluid to the mining zone (Pay Dirt, 1999). However, to ensure that no lixiviant travels off site or escapes into overlying or underlying aquifers, the Nuclear Regulatory Commission (NRC) license application plan (1997) and State laws and regulations (such as Chapter XI of the Noncoal Rules and Regulations of the Department of Environmental Quality in Wyoming (1993), and Title 122 of the Department of Environmental Control in Nebraska (1990)) require companies to submit plans for monitoring wells and to implement a regular monitoring program surrounding the mining area (see Figure XI.C.4). Monitor wells are established in overlying and underlying aquifers as well as surrounding the mining area in the aquifer being mined (see Figure XI.C.5). A typical 'five-spot' pattern of injection and production wells surrounded by monitor wells is shown in Figure XI.C.2. The level of treatment of the 'bleed water' depends in part on the disposal method, which may include: deep well disposal, land application, evaporation, or surface discharge. Surface disposal methods may require treatment of water to meet baseline/class-of-use requirements. It should be noted that even before mining, some groundwater is unsuitable for uses other than mining because the water contains naturally high levels of radium and radon. The small volume of radioactive sludge that results from treatment is disposed of at a NRC-licensed uranium tailings facility.

Figure XI.C.4: In-situ uranium well field with overlying and underlying monitor wells (from SME Mining Engineering Handbook, 2nd Edition, Volume 2, p. 1526; by permission)

Figure XI.C.5: Monitoring well in overlying aquifer, Highland ISL uranium mine, Wyoming (Figure by Ed Heffern, BLM; used with permission of Power Resources, Inc.)

c. Closure requirements: NRC (1997) and State permits also require companies to restore groundwater quality at the end of the mining operation. At the end of the project, the injection and production wells are used to restore the affected groundwater. Two to three 'steps' are generally involved: (1) groundwater 'sweep', in which only pumping takes place to 'pull' any affected water back toward the wellfield; (2) recycling water that is cleaned with reverse osmosis; and (3) adding reductant to precipitate any metals remaining in solution. Treatment/disposal methods for liquid wastes from well field over-production, process 'bleeds', and water treatment to restore aquifers, are handled by methods similar to those for production 'bleed' (Hunter, 1996; Ahlness et al., 1992, p. 1525).

3. Copper: In-situ leaching of copper oxides is being conducted on a limited basis in underground rubble zones in mines that have been developed by block caving. Leaching also occurs on waste dumps associated with open pit mines. In this case, the lixiviant used consists of dilute sulfuric acid - a more toxic liquid than that used for uranium. Pregnant leach solution is recovered from the recovery wells and is processed in a solvent extraction/electrowinning (SX/EW) plant on the surface. Prior mine development makes the site more complex hydrologically due to mine induced fracturing, void spaces, and rubbleization of the ore (Ahlness et al., 1992). This makes the fluid injection-recovery system more complicated and the consequences of any excursion of lixiviant more severe. These sites must comply with EPA standards under the Underground Injection Control (UIC) program. *(Contact Byard Kershaw, BLM Arizona, for details on active operations)*

4. Trona and Other Evaporites

a. The evaporite leaching process: Commercial operations involving the solution mining of water-soluble evaporites - such as trona, nahcolite, potash, borates, magnesium chloride, and sodium chloride - are on the increase (Richner, 1992). In-situ mining is the standard operating procedure for evaporites on dry lakebeds in the California desert and for nahcolite in the Piceance Basin of Colorado, and is being tried on trona beds in southwest Wyoming. At Searles Lake in the

California desert, trona, borax, and thenardite are being mined; earlier operations recovered potash but the quality of potash in the brine declined to the point where it was not economical to recover. Plant effluent is either directly injected or ponded on the lake where it percolates into the salts. The recharge dissolves additional minerals, undergoes some evaporation and then is captured by production wells in a saturated state and returned to the plant for extraction (Fairchild et al., 1998). In the Piceance Basin, a combination of hot water solution mining and horizontal drilling in a nahcolite bed 2,000 feet below the surface is used to open linear mining cavities where the nahcolite is dissolved. The hot solution is pumped from the cavity to the surface where it is cooled, causing the nahcolite to crystallize as high purity sodium bicarbonate (Day, 1998). The mine plan includes drinking water aquifer protection and monitoring requirements, and analysis of potential subsidence impacts. The leached zone above the nacohlite bed is an aquifer, requiring extra drill hole design, pump installation, and monitoring requirements to prevent mining solution from entering the aquifer should the cemented casing or the mining chamber develop a leak. Such elongated cavities are also being considered for mining deep trona beds in southwest Wyoming (Rosar and Kube, 1998).

In the Green River Basin of southwest Wyoming, at least three companies have flooded low spots in areas of previous room-and-pillar mining, creating underground impoundments. This is part of an effort to pump slurries of insoluble tailings from the processing plants back into the underground mine voids, to reduce the size and environmental impact of tailings ponds at the surface. The slurry dissolves trona from the pillars, floor, and roof and the brine is pumped to the surface for processing (Haynes, 1997). The brine, however, has a high level of soluble impurities, such as chloride, sulfide, and organics, because the carrier for the injected tailings is the waste solution from the surface plant processing. FMC Corp. developed a double crystallization (ELDM) process and a special plant to process this contaminated feedstock (Frint, 1998). Several attempts have been made to solution mine unmined trona beds, and two solution mine pilot facilities have been tested in the central portion of the basin. Fresh water or a heated dilute solution of sodium hydroxide, sodium carbonate, sodium sulfide, or ammonia (to prevent bicarbonate “blinding” and salt buildup) have been tried as solvents (Rosar and Kube, 1998; Haynes, 1997; Haynes and Ukidwe, 1998). One in-situ potash mine has operated near Moab, Utah, since the 1960's. Solution mining of potash from underground mine workings in southeast New Mexico has been discussed but has not occurred commercially to date.

b. Reclamation: Many of these evaporites, being compounds of sodium and potassium, are leasable minerals and as such are covered in the solid leasable mineral regulations (43 CFR 3500) rather than the mining law regulations (43 CFR 3800). Approved mine plans are required under 43 CFR 3592 and in-situ operations are addressed in 43 CFR 3594.5. A lease can only be relinquished when the lessee has met all terms and conditions of the lease, including reclamation obligations (43 CFR 3514). Some states also impose requirements. The Wyoming Department of Environmental Quality (1993), for example, requires a reclamation plan containing information to demonstrate that the in-situ operation will restore all affected groundwater to a quality of use equal or better than the use prior to the operation. The plan also requires cost estimates and procedures to: control subsidence, establish post-reclamation surface contours, reestablish surface drainages and reclaim diversion ditches and impoundments, dispose of toxic or acid-forming materials, remove structures, replace topsoil, control erosion, revegetate disturbed areas, and plug and seal all wells. Bonds and reclamation time schedules are also required.

Unlike uranium, where in-situ leaching only removes uranium coatings on mineral grains and in the sandstone matrix, and otherwise leaves the host rock intact, solution mining of bedded evaporite deposits removes the entire rock and can result in subsidence of overlying aquifers and/or the land surface if the mining method is not carefully controlled. Surface evaporation ponds need to be cleaned out, sludge tested, and heavy metals disposed of. *(get paragraph from Terry).*

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C. ALKALINE AND SALINE DRAINAGE

Alkaline and saline soils and waste materials most often occur in arid to semi-arid regions where annual precipitation is less than 15 inches and the topographic and physiographic position allows salt accumulation. In these areas, evaporation exceeds precipitation resulting in higher levels of alkalinity or salinity. These areas may be characterized by the following:

Limited vegetative cover.

Dessication cracks in ground surface.

Usually light colored soils and wastes with noticeable accumulation of salts.

Over-neutralization of AMD can create alkaline drainage. Alkaline or saline mine drainage should be treated or prevented in a similar manner to the ways in which AMD is treated or prevented. Soils and material that will comprise mine wastes should be sampled and characterized as a part of plan development to determine the potential for alkaline or saline drainage. Prevention of water infiltration is extremely effective in limiting alkaline and saline mine drainages.

In general, it is necessary to isolate alkaline or saline materials and to utilize suitable growth media if revegetation of alkaline or saline sites is desired. The selection of alkaline or saline tolerant species is critical to revegetation success. The placement of coarse material as a capillary break between alkaline or saline materials and the growth media can aid in limiting upward migration of mineral salts and the growth of plant roots in the alkaline or saline materials.

D. CYANIDE MANAGEMENT

Dilute solutions of sodium cyanide (NaCN) or potassium cyanide (KCN) are used to extract precious metals from ores. Concentrations of cyanide solution utilized range from 300 to 500 ppm for heap leach operations to 2000 ppm (0.2%) for vat leach systems.

Low-grade ores can be economically leached in heaps placed on impermeable pads where cyanide solution is sprinkled onto the ore. The solution preferentially collects the metals as it percolates downward and is recovered at the bottom of the heap through various means. Other metals besides gold and silver are also mobilized by cyanide solutions.

Higher grade ores may be crushed, ground and agitated with cyanide solution in vats or tanks. The solids are then separated from the gold or silver-bearing (pregnant) solution. The precious metals are recovered from the pregnant solution and the solids are transferred to a tailings impoundment. The tailings are often deposited in a slurry form and may contain several hundred parts per million of cyanide.

Part of the overall mine reclamation plan should include detoxification of residual cyanide solutions, ore heaps, tailing impoundments, and various processing components. The following are general reclamation guidance and approaches for cyanide facilities. Specific performance criteria may be found in individual State Cyanide Management Plans.

1. Cyanide Solutions: Successful reclamation of cyanidated mine waste depends upon an up front determination of the appropriate technology for waste treatment given the site specific environmental conditions and the relevant state or federal standards. Bench or field scale tests should be conducted to arrive at the treatment technology that is most applicable to the site. This can often be accomplished at the same time testing is being conducted by the operator on the leachability of the ore for their economic evaluations. The ultimate detoxification standard will be site specific, dependent on the resources present and their susceptibility to cyanide and metal contamination. A minimum requirement would have to be the specific state standard. Other considerations include the health advisory guideline used by EPA of 0.2 mg/l for cyanide in drinking water; and the freshwater chronic standard of 0.0052 mg/l for aquatic organisms. Some species of fish are especially sensitive to cyanide. Likewise metals, and other constituent levels, need to be considered when establishing detoxification criteria for cyanide solutions.

   It is worthwhile to mention the various analytical procedures for cyanide in solutions. Three frequently employed categories are "free", "weak-acid-dissociable" (WAD), and "total" cyanide. These are listed in order of decreasing toxicity and increasing stability under ambient conditions. The preferred method for regulatory purposes is to use WAD cyanide. This method is most representative of potential toxicity and the least susceptible to analytical interference.

   There are a variety of methods for achieving detoxification of cyanide solutions. These range from simple natural degradation, to active chemical or physical treatment of process wastewaters. A thorough understanding of the metallurgical process generating the waste, and of the chemistry of the waste stream is necessary to select the most effective cyanide destruction technique. Laboratory studies and preferably pilot studies should be performed when evaluating the best method to treat cyanide wastes. The following is a brief description of cyanide treatment procedures and their advantages and disadvantages (condensed from McGill and Comba, 1990). More detailed technical articles should be consulted for additional information on any of these processes:

2. Natural Degradation and Fresh Water Rinse

If enough time is available, natural degradation has a lot of advantages for detoxification of cyanide leachate. The natural processes which reduce cyanide concentrations over time include; dilution via precipitation, UV radiation, oxidation, hydrolysis, biodegradation and volatilization.

Volatilization often dominates removal of the degraded cyanide compounds from the system. As the pH of the solution drops the cyanide anion (CN^-) is converted to HCN. At a pH of 7 or less essentially all of the cyanide will be in the HCN form and can come out of solution as a gas. Volatilization is temperature dependent and will be very minimal during cold winter months. This is probably the most cost effective approach and produces the least amount of undesirable by products.

Natural degradation processes can be enhanced by introduction of fresh water rinsing which lowers pH and dilutes cyanide concentrations. However, the disadvantage of fresh water rinsing is that large amounts of partially contaminated solution may be generated that could eventually require chemical treatment prior to ultimate disposal and decommissioning of the leaching facility or impoundment.

3. Alkaline Chlorination

Alkaline chlorination is probably the most widely recognized destruction technique used in the mining industry in terms of engineering expertise and operating experience, although this is rapidly being replaced by peroxide treatment or by biological treatment methods. The oxidation reaction will destroy free cyanide and cyanide complexed with metals such as Au, Ag, Ni, Zn, Cu, Cr, and Cd, but the ferrocyanide and ferricyanide compounds are not oxidized (Ritcey, 1989). The oxidizing agent is hypochlorite, OCL^-. The source of hypochlorite may be calcium or sodium hypochlorite, chlorine gas or chlorine dioxide. The reaction of cyanide to cyanate requires a pH > 10.5, and about 3 parts chlorine per part cyanide. In practice chlorine consumption is highly dependent on concentrations of other oxidizable compounds such as thiocyanate (CNS^-) which are oxidized in preference to cyanide (Scott, 1984). Chlorine consumption rates as high as 12 parts chlorine per part cyanide can occur.

Effluent concentrations of <0.2 mg/l cyanide (WAD) can be produced with chlorination. Metals which were complexed with the cyanides will precipitate as hydroxides at the elevated pH used in the process.

Residual chlorine and cyanate compounds present can be toxic to aquatic life and to vegetation in land application areas. Dechlorination of discharge waters may be necessary.

a. Advantages of Alkaline Chlorination

Widely used method; operating expertise available with process equipment and control reliable.

Reaction reasonably rapid. Suitable for emergency use.

Free and WAD cyanide complexes removed to <0.2 mg/l.

Thiocyanate can be oxidized, but greatly increases reagent consumption and cost.

Most metals complexed with cyanide are precipitated as hydroxides.

Chlorine is readily available in several forms.

System adaptable to either continuous of batch operation.

Process can be used for slurries and for clear solutions.

a. Disadvantages of Alkaline Chlorination

Reagent costs can be high, particularly if complete oxidation is required. Thiocyanate, thio-salts and ammonia are heavy consumers of chlorine.

Control of pH necessary to prevent release of cyanogen chloride gas, a very toxic substance.

Complexed iron cyanides are not removed.

Residual chlorine compounds can be toxic to aquatic species. Dechlorination may be necessary.

4. SO_2/Air Process

The SO_2 method is another chemical oxidation process that converts free and complexed cyanides to cyanate with the exception of ferrocyanide. Metals dissociated during oxidation precipitate as hydroxides. Two SO_2 processes have been patented, one by INCO Ltd. and the other by Noranda Inc. The INCO process sparges the cyanide solution with SO_2 in an air stream whereas the Noranda process does not dilute the SO_2 with air but adds it directly to the cyanide solution. In the INCO process, 2 to 5% SO_2 in air is sparged into the solution containing at least 50 mg/l Cu^{2+}, which can either be from the Cu leached from the ore, or added as copper sulfate.

The process is highly pH dependent. Best results are obtained at pH 8-10, preferably 9.0. Very slow reaction rates occur at pH 5-6, and conversion to cyanate is limited at pH 11 (Ritcey, 1989). Since acid is produced by the process lime must be added to maintain proper pH. The reaction is also temperature dependent. At 25°C the reaction is rapid, leaving a residual cyanide of 0.2 mg/l. Residence times very from 5 to 60 minutes.

Reagent consumptions are typically 5 to 6 parts liquid SO_2 and 0.11 parts Cu per part total cyanide (Devuyst, 1989).

Sulfides and thiocyanates are only oxidized to a limited extent (Piret, 1989), thereby reducing reagent consumption. If necessary thiocyanate can be oxidized, but only after the cyanide has been oxidized. Any ferricyanide present is reduced to ferrocyanide which will precipitate out of solution.

a. Advantages of Sulfur Dioxide/Air Process

Effective in treatment of pulps as well as clarified barren and decant solutions.

Suitable for batch or continuous treatment.

All forms of cyanide are removed including stable iron complexed cyanides.

Heavy metals are removed through precipitation.

b. Disadvantages of Sulfur Dioxide/Air Process

With some waste streams the reagent costs (SO_2, lime, copper sulfate) can be excessive.

Large quantities of sludge are produced which may be considered hazardous.

Additional treatment may be necessary for removal of total cyanide, thiocyanate, cyanate, metals, and ammonia if stringent effluent requirements must be met.

The process creates high amounts of dissolved solids which may have undesirable environmental effects.

Strict control of process pH is required.

5. Hydrogen Peroxide

Two processes have been designed and patented for cyanide destruction with hydrogen peroxide, the Kastone process and the Degussa process. The Kastone process uses a solution containing 41% H_2O_2. The peroxide solution containing 5 to 10 mg/l formaldehyde and 5 mg/l Cu^{2+} is added to the cyanide solution. If the H_2O_2 excess is 75 to 100 mg/l, the treatment time required is less than 2 hours to reach effluent cyanide levels of <0.2 mg/l.

The Degussa process uses copper in the form of copper sulfate, but without formaldehyde. The optimal pH for the process is 9.0 to 10.5, although the process will operate over a wide range of pH values. This pH range provides optimal removal of copper and iron complexed cyanide. Copper consumption is usually about one tenth the concentration of WAD cyanide. An excess of hydrogen peroxide of about 200 to 600 percent greater than theoretical is generally used in full scale operation. Reaction times vary from 5 minutes to 2 hours. Total cyanide levels of 1 mg/l can be achieved. WAD cyanide levels of less than 0.5 mg/l are obtained, and can be lowered to 0.1 mg/l with increased H_2O_2 consumption. Solutions with high nickel content decompose the peroxide causing increased consumption to oxidize the cyanide.

a. Advantages of Hydrogen Peroxide Process

Process relatively simple in design and operation.

All forms of cyanide in solution including iron and complexed forms, can be lowered to environmentally acceptable levels.

Heavy metals are significantly reduced through precipitation.

The process is adaptable for batch and continuous treatment operations.

The process has been used in treatment of pulps and clarified process solutions.

Close pH control is not required provided an alkaline pH is maintained.

The process does not produce high quantities of waste sludge.

No toxic intermediates are formed or undesired residual chemicals left in solution as a result of treatment.

b. Disadvantages of Hydrogen Peroxide Process

Reagent costs and consumption for copper sulfate and hydrogen peroxide can be high.

High reagent dosages required to remove ammonia and thiocyanate.

Additional treatment may be required if residual effluent concentrations of ammonia, thiocyanate and metals exceed acceptable environmental levels.

High Ni^{2+} in solution may decompose the peroxide.

5. Ferrous Sulfate Complexing

The addition of excess ferrous sulfate to solutions of free cyanide and the complexed cyanides of zinc and copper at pH 7.5 to 10.5, converts most of the cyanide to ferrocyanide (Huiatt, 1982). This is one of the oldest cyanide disposal methods.

The stable ferrocyanide salts formed settle to the bottom of the impoundment. Although iron-cyanide complexes are considered stable and non-toxic, they do decompose upon exposure to direct sunlight, releasing HCN. Photo-decomposition is slow in deep, turbid, and shaded receiving waters. Any release of HCN in these environments would be offset by loss of HCN to the atmosphere, or through other chemical and biological reactions.

Since long term stability of the iron cyanide precipitates is not determined this method may best be suited as a pre-treatment step for cyanide in a tailings slurry prior to discharge to an impoundment (Mudder, 1989).

a. Advantages of Ferrous Sulfate Complexing

Reagent costs are low.

Necessary equipment can be readily installed into existing mills with minimal capital investment.

Ferrous sulfate is a safer reagent to store on site than an oxidizer.

The process can be used in treatment of slurries and clear solutions.

For some waste streams the process provides a quick, easy method for decreasing free cyanide prior to impoundment.

b. Disadvantages of Ferrous Sulfate Complexing

The stability and fate of iron cyanide is not yet fully understood.

Some of the metals in solution do not precipitate as ferri- or ferrocyanides.

Intimate mixing of the ferrous sulfate into the waste stream is required.

Method has not been well documented and is not fully understood. More lab studies needed.

6. Other Processes

Some of the other treatment processes in use include acidification-volitilization-recovery (AVR), reverse osmosis (RO), and biological treatments.

The AVR process involves acidifying the cyanide solution with sulfuric acid. This converts the cyanide in solution to HCN gas which volatilizes out of solution and is recaptured for reuse. Lime is then added to raise the pH to 9.5 for metals removal. Total cyanide concentration of impoundment waters can be lowered to <5.0 mg/l. Additional treatment may be required for more stringent effluent standards. The big advantage of AVR is that cyanide is recovered for reuse. Disadvantages of AVR include the high capital cost for plant construction, high energy requirements for aeration, and the stringent safety precautions that are required when working with HCN vapor.

The reverse osmosis process passes solution through a semi-permeable membrane to produce a fresh water product (permeate) and a concentrate. Mobile RO units can be onsite in a matter of days for emergency use. Advantages include removal of most metals and metal-cyanide complexes, recovery of reagents and gold-silver values, and permeate low in metals that may be suitable for direct discharge. The main disadvantages are the need for secondary treatment of the permeate due to incomplete removal of free cyanide, and the creation of a concentrate that requires its own treatment. Essentially, reverse osmosis reduces the volume of solution but leaves the contaminants which require further treatment and disposal.

Suitable microbes have been found to metabolize cyanide under aerobic conditions and employed in treatment systems. All forms of cyanide are treatable including the stable iron complexed cyanides. Cyanide biodegradation is currently in use to treat wastewater at Homestake Mining Company (Mudder, 1989). Considerable advances have been made in recent years on the use of biological treatment of cyanide wastes within heaps. The application of biological treatment is highly site specific. There are several consulting firms that develop onsite treatments programs. The big advantage is the low treatment costs when compared to chemical methods. The disadvantage is that is may take considerable time to cultivate the bacteria and realize results.

a. Disposal of Treated Solutions

During mine life concurrent reclamation of process facilities should be undertaken to minimize the solution present at mine closure. For example, a heap leaching operation may have several pads, or one pad segmented into units. Make-up water for new ore can be introduced into the process circuit as fresh water rinse for spent ore heaps or tailings and then directed into the new process unit. In this fashion sequential detoxification of older heaps, concurrent with operation of the mine, can be achieved. This will prevent accumulation of a large solution inventory of partially contaminated rinsate that would require treatment at the end of mine life.

Final mine closure will require treatment and disposal of process solutions. Treatment options are discussed above. Disposal of the final treated solution may be accomplished by direct discharge, evaporation, physical removal to a disposal facility, (or another mine) or by spray irrigation in a land application area.

Direct discharge is desirable, but difficult to achieve. Treated water typically contains enough residual contaminants that it will not meet direct discharge requirements of most states, or would require additional permits (e.g. NPDES permit).

Evaporation is useful in reducing solution volumes but can also result in increased contaminant concentrations. High increases in salinity occur as evaporation proceeds. Additional may be necessary.

Land application disposal (LAD) has been proven effective at several mine sites. The LAD system is used to dispose of solutions that have been treated to remove cyanide. The soil profile is used as a medium for attenuating residual metals in the applied solutions. Development of a LAD system requires evaluation during mine permitting to characterize the soils' metal attenuation capacity and determine the disposal capacity of the spray area. LAD systems are also useful for control of water balance during operations in net precipitation regions. These systems must be carefully designed and managed to prevent impacts to adjacent surface or groundwater, and to prevent bio-accumulation of undesirable elements in vegetation which may pose a threat to wildlife or livestock.

b. Spent Ore Heaps and Tailings

i. Material Characterization: In order to develop a detoxification plan during mine permitting a testing program should be undertaken in cooperation with the mine operator. This can include column tests or small scale test heaps. Often the same material that is used for metallurgical testing can afterward be used for reclamation testing. However, the relationship between rinse solutions from 10- to 20-foot column tests to a heap over 200 feet thick is severely strained.

   It is important to know how the ore material was processed and placed on the heap. Run of mine ore will rinse quite differently than crushed and agglomerated ore. Two other important items to consider for ore heaps is the materials specific moisture retention, and the potential for development of blind-offs. Specific retention is the amount of water or solution retained in the heap after drain down. It may range from as low as 4%, by weight, in coarse ores to over 15% in fine or clayey ore. Blind-offs are zones inaccessible to solution movement and where cyanide degradation is limited. Blind-offs develop as preferential flow paths are established during leaching by migration of fines. In general, the finer the ore and the higher the clay content the greater potential for development of blind-offs.

Another consideration is whether the mine waste material has a net acid generating capacity. If this is the case then the measures to prevent development of acid rock drainage need to be incorporated into the reclamation plan for the cyanide facility (see section.—). It is quite possible for heaps composed of potentially acid forming material to "go acid" years after reclamation is complete as the residual alkalinity from the leaching process is used up. In some cases the ARD potential of the mine waste is the overriding concern and it is desirable to leave the pH elevated at reclamation to assist in buffering the acid forming minerals. In these cases, residual cyanide content may be consumed or reduced by reaction with the sulfuric acid generated from subsequent oxidation of sulfide minerals.

ii Detoxification Evaluation: To determine the amount of rinsing required, the pore volume of the heap material must be known and an estimate made as to the concentration of cyanide in the retained solution. However, this will only provide an estimate. Depending on ore character and treatment methods rinsing requirements may vary from less than one-half to greater than 5 pore volumes. Actual experience at the mine site (or a mine site with similar ore) will be the best source of information for establishing the detoxification process.

The amount of neutralizing solution to be applied to the ore heap per unit area has to be calculated based on the estimated rinsate required per ton of ore and the surface area to tonnage ratio. During the rinsing process cyanide will diffuse from high concentration areas (blind-offs or low permeability zones) to low concentration areas (preferential flow paths) until an equilibrium is reached. For ores with a high amount of retained solution or with blind-off development this process will dominate cyanide movement. To conserve water and reagent use the rinsing period should be followed by a rest period to allow for diffusion of retained cyanide into the more accessible flow paths. This is a more efficient means of accomplishing heap detoxification than by continuous rinsing.

Cyanidated tailings from vat or tank leaching operations can be extremely difficult to detoxify. This is due to the very fine nature of the tailings and the higher cyanide concentrations used in processing. Treatment of tailings during placement in the impoundment is necessary to achieve most reclamation criteria and to prevent a hazard to wildlife and area waters during operation.

Cyanide tailings impoundments need to be dewatered during reclamation. This serves several purposes by removing any potentially toxic effluent, improving overall mass stability, and providing a competent surface for use of reclamation earthmoving equipment. Internal drains and sumps should be placed in the tailings impoundment during construction to provide for dewatering.

No matter how well treated some cyanide will be retained in tailings and most heaps after rinsing. The amount, ultimate fate, and pathway of retained cyanide should be considered during reclamation planning. The degree to which this is of concern depends upon site specific conditions.

If detoxification of tailings or heaps cannot be achieved to necessary levels through treatment and rinsing, then capping of the facility with a low permeability material may be required. This is necessary to prevent infiltration of precipitation and subsequent generation of undesirable leachate. Long term monitoring with provisions for capture and treatment may be needed.

In evaluating detoxification success both effluent and solid sampling may be employed. Solids sampling can be useful in checking for retained cyanide solutions. However, there is no approved method for collecting samples of solids for cyanide analysis. Significant degradation of cyanide may occur during solid sample collection so the results should be considered as the minimum in-place levels. Effluent sampling at the discharge point(s) is more representative of potential environmental concerns. An extended period of time should be allowed between cessation of neutralization and evaluation of effluent for establishing detoxification success. A six month or longer evaluation period, over a spring runoff or substantial precipitation event, may be necessary to demonstrate there will be no spiked releases and that the detoxification criteria has been reached. Once this has been established, surface reclamation can begin.

Once detoxification criteria has been met, and the post-reclamation leachate quality is assured, the containment dike should be breached, and/or the liner material should be punctured and the drain holes filled with sized rock. This provides post-reclamation passage of infiltrating waters thus preventing a build-up of precipitation within the facility which could generate leachate and/or affect stability due to saturation.

7. Shaping and Revegetation

After detoxification is complete, or concurrent with detoxification efforts, shaping is necessary prior to placement of topsoil, or growth medium, and revegetation. Overly steep slopes will be susceptible to erosion and exposure of the underlying cyanidated material. This could cause direct precipitation recharges and generate undesirable leachate from retained cyanide or metals that were not removed by rinsing or through treatment.

Reclaimed ore heaps should be reduced in slope to at least 2h:1v. At this grade slope length should not exceed 200 feet and benching or terracing may be necessary. Tailings, generally being finer material, are more likely to undergo water and wind erosion. Slopes flatter than 3h:1v are usually required for reasonable erosion resistance and revegetation of tailings (Vick, 1983). The detoxified material may be pushed off the liner to achieve necessary slope reduction provided the character of the material is assured and the off-liner regrade is placed so as to minimize potential impacts to water quality should leachate be released. Reshaping of cyanide facilities should include a collection point to allow representative sampling of discharge waters for post-reclamation monitoring.

Revegetation is important on heaps or tailings to provide for interception of precipitation that could generate leachate. Salvaged topsoil, or other available growth medium, should be applied as soon as possible to the reclaimed facility. Topsoil requirements and revegetation species selection and procedures should be addressed in the operation's reclamation plan (see section 14 for topsoil and revegetation guidance).

8. Surface Water Diversions

Post-reclamation drainage for surface water run-off from reclaimed cyanide facilities should be designed to pass precipitation collected by the 100-year, 24-hour storm event or spring snowmelt. Reshaping should normally be completed so as not to collect or pond precipitation in the facility.

Post-reclamation diversion ditches or drains need to be constructed up gradient to prevent surface run-on from entering cyanide facilities. The structures should be designed to divert at least the anticipated run-on from the 100-year, 24-hour storm event or spring snowmelt. For facilities located in extremely sensitive areas it may be necessary to size diversion structures capable of handling the maximum probable flood event.

a. Process Ponds

Solution removal:Cyanide solutions are removed from the process ponds, treated, and disposed of as part of overall mine reclamation as discussed above.

b. Sludges

Sludge which accumulates in process ponds should be tested to make certain it does not constitute a hazardous waste. Hazardous sludges need to be disposed of offsite at an approved disposal facility. Non hazardous sludges can still have adverse environmental effects. Mixing with cement and onsite burial are appropriate disposal means.

c. Liner Disposal

Liners can either be removed and disposed of offsite, in an approved landfill, or folded, ripped and buried onsite in a manner that does not effect groundwater movement or revegetation.

d. Reshaping and Revegetation

Pond areas are backfilled and reshaped in a manner so as not to collect and pond precipitation unless a secondary use has been approved.

9. Facilities Removal

All tanks, plants, pipelines, and other processing equipment that have contained or contacted cyanide solutions are triple rinsed with neutralizing solution. Rinsate may be disposed of in conjunction with mineral processing solutions. These facilities are to be disposed of in an approved landfill or may be buried onsite if a suitable area identified during review of the mine plan.

10. Final Closure

a. Monitoring

Monitoring of post-reclamation leachate from cyanide facilities should continue for at least 5 years before final bond release. Longer term monitoring may be necessary for some sites to verify closure success.

While it may be acceptable to establish a trust fund for remedial action as a post-reclamation contingency; operations which propose perpetual treatment of effluent from a cyanide facility do not meet the definition of reclamation, and should be rejected.

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CHAPTER 10. PIT BACKFILL

Where feasible, backfilling of pits should be considered as an element of reclamation. Advantages of backfilling include improved visual resources and public safety, increased post-mining land productivity, and in some cases, the elimination of potentially dangerous and/or toxic pit lakes. Where pits are not backfilled, the operator should present adequate documentation to show that backfilling is not feasible, including discussions of the option that allow independent evaluation of the decision to not backfill. Where backfilling is not performed, consideration should be given to highwall modification to enhance wildlife habitat. In addition, large pits require safety berming and fencing, which require perpetual maintenance and may not adequately deter access by humans and wildlife.

In backfill planning, it is important to account for the 30-40% expansion of waste rock during mining and processing. Even if a pit is completely backfilled, there will be considerable waste rock left over. In addition, where the pit intersects the groundwater, water quality may be impaired if the backfill material has the potential to increase acidity or contaminants in the water. Waste rock must be characterized for such potential before backfilling, and problem materials either avoided or placed above the projected pit water level.

Potential advantages to pit backfilling

More land available for revegetation and subsequent post-mining use (grazing, wildlife, recreation, hunting, etc.

Less fragmentation of wildlife habitat, migration routes, etc.

Elimination of human and wildlife pit safety issues

Where pit lakes are involved, elimination of evaporative water loss and elimination of pathways by which potential contaminants enter food chain.

Improved land form stability

Decreased visual resource impairment

Potential disadvantages to pit backfilling:

Restriction of access to underlying ore

Environmental impact of backfilling (fuel consumption, dust, increased post-mining activity, possibility of acid drainage increase)

Possible destruction of potential highwall bird and mammal habitat

Where pit lakes are involved, possibility of degrading ground water by increased water contact with contaminant-generating rock material and creating pathways by which potential contaminants enter the food chain.

Loss of potential aquatic habitat

NEPA evaluation of the backfilling option should include consideration of the following:

Health and values of the affected ecosystem.

Compliance with Federal and State laws

Assurance against pollution of water resources

Provision for protection of human health and safety

Consideration of other consequences of backfilling, such as energy use, dust, noise, cost, etc.

Development of reasonable measures to protect the scenic, scientific and environmental values of the impacted area.

Providence of secondary land use of the open pit after mining, such as raptor and other wildlife habitat.

Alternatives to conventional pit backfilling include:

Sequential backfilling where old pits are used as a repository for waste rock generated during the excavation of a new pit. This is only practical when pits are close together and worked sequentially.

Shooting down of highwalls, to increase landform stability and to improve visual resources.

Construction of raptor habitat

Mitigation of non-backfilled pits may include creation of raptor (hawk, owl, eagle habitat), either as development of suitable nest sites or as creation of habitat which leads to the development of a sustainable prey base. Cliff ledges which are modified to prevent access by mammalian predators serve as eagle and hawk nesting habitat. Overhangs with shelf backslope at eastern exposures are ideal, especially if sticks are scattered on the site. Small 6-8" cracks in highwalls are used by barn owls and others. Hand-excavated or blasted cavities are used by falcons. These should be placed above a ledge, and should be .5 meters wide and deep by .7 meters high, with a level, or inward sloping floor. A substrate of five gallons of decomposed granite or pea gravel is placed in the cavity, and white paint dribbled in a five-foot "Vee" outside.

Pit bottoms may be covered with growth medium and seeded as are other mine disturbances. Rock and/or brush piles may encourage small prey animals.

CHAPTER 11: COVER SYSTEMS

A. INTRODUCTION:

Virtually all mines involving surface disturbance will require some form of cover system as part of the site reclamation. This can vary from something as simple as replacing salvaged cover soil, to complex engineered cover systems for acid generating, reactive or radioactive mine waste that might be susceptible to leaching. Cover systems can be critical both for limiting water availability for chemical reactions in waste and even more importantly, for limiting the availability of water as a transport mechanism for contaminants out of disturbed areas.

1. Simple Cover Systems:

For inert waste materials a cover system will typically consist of simple replacement of salvaged cover soil. There are often opportunities for improved reclamation success and or cost savings even with simple cover systems. All potentially suitable materials should be tested for use as cover soil or growth medium. Typical soil parameters tested include: texture, pH, EC, potential acidity, SAR and soil nutrients. In some cases there may be overburden units that are more suitable for use as growth medium or cover soil than the existing soil material. Where practicable, direct haulage of salvaged cover soil to concurrent reclamation sites offers substantial cost savings and improved reclamation opportunities. When this is not practicable salvaged soil must be stockpiled. Stockpiled soil should be placed either on disturbed lands, or on lands that will ultimately be disturbed when possible. Salvaged soils should be seeded with a quick growing reclamation mix to protect the soil from erosion. Additional information on soils management can be found in the Revegetation Chapter (Chapter XVIII, Revegetation)

The principal purpose for soil placement on reclamation involving inert waste materials is simply to provide a suitable growth medium for revegetation as part of site reclamation.

Any leachate produced from acid generating, reactive, or radioactive waste materials would have negative impacts to either receiving ground or surface waters or other environmental values. For these situations a carefully engineered and constructed cover system is essential. In this case the cover soil and vegetation serve an important function as erosion protection and leachate mitigation. Erosion of the cover system would lead directly to adverse environmental impacts. Some cover systems utilize a horizon of inert material below the cover soil to store additional water and provide for additional rooting depth. The cover system, together with the drainage system is a major component of the mine water management program. A well-engineered and constructed cover can limit infiltration of direct precipitation of rain and snow, which reduces the water available as both a reactant and transport for contamination. Cover systems generally do not limit the availability of oxygen unless they are kept saturated. Saturated covers are special cases and are discussed later in this section.

2. Water Balance or Storage Covers:

Water balance ET (evapotranspitration) or storage water balance covers are a popular form of cover system in the Intermountain West. They can often be constructed using readily available native and waste materials. These cover systems require adequate material to ensure that precipitation can indeed be stored in the cap/cover until either evaporated or transpired by plants. In temperate areas where the precipitation occurs mostly in the winter and the growing season is in the late spring and early summer, this may require more material than in areas where the precipitation season and the growing season coincide. Growth media or cover soil requirements and plant rooting depths are frequently underestimated in the cover system design. Where the plant rooting depth exceeds the depth of growth media or cover soil, the plants may suffer when the roots reach the underlying waste material. This may also provide preferential pathways for water movement in the cover soil profile.

Models of cover systems generally assume that vegetation on the cover system will not be harvested. These revegetated slopes may not be available for post-mining land uses such as grazing (and perhaps wildlife). The HELP model, which is widely used for modeling cover performance, is generally not valid in arid areas, having been developed using only one western site in Sonoma County, California, where plants are growing during the precipitation season.

Where EVT is proposed as the mechanism for the removal of water from the cover system, it will be necessary to provide financial guarantees in perpetuity (?) For the re-establishment of the proposed plant community in the event it is lost through fire, drought, weed invasion, grazing trespass etc., for the maintenance of fences to prevent loss of vegetation due to grazing.

The long term performance of these cover systems remains an uncertainty and it will be necessary to closely monitor the performance of this type of cover design to assure the performance objectives can be met. There is some evidence that these cover systems will not be as effective in reducing long-term infiltration as had been hoped. Failure to meet the performance objectives may result in substantial additional leachate requiring some form of handling or treatment.

3. Criteria for an effective cover system include:

    a. The cover system should be a low permeability material to limit infiltration of direct precipitation or run-on.

b. The cover system should have a low overall permeability if the design of the cover system is intended to limit infiltration into the underlying waste material.

c. The cover should have a shallow slope to engineered drainageways. The slope should be free of depressions that contribute to the retention of water.

d. The cover system should be of a suitable thickness compatible with the performance objectives.

e. The construction of the cover system should use locally available materials to the extent practicable.

f. Portions of the cover system that constitute steep slopes may require erosion protection prior to the establishment of vegetation.

g. The cover system should support a vegetative cover in order to maximize the capacity of the cover system to intercept and store direct precipitation and provide erosion resistance.

h. The cover system should be free of long-term maintenance requirements to the extent practicable. If maintenance is anticipated, then access should be designed into the cover system, and provisions included to provide a financial guarantee that assures maintenance will be performed.

i. Cover systems can vary depending on site-specific criteria, but are usually a mix of the following layers, from top to bottom:

   Erosion Resistant Zone. This is typically the uppermost layer and consists of cover soil and or growth medium and vegetation, the vegetation providing the erosion resistance. In some cases the erosion resistant zone may be coarse material without vegetation. This layer can include slash material, rock fragments, dozer basins or other small-scale surface features to help limit erosion, especially prior to the establishment of vegetation.

   Moisture Retention Zone. This material is often similar in characteristics to the cover soil and simply provides additional rooting depth and moisture storage capacity. This horizon is often a critical element of cover systems characterized as a “Water Balance Cover”. Obviously this horizon should not be composed of deleterious waste material.

Capillary Break. A capillary break may be included as part of the cover system. A capillary break is usually 2 size classes different than the cover soil horizon and serves to restrict movement of water up or down in the soil profile.

Drain Horizon. Some complex cover systems include a drain horizon above the moisture barrier to transport moisture out of the cover system, usually draining to the side of the dump complex.

Moisture Barrier. This is often the basal layer of a complex cover system, being located immediately above the waste material. Some common materials include geomembranes (plastic, synthetic rubber, by a variety of names, etc.) clay, and GCL (geosynthetic clay liner, a composite of bentonite and geofabrics). To be effective clay horizons must be below the frost horizon, be kept saturated, and protected from long term disruptive forces such as root penetration, animal and insect burrowing, etc. <u>They are generally not effective in semi-arid to arid climates.</u>

In some cases it may be beneficial to incorporate a geosynthetic fabric between the various cover layers. This can be either for the ease of construction or to prevent movement of material either up or down between cover horizons.

Steep slopes will require special consideration for both construction and erosion protection. When constructing layered cover systems on steeper slopes, traditional survey techniques have tended to limit steep slope construction to a fairly limited topography without complex landforms. Dozer mounted GPS units open up a range of varied topography, which can more closely mimic native slopes.

If the cover design includes a specific assemblage of plant species to accomplish the desired goal of the cover system....this assemblage WILL change over time and this change may need to be accounted for in the reclamation and monitoring plan. IE the vegetation may evolve into a habitat type that will either not meet the ultimate reclamation objectives...or, may in fact be destructive to the ultimate reclamation objectives. If this is the case it may be necessary to include bonding provisions for future vegetative manipulation to assure reclamation objectives will continue to be met.

In order for the reclamation cover to meet the desired objectives it may be necessary to restrict land uses on the reclaimed surfaces. This could involve restricting grazing or recreational site access through fencing or other control features. If this is the case it will be necessary to bond for the long-term maintenance of these institutional controls.

4. Water Covers

Water covers are probably the most effective means of limiting oxygen and are thus highly effective at limiting acid generation. The chemical activity of oxygen under water is sufficiently slight as to make acid generation rates negligible. Previously oxidized wastes are not suitable for subaqueous deposition because oxidation products are easily soluble in water and will cause impacts to water quality and may actually increase acid production. Water covers can be achieved using disposal into natural waters, constructed impoundments, flooded underground workings or pits or by using a saturated soil or bog cover.

Obviously, water covers in much of the west will be impractical for inherent climatic and topographic reasons, however, there are occasions where they might be appropriate and could be considered.

Disposal of any mine wastes into natural water bodies is often politically sensitive and this can be an important consideration in developing a waste disposal plan.

5. Long Term Disruptive Forces

In addition to artificial disruptive forces over which there is some possibility of control, as noted above, all reclaimed surfaces and cover systems are subject to long term disruptive forces. These can include but are not limited to: unintended root penetration of cover system layers that can compromise cover effectiveness, toppling of trees compromising cover integrity, small or medium size animal burrowing or digging, freeze thaw cycles that can crack or modify cover structure, fires that may remove vegetation, either seasonally or for longer time periods, and normal slope movement over time. If these disruptive forces have the potential for compromising the overall effectiveness of the cover system, it may be necessary to include provisions for periodic repair in the bond calculations.

CHAPTER 14. UNDERGROUND

A. INTRODUCTION

The closure of underground mine access presents special concerns from the standpoint of protection of the environment and public health and safety. The costs associated with appropriate closure techniques are often quite extensive. In addition, special expertise is necessary to design and evaluate the design of closure techniques. Different methods are applicable to temporary and permanent closures. The illustrations in this section show various temporary and permanent mine closure methods. The BLM wishes to specifically acknowledge the use of notes and illustrations excerpted from the National Coal Board Handbook entitled: The Treatment of Disused Mine Shafts and Adits, published in 1982, and Office of Surface Mining (OSM) AML Handbook, 1998.

Underground closure is complex and site specific. Closures in one geographic area will not necessarily work in another geographic area. It is recommended that users of this handbook consult with experts in their area for special considerations I.E.; unusually dry conditions/wet conditions, high saline environment, radioactive environment, high earthquake conditions, etc,. Under all conditions you wildlife and cultural resource specialist will need to be consulted for special closure criteria. It may also be necessary to prepare NEPA documentation for the site particularly AML sites.

B. IMPLEMENTATION

An experienced underground mining engineer shall review the proposed closure plan involving underground mine access which meets the applicable State and Federal requirements. The mining engineer should make periodic inspections of the closure site as the work progresses and shall also inspect the results upon completion. Thereafter, periodic inspections should be conducted to ensure that the closure remains adequate.

C. CLOSURE OF SURFACE OPENINGS

Closure of surface openings must incorporate sound engineering and construction principles in order to ensure the health and safety of human life and the protection of all resources. In most cases, the method used to close the surface opening will depend upon whether the closure is to be permanent or temporary, and may also be site specific due to on-site conditions. Prior to closure, an on-site investigation should be conducted by a qualified individual to determine if bats or other wildlife inhabit use the underground workings. The method of closure may need to be designed to allow for ingress and egress of small animals. Be aware that specific IM's may have been issued regarding wildlife use, in particular, Bats.

1. General Guidelines--Surface Openings

All surface openings must be properly closed when: (1) they are declared inactive by the operator; (2) State law or regulations require that they be closed; or (3) closure is necessary to mitigate hazards to public health and safety. Reclamation or protection of surface areas no longer needed for operations shall commence without delay. The AO should designate such areas where restoration or protection measures, or both, are to be taken.

In mining or prospecting deposits of sodium, potassium or other minerals soluble in water, all wells, shafts, prospecting holes and other openings must be adequately protected with cement or other suitable materials against the coursing or entrance of water. In accordance with the regulations (43 CFR 3594.5(a)), the operator/lessee shall, when ordered by the AO, backfill with rock or other suitable material to protect the roof from breakage when there is a danger of the entrance of water.

2. Temporary Closures (Less than one year)

In areas in which there are no current operations, but operations are to be resumed under an approved plan, the operator shall maintain the site, structures, and other facilities of the operation in a safe and clean condition during any non-operating periods (also see CFR 3809 and CFR 3715 concerning closure periods). Temporary closure measures such as fencing, barricading, or substantially filling in surface openings may be required for short-term non-operation. All operators may be required, after an extended period of non-operation for other than seasonal operations, to remove all structures, equipment, and other facilities, and reclaim the site of operations. Permission may be granted by the AO to do otherwise. Conspicuous signs shall be posted prohibiting entrance of unauthorized persons and warning of danger. Warning signs shall be constructed of durable materials and comply with applicable Federal and State regulations. All such protective measures must be maintained in a secure condition by the operator until such operations are resumed or permanently closed.

For leasable minerals, extensions for temporary closures may be granted by the AO in one year increments provided the operator can show just cause for not permanently closing the mine access. Under no circumstances may a lease be relinquished or bond terminated until all mine openings are permanently closed. It is the responsibility of the operator to periodically inspect temporary closures to ensure their structural competence and make repairs to any damaged portion which would permit unauthorized entrance.

3. Permanent Closure

Before permanent closure of exploration or mining operations, all openings and excavations, including mine shafts, portals, and acid mine drainage discharge points, must be closed or sealed in accordance with sound engineering practices, environmental requirements and adherence to an approved plan. Reclamation and clean-up around and near permanently closed underground mines includes, except where otherwise expressly provided for in an approved plan, removal of equipment and structures related to the mining operation. No underground workings shall be permanently abandoned and rendered inaccessible without the advance consultation or written approval of the AO.

Historically, poorly engineered and constructed closures have failed because of settling, erosion, vandalism, pressure failure, deterioration, etc. Pushing dirt into the entrance of an adit or shooting down the portal are not acceptable practices, except for the possible case of shallow or minor underground workings. As a part of the closure plan, the operator shall furnish drawings in plan view, front view, and side view of all proposed closures and describe the specifications of the construction materials to be used.

Closure must take any water discharging from openings into consideration. If the mine emits potable water, the design of the closure may allow for its discharge. In the case of contaminated water (e.g., acid mine drainage), the closure shall be designed to prohibit its release or provide for remedial treatment (see Mine Waste and Pollution Control section).

4. Closure of Mine Openings

In order to minimize potential hazards and problems, a complete report by the lessee/operator should be furnished to the AO. This report may consist of a copy of the material required by State or other Federal agencies. The report should include:

> Detailed description of the proposed method of closing the shaft.
>
> Geographic report shall include a map showing the location of the shaft in relation to all man-made facilities, other mines, roads, rivers, streams, lakes, etc., which may be influenced by the shaft and which may influence the future surface use surrounding the shaft. All anticipated subsidence must be shown.
>
> The AO may request other information as needed for each specific shaft closure site.

In addition, for leasable mineral operations, the report must contain the following. This information may also be useful in evaluating the prevention of unnecessary or undue degradation for locatable mineral operations.

> Geologic report including maps of all strata, faults, fracture and joint pattern,

geologic structure, potential subsidence and any other facts which may influence the abandonment.

Hydro logic report of all aquifers, including the quantity, and quality of waters present, maximum and minimum flow rates, possibility for contamination, solubility of minerals present, the anticipated head which will develop if the workings flood, and any other relevant matters. In the event of subsidence, consideration must be given to potential for subsidence features to act as a conduit for surface waters to enter the underground workings.

Engineering report of shaft construction including all physical dimensions, (vertical cross section and plan view), materials, thickness of shaft lining, utilities present, obstructions, elevation of shaft collar, total depth, and all landings, present structural condition, and shaft pillar size.

Historical report of when construction began on the shaft, problems encountered, when it was completed, what its purpose was (e.g., ventilation, ore hoisting, supplies, man cage, emergency exit, etc.), and location of other mines in the surrounding area.

After thorough investigation, the AO shall approve in writing the method of closure after consultation with the surface management agency, the surface owner, the appropriate State agency, other Federal agencies and the operator. At a minimum, the AO should require the following:

Incombustible fill material;

Isolation of aquifers;

Closures and caps of reinforced concrete anchored to competent rock by keying, or adequate mechanical means; and,

A permanent brass or aluminum plug giving the BLM case number, company name, and date of closure.

The final relinquishment of responsibility and financial bond shall not be made until a joint site inspection has been conducted by the AO and other appropriate State and Federal agencies and all are satisfied with the work performed.

E. <u>SAFETY NOTES</u>

Underground workings which are not actively being mined should only be entered when absolutely necessary, and then only by those qualified as per BLM Underground Entry Policy. In all cases, BLM personnel should inform the operator and State and Federal agencies involved with mine safety. BLM personnel conducting or participating in inspections shall: be knowledgeable of and comply with MSHA and OSHA safety requirements; shall have the appropriate and mandatory safety and health training for personnel working in and around underground mining operations; and, shall comply with any additional safety rules and regulations required by the operator.

1. Personal Safety Precautions

Persons engaged in underground mine access closure projects or in searching for old shafts and workings should be ever mindful of their own safety, and meet the requirements of BLM Underground Entry Policy. A Job Hazard Analysis (JHA) may be required and the contractor must meet the requirements of the policy. There should always be at least two persons present and they should be equipped with appropriate safety equipment, such as safety harnesses, ropes and anchorage pickets. If operating in remote country, the party's plans must be known to a responsible person who should be informed of any major changes of plan and when the day's task is complete. Extra care is necessary where the ground may be unstable, when mine gas may be present, and when working in adverse weather.

2. Security of Surface Operations

3. Ground Stability

The factors influencing the stability include:

nature of superficial deposits;

groundwater levels;

depth of firm bedrock;

existence of shallow workings;

other possible voids, for example, concealed ventilation drifts;

strength and condition of the shaft lining.

These factors should be evaluated and where there is any doubt about the ability of a shaft lining to withstand the thrust from the ground and from any additional loading arising from the operations a potential collapse zone should be determined and clearly marked with fences and notices as may be appropriate (Figure IX-3). Similarly where cratering has occurred, the (potential) collapse zone is likely to extend beyond the crater edge. Cracking of the ground usually indicates that further failure is likely.

The operator should avoid using trackless equipment above or below areas where the possibility exists for ground collapse. In such cases, conveyors or other equipment allowing operator personal safety should be used.

No person should enter a collapse zone unless he is wearing a safety harness attached to a line anchored at least 15 feet outside of the zone. The safety line can be arranged to run overhead and be used for several harnesses. Plant and equipment should be similarly anchored to prepared points at least 30 feet outside of the zone, and such additional arrangements made as may be necessary for mobile equipment. Steel posts concreted into boreholes form reasonable anchorages for most purposes.

4. Mine Gases

When final closure of underground workings is being conducted, gases may accumulate in the mine due to a change in mine ventilation. After mechanical ventilation ceases at a mine (which at the time may have both upcast and downcast shafts) the natural flow will depend on barometric pressure, variation of temperature and humidity, mine depth and changes taking place in the mine such as rising water levels or collapsing workings. In some cases, there may be no ventilation.

5. Types of Mine Gases

Firedamp (principally methane) may be found at some shafts, and blackdamp (carbon dioxide and nitrogen) is almost certain to be found in all shafts, adits and old workings. Firedamp is a dangerous combustible and explosive gas; but like blackdamp, it can also create an oxygen deficient atmosphere and so cause asphyxiation. More rarely, other gases may be found, notably carbon monoxide and hydrogen sulphide (stinkdamp) which are very poisonous even at low concentrations.

Firedamp, being lighter than air, tends to rise and in gassy mines significant volumes continue to be emitted from the strata for some time after working ceases. Eventually, the production of gas from the deposit dwindles. Blackdamp, being heavier than air, is likely to be found in old workings generally, particularly in the lower parts of shafts and adits.

Any of the gases may migrate to and accumulate in shafts, adits and other voids - in particular in shafts there is a danger that gas may migrate along the annulus between the lining and the strata. It is most important to note that if barometric pressure falls, gas may appear rapidly in places where it is not normally present.

Mine gases which may exist before, during or after shaft treatment have an important influence in determining the nature of the treatment and the operational methods to be adopted. Air, together with any included gas, is displaced during filling; when connected shafts are involved, fill placed in an upcast shaft is likely to cause complete reversal of any air flow and possibly emissions of gas in the downcast shaft. The filling of shafts reduces the possibility of the accumulation in them of large quantities of gas, but voids in which gas may accumulate can be formed as fill is being deposited and during subsequent settlement. This can be of importance when drilling through fills.

If domestic or industrial refuse has been deposited in the shaft, dangerous gases other than those mentioned above may be produced.

When entrances are to be sealed it may be necessary to provide vent pipes, fitted with flame arrestors and protected by lightning conductors, to allow gas to escape freely to atmosphere so preventing it from accumulating immediately below a shaft cap or plug or behind a stopping. In the absence of a vent pipe, gas may flow along paths provided by cracks, fissures, fan drifts, service pipes, culverts, etc. and collect in unventilated voids and buildings.

Gypsum, cement or resin-based products or other suitable materials may be used to seal shaft covers and caps to restrict the emission of gases.

6. Mine Gas Precautions

The guidance of ventilation engineers should be sought on the precautions required to deal with gas at shafts requiring treatment. Approved handheld methanometers, automatic firedamp detectors and flame safety lamps should always be available.

At shafts where mechanical ventilation has ceased, the primary precaution, particularly where the conditions are unknown, is to establish a security zone within which all possible sources of ignition are prohibited. Ignition sources may be:

smoking;

braziers and other open fires or naked lights;

spark ignited internal combustion engines; and

electrical apparatus which is not flameproof or intrinsically safe.

The security zone should be at least the same size as a potential collapse zone (Figure IX-3) and should be tested with flame safety lamps and hand held methanometers, working inward from the periphery to the shaft, to establish the conditions. Then all buildings, air locks, or other roofed enclosures within the zone should be opened up (demolished if necessary) so that the shaft or adit mouth and any buildings, etc., are well ventilated.

Where gas may be a hazard the best conditions for its ready dispersal are provided by clearing the area generally, including removing stockpiles of material and grading out any hollows in the ground.

Tests for firedamp should be made immediately before any operations are begun and when they are to be restarted after a period of stoppage. The tests should be made at the shaft mouth itself and at positions 60, 120, 180, 240, and 300 feet down the shaft in accordance with the regulations. If firedamp is detected at any of these locations, no work which involves open flames or sparks (for example flame cutting or welding) should be undertaken within the security zone.

The ventilation engineer's guidance should specify in each case the intervals between taking samples and when other work should cease because of the presence of firedamp. Whether or not work should cease will depend not only on the percentage of firedamp in the atmosphere but also upon other circumstances, for example:

location of the site (whether in open ground, or a built-up area);

type of any work being done (stripping-out, removal of lining, filling);

use of conveyors, dump trucks, draglines and other equipment;

use of explosives; and,

special circumstances (for example, the necessity of emergency work).

Where blackdamp is the sole hazard, the work need not be restricted in any way except that the oxygen content must be checked regularly and when the shaft is being filled care is required at the shaft site as the gas will rise on top of the filling and eventually spill out at the surface.

At shafts where mechanical ventilation is available (at operational mines), it will normally be essential to retain the system in operation until the last connection is reached and then when the ventilation is stopped to make the seals as quickly as possible so as to minimize the emission of gas. This means that seals should be placed simultaneously on all the shafts or drifts when a mine is being abandoned or on the shaft and an underground roadway when only one shaft is being abandoned. It is necessary to ensure that the ventilating fan is kept within the acceptable range of its operating characteristics. The specific guidance of a ventilation engineer is required in all case with regard to the fan and the general precautions to be taken at the surface.

F. PRINCIPAL FILL MATERIALS

The materials used for the bulk of filling in unused shafts and adits may be termed general purpose fill. Other materials used for special purposes include hardcore, clay (including suitable froth flotation tailings), concrete and grouts.

1. General Purpose Fill

General fill should be of a granular nature and should have no unacceptably adverse quality such as toxicity, combustibility or poor engineering property which could affect its performance during or after filling. Mine waste may be used as fill material if it has appropriate characteristics. The chemistry of waters which will come in contact with the fill must be known in order to identify fill materials which will be nonreactive and in equilibrium with the water.

Most stable granular materials are acceptable, including some mining wastes. Hot or combustible materials and wastes with excessive carbonaceous matter must be excluded. Quartzitic or other hard rocks with high incendive temperature potential can cause sparking when striking iron and steel, and their inclusion in fills must be carefully considered in conditions where there may be firedamp. For the same reason, steel and iron should also be excluded from all fill materials as should be aluminum, magnesium and their alloys because of the possibility of thermite reaction.

Hardcore, as described below, is a better material and can obviously be used for general fill when economically available.

2. Hardcore

Hardcore includes such materials as broken stone, brick or concrete demolition rubble and quarry and steelworks wastes. Its chief uses in shaft fills are: in shaft bottoms and at intermediate shaft insets into which it will run and build up at its angle of repose; in water-filled shafts; and where fill settlement must be minimized. Given sufficient length in the shaft above an opening, hardcore can give support to a weaker general fill material which is incapable of supporting itself or, worse, could hold up at first but fail some time later. Hardcore is free draining and will permit water to seep down into the workings, provided that the drainage paths do not become blocked.

Hardcore includes most clean, hard (uniaxial strength exceeding 2,900 psi) granular material of the types described above. The maximum size should not normally exceed a 12 inch cube. Hardcore larger than 15 inches in one dimension should be avoided, as it can damage shaft supports and cause obstructions which may interfere with closure objectives. The grading should be such as to give a reasonable density of filling while enabling water to drain through easily, suitable proportions being:

12" to 3/4" - not less than 80%

3/4" to 1/16" - not more than 15%

minus 1/16" - not more than 5%

The material should have a high and reasonably consistent angle of internal friction, be insoluble and be resistant to chemical attack. As noted under general fill, materials with high incendive temperature potential must be carefully considered before their use is permitted in conditions where there may be firedamp.

3. Clay

Material in the fine silt to clay particle size range with a coefficient of permeability less than 1 x 10-6 cm/sec can be used to restrict the movement of water within a shaft or its entry from the surface. Satisfactory material can sometimes be found close to the site. If the clay is dry, it should be thoroughly wetted and worked until sufficiently plastic to consolidate into an effective seal. The plasticity and sealing properties of clay materials can be improved by the addition of pulverized fuel ash (pfa) or, when economically justified, bentonite.

Some tailings waste in the form of filter press cakes may be of sufficiently fine particle size to be suitable for use as clay. The cakes should be sufficiently plastic to compact and consolidate into a solid mass.

4. Concrete

Concrete used for good quality mass fill (3,600 psi) or for structural engineering purposes (4,300 psi) should comply with American Concrete Institute (ACI) Specifications. The placing, compaction, reinforcement, forming and curing should generally be in accordance with ACI standards. As concrete in shafts is liable to be subjected to chemical attack by aggressive groundwater, appropriate cements (for example sulphate-resisting) and aggregates should be selected.

5. Grouts

Grouts comprise a range of various materials injected into pores, fissures and cavities in soils and rocks as liquids or suspensions which solidify and thereby increase the strength, or reduce the permeability, of the soil or rock. The particular grout for a given situation depends upon the size of pores, fissures, or cavities to be filled and the purpose of the operation. The two main types in use are cement and chemical grouts. For grouting shaft fills having large pore spaces and other cavities, Portland cement may be used with the addition of sand, bentonite, slag or pfa; if necessary, large cavities should be filled with pea gravel.

Chemical grouts (which are more expensive than Portland cement-based materials) have been developed for use in fine grained rocks and sand, and may be required for injecting the strata around shaft plugs and adit or roadway dams.

Pfa mixed with 5 to 10 percent of Portland cement sets in a similar way to concrete and, while it has lower strength, it is still adequate for filling voids in shaft fills. It has advantages in that it does not segregate when dropped through appreciable heights and, being of low bulk density, weight for weight it fills more void than other types of grout.

G. MEASURES USED IN SHAFT TREATMENTS

Apart from the cases warranting special consideration and design, the various shaft treatments can involve the following measures:

controlled filling;

enclosure;

covers;

caps;

shaft plugs; and

roadway stoppings and dams.

These are described below mainly with references to shafts, any comparable measures for adits being referred to as appropriate. In selecting the measures to be adopted, the particular purpose of the treatment should constantly be borne in mind.

1. Filling

For shafts with shallow sumps, controlled filling should be commenced with hardcore and brought above the roof of the shaft bottom roadways to a height equal to not less than five diameters for shafts up to 650 feet deep. Additional fill equivalent 0.25 diameters for every additional 650 feet of depth should be used. (See Figure IX-4.) This calculated height includes two diameters to allow for the possibility of weak strata at the inset roofs and for the margin of error in depth measurements. The hardcore may then be followed by general purpose fill, further hardcore being used at any other insets in the length of the shaft.

Deep sumps may be filled with general purpose material, but allowances must be made for settlement. The height of hardcore above the shaft bottom roadway should therefore be increased by 5 to 7 percent of depth of the general purpose fill in the sump below. Similar allowance is required for settlement at a mid-shaft inset (Figure IX-5). For all shafts, bulkheads should be considered when backfilling to prevent materials from washing out of the shaft into the workings.

In shafts where the positions of insets are unknown, hardcore should at least be used until it has been brought above the level of all likely locations. Hardcore is also to be preferred for fill in shafts containing water. Placing fill in a shaft containing water may result in a rise of the water level in the shaft causing an overflow of water at the surface. A catchment basin or sedimentation pond may be needed to treat this water before it is released to the environment. Concrete, or concrete and hardcore used in alternate phases at the shaft bottom, provides a higher degree of security than hardcore by itself.

Clay may be sandwiched between lengths of general fill to limit the passage of gas and/or water moving up or down the shaft. When internal access is available, the shaft lining, and all longitudinal materials, such as pipe, shaft guides, cables, anchors or buntons, boards, ladders, etc., should be removed at the shaft seal location. An impermeable strata, such as mudstone, should be selected for the location and placement of the clay seal. This will enable the clay to be squeezed tight up to impermeable strata. The clay seal should be installed below the water table to prevent it from drying out and developing shrinkage cracks; otherwise, the seal would be ineffective. The length of a clay seal against exposed strata should be not less than 3 feet per 300 feet head of water, subject to a minimum length of six feet.

Allowance should be made for a margin of error in measurement of the depth and of 5 to 7 percent for settlement in the length of clay and underlying general purpose fill. The time required for the settlement will depend upon the quality and quantity of the materials that were used. General fill containing large amounts of clay will take longer to settle than granular fill. Complete settlement of shaft fill may take several years.

When filling is complete, the shaft should be temporarily mounded over, fenced, and provided with warning notices until the fill settles and permanent capping is placed.

Alternatively, if it is desired to clear the site quickly, the shaft can be capped immediately after the filling is complete, provided that provisions are made for eventual permanent closure treatment (e.g. grout the fill using pre-formed or drilled holes for grouting through the cap).

2. Enclosures

The combination of a properly maintained enclosure and a light shaft cover is normally an adequate temporary measure to prevent accidental access to an open shaft or adit.

New enclosures, normally of fencing, should be of sufficient area to allow for subsequent operations and, wherever possible, a permanent access to the site should be made. Two or more shafts may be conveniently included within one enclosure. At an adit mouth the enclosure should extend along the line of the roadway to a point where the rock is sufficiently thick to ensure protection. The standard of fencing or walling to be provided should be determined by the circumstances at each location. Recently-filled shafts where settlement is taking place should be temporarily protected by an enclosure.

Damage and normal deterioration of fencing usually entails regular inspection and maintenance. Enclosures should not be necessary following proper closure and reclamation.

3. Covers

Covers are intended to prevent the accidental entry of persons and illegal dumping into an unfilled shaft but are not designed to protect the surface against subsidence by cratering. Generally, covers should not be used as permanent mine closures. Only backfilling will permanently support shaft lining walls and the shaft cap or plugged surface.

Covers should be clearly visible, self draining, and protected from being overloaded. They should be used only where the lining is sound or has been suitably repaired or strengthened to ensure long term security of the ground surrounding the shaft mouth. Gas vent pipes with flame arrestors may be necessary and fencing may be required to limit access to them . The cover and any fittings should be vandal-proof and designed to preclude possibilities of burrowing under the edges, or of the easy lifting of any removable section of the cover. Shaft covers may be divided into two classes -- light and heavy duty.

Light duty covers (Figure. IX-6) may be constructed of timber, steel or concrete and should be designed for a uniformly distributed superimposed loading of 270 pounds per square foot. They should only be used in circumstances where an enclosure can be provided to prevent access by unauthorized persons and vehicles. Frequent inspection and maintenance of the cover are likely to be necessary.

Heavy duty covers (Figure IX-7) should be constructed of reinforced concrete and be designed to carry a uniformly distributed superimposed load of 700 pounds per square foot and should be not less than 12 inches thick. They should incorporate a strong central monument to prevent vehicles from traveling over the cover and to mark the shaft. The reference number, position of the center and the diameter and depth of the shaft should be recorded on the monument or the cover itself. Enclosures may be required at some sites.

Comparable measures at an adit simply comprise walling-up the entrance, or fitting it with a strong steel door, and securing the roof against intrusion from the surface. Provision for drainage and gas vent pipes may be required. While regular inspection and possibly some maintenance may be necessary, an enclosure is not usually required.

4. Caps

Caps are intended to enable shafts to be permanently closed with little risk of subsidence at the surface even in the event of the loss of any fill or the collapse of the shaft walling. They should be constructed of reinforced concrete and be designed to carry the weight of the overburden and a uniformly distributed superimposed load of 700 pounds per square foot. The length of side (or diameter) of a cap should be not less than twice the internal diameter of the shaft (or twice the diagonal of a rectangular shaft) and there should be an 18 inch minimum thickness of 4,350 psi concrete.

Caps should be founded on competent material or solid rock where the solid rock is accessible from the surface (e.g., to a depth of approximately 20 feet) (Figure IX-8).

If rock is not within such reach, or if the excavation would be difficult (for example through water bearing ground), the cap can be founded in superficial deposits on a competent strata accessible from the surface (Figure IX-9). In this case, if the shaft is one which has not already been treated, the full shaft treatment should incorporate measures which either preclude the loss of fill or strengthen the length of the shaft through the superficial deposits (Figure IX-9(A)).

If the shaft has been treated in the past, the fill may be strengthened by grouting, or excavated to bedrock level and replaced with grouted hardcore (Figure IX-9(B)). In exceptional circumstances where the above measures are not reasonably practicable, it may be possible to accept the risk of loss of fill if the ground from the cap down to the bedrock is all reasonably competent and failure is not likely to cause a major disturbance of the site (Figure IX-9(C)). Other engineering treatments of the ground outside the shaft may be devised.

If production of gas from the mine is expected, a vent pipe fitted with a flame arrestor should be provided and, if necessary, the site should be enclosed until the issue ceases. If the gas is discovered outside the shaft lining, grouting may seal it off or force it into the interior of the shaft from where it can be vented. In some cases, a sealant coating on the cap may be advantageous.

The cap should be marked with the reference number of the shaft, the position of the center and the diameter and depth of the shaft. Though monuments are not normally necessary, it may be appropriate in some situations to mark the site of some shafts permanently with a decorative or other feature.

The comparable treatment for an adit would be a plug, stopping or dam as described below.

5. Shaft Plugs

A concrete plug placed at an appropriate position within a shaft is intended to prevent the loss of fill and, if required, to protect underground workings. As the construction of plugs demands internal access deep into the shaft, this is normally practicable only in operational shafts about to be abandoned. Plugs which must be watertight require the concrete/rock interface, and possibly the strata, to be injected with grout.

Figure IX-10 illustrates three types of shaft plugs for horizontal strata. Figure IX-10(A) shows the traditional conical shape where the load is carried by the strata in direct compression. The volumes of excavation and concrete needed and, if required, rock to be grouted are considerably greater than for the parallel plug (Figure IX-10(B)) which requires little excavation beyond the removal of the lining and any loose rock. Under vertical loading a plug shortens in length and expands laterally, which enables the plug to carry considerably higher loads than a design based on simple shear would permit.

Inset plugs (Figure IX-10(C)) are simple to construct but care is necessary to ensure that security is obtained at the inset roof/shaft junction, possibly requiring the removal of the shaft lining in this area and an extended length of plug up the shaft.

The plugs shown in Figure IX-10 assume horizontal strata; dipping strata may require the shapes to be slightly modified to suit. Shaft plugs require the design and construction of a substantial bottom form which must withstand the weight and pressure of the wet concrete placed on top of, or against, the form. A preferred design would be the use of steel beams hitched into the shaft sidewalls, decked over with 0.25 inch steel plate. Sand bags placed around the edge of the rock/steel plate interface will prevent the loss of wet concrete during the pouring operation. A concrete plug should be poured in one continuous operation to avoid the formation of latence (a plane of weakness) which will occur at the top of intermittent pouring operations.

Plugs may incorporate pipes through which water from the upper part of the shaft can be drained into the workings below during construction. The drain pipe is grouted off after the drain pipe has had a chance to cure and after formation and contact grouting has been completed. Ventilation is an important consideration.

Shaft plugs should normally have a minimum length equal to the shaft diameter. Water will leak extensively past an ungrouted plug unless the hydraulic gradient or pressure drop from the 'wetside' (top of plug), to the 'dry side' (bottom of plug) can be adjusted by proper plug length and pressure grouting. If the plug is to be watertight or where water cannot be permitted to flow into the shaft and workings below the plug, the length must be such that the pressure drop should not exceed 161 psi/ft. The factor of safety for the hydraulic gradient divided by the plug length should be at least 4. If the concrete/rock interface is grouted to a pressure equal to twice the head of water, then the safe pressure drop can be achieved.

In some circumstances it may be necessary to design a plug for possible uplift pressures caused by water from the mine rising within the shaft.

Plugs whose height/diameter ratio is in the order of one do not generally require steel reinforcement except across the base and around the periphery. But if watertightness is critical, consideration should be given to including nominal reinforcement throughout in order to control shrinkage cracking. A degree of watertightness may also be provided by a clay seal placed on top of the concrete plug.

6. Roadway Stoppings and Dams

Roadway stoppings and dams are used to seal adits. If desired, they can also be used as alternatives to shaft plugs in operational mines which are about to be abandoned. Figure IX-11 illustrates the use of chain link fence, channel iron and rock bolts to make a temporary adit closure for a timbered opening and a non-timbered opening. Figure IX-12 illustrates a method for permanent adit closure.

Stoppings are intended to retain only solid fill material; dams to retain both solids and water. Stoppings may be constructed of hard sandstone from the mine or hardcore or rubble packed tight to the roof and sides and between the end retaining walls. In level roadways, the length of the stopping between end walls should be not less than three times the roadway height or width, whichever is greater, at depths up to 650 feet. Over 650 feet, an additional length of 0.1 times the roadway height or width should be provided for each additional 300 feet of depth. In dipping roadways, the length may need to be increased by up to 33 percent.

Dams should be designed and constructed in concrete on the same basis as watertight plugs (Figure IX-13). In no case should their length be less than the roadway height or width, whichever is greater. The permeability of the rock at possible sites for dams in the mine roadways near the shaft is likely to be high and large quantities of grout may be absorbed in ground injection. It may therefore be preferable to use the combination of a dam located in by with a stopping at the shaft. Where access to the in by side of a dam will remain, provision should be made for the measurement of the pressure on the dam face.

In addition to constructed roadway stoppings and dams, it may be necessary to consider the structural strength and permeability of thin rock pillars separating a roadway or shaft from voids capable of accepting any substantial quantity of material should the pillar fall.

CHAPTER 12: RADIONUCLIDE RECLAMATION

A. INTRODUCTION

Reclamation of post mined radioactive materials sometimes requires special techniques or considerations. Considerations include: offsite uranium migration by surface or groundwater; worker exposure to radon, radon daughter products, and radionuclide contaminated dust; post reclamation exposure to humans; and appropriate limits of bat and human exposure in grated shafts and adits.

B. HAZARD DESCRIPTION

Radon is a gaseous radioactive decay product of radioactive uranium (U238). Radon continues to decay through short-lived daughter products into a stable form of lead (Pb208). Alpha particles (each containing two protons and two neutrons), beta particles (each an ejected electron caused by a neutron converting to a proton) and gamma rays (the high frequency energy released by creation of alpha or beta particles) are released during decay. Inhalation of alpha particles or exposure to beta particles or gamma rays is incrementally carcinogenic.

Some radon is present in the atmosphere resulting from the natural decay of radionuclides in soil and rock. Radon concentrates in closed areas with poor air circulation.. Radon levels may be extremely high when such areas contain a rich source of uranium or thorium. Abandoned uranium mines contain radon levels thousands of times higher than atmospheric concentration. Radon tends to collect in low areas, and may be expelled from a vent or adit in increased concentrations with dropping atmospheric pressure or diurnal tidal fluctuations.

Radon daughters have an affinity for dust particles. Some particles of inhaled dust may become lodged in lung tissue. Consequently airborne dust in high radon areas is a health hazard.

C. OCCURRENCE AND CHARACTERISTICS

Radionuclides including radon and its progeny are associated with uranium mines and thorium deposits. Radioactive elements may be associated with other metals in mineralized zones. Such associated metals may include, but are not exclusive to; gold, silver, copper, molybdenum, vanadium and cobalt. Exposure to significant mass of pitchblende, a primary uranium ore or high natural concentrations of thorium ores are of particular concern. There are a few rare earth deposits associated with concentrated thorium in the continental United States.

Uranium occurs naturally in tetravalent and hexavalent states. Tetravalent, the less soluble, sometimes occurs above the reduction/ oxidation zone. Hexavalent, the more soluble and more common, usually occurs at or below the reduction/ oxidation zone. Current reclamation procedures do not differentiate between the two. Oxygenated alkaline water will transport uranium in solution as a carbonate complex. Acidic waters with low concentrations of inorganic ions and high concentrations of organic matter will transport uranium in solution complexed to organic matter.

D. REGULATORY AUTHORITY

40 CFR § 192 regulations only apply to mill sites and mill type waste related to the Manhattan Project. Acid and carbonate recovery processes may render mill tailings as more soluble or more hazardous than naturally occurring mine waste. If any ore or radioactive mine waste is present at a mill site, such material is considered as millsite tailings, not mine waste when the site is reclaimed.

10 CFR 20, D or FR Notice (Vol.59, #246, Friday, December 23, 1994 sets 100 mrem/yr as the allowable radiation limit for non-radiation workers.

10 CFR 20, D & K, and 10 CFR 40, Appendix A, cover applications and proposals for disposal of liquid waste at in-situ uranium leaching facilities, including surface impoundments, seepage control, groundwater monitoring and closure requirements.

10 CFR § 835, E & F regulations address occupational radiation protection. This is a codification of some of the worker safety measures discussed in subsection G, below. However, this regulation is only applicable to Department of Energy sites.

E. RECLAMATION

1. Adits, Declines, Shafts and Vents

Close adits using grouted rock bulkhead or backfill. Grouted rock bulkhead is preferable for more remote sites where rock is available and there is no equipment access to the site. Scale the back and sides or preferably machine backfill if the opening has unstable rock. Partially collapsed openings should be excavated and cleaned out prior to backfilling, if it is safe to do so.

Declines are usually backfilled. When backfilling declines, large rock should be pushed in first to form a barrier to movement of loose backfill material. See IX-30 for specified length of fill zone.

Backfill shallow shafts with mine waste or other material, placing larger rock into the shaft first. Because of potential bridging and subsidence, deeper shafts should be sealed at the surface using foam or concrete plug or panel (see IX-20, 4 & 5). The plug is constructed at the bedrock contact and then backfilled to surface.

Vent holes, present at many mines, are sealed at the surface with foam or cement, except for bat gate mine closures, which require grating on the vent hole.

When reclaiming adits or declines allow for sufficient fill above brow of opening for settling and to create a filter seal against mine exhalation of radon rich air. Do not backfill with foam. Foam or inflated weather balloons may be situated behind the fill location. Use of these materials inhibits radon ingress from deeper within the mine to create a relatively radon free zone for workers to emplace the closure material. Backfill material in adits, declines and shafts should be the highest radioactive mine waste available.

2. Drill holes

Uranium development drilling was commonly done on 100' or 100' X 200' centers. Such drilling was often, but not always grid controlled. Many of the unplugged exploration and development drill holes are not easily located. Backfill or plug open holes with foam or other acceptable surface plug, such as a plastic plug. Backfill dry holes exceeding 8 inches in diameter with free flowing non-reactive material, such as bentonite granules and cap with a minimum of 3 feet of impermeable material. Smaller diameter holes shall be plugged a minimum of 3 feet or more below surface, and backfilled with cuttings or other suitable material. Drill holes that penetrate an aquifer shall be abandoned as required by section V. B.

3. Foam exposure to ultraviolet light

When reclamation foam is exposed to sunlight for long periods of time it may deteriorate. To avoid this, cover foam with fill, rock or other material where such foam may be exposed to direct sunlight.

4. In-Situ Reclamation

In the United States today, uranium is only being produced by in-situ leaching (ISL) methods. A Nuclear Regulatory Commission (NRC) source and byproduct material license is required under the provisions of 10 CFR 40 to recover uranium by in-situ solution mining techniques (NRC, 1997). This mine-specific license spells out requirements for control and reclamation of radioactive waste. The NRC Report NUREG-1569, titled “Draft Standard Review Plan for In Situ Leach Uranium Extraction License Applications”, details these procedures for new license applications, operations, and plant closures.

Radioactive waste can include liquid effluent, particulate emissions, and ore cuttings. This waste comes from five main sources at an ISL mine: 1) drilling operations at new well fields; 2) uranium extraction at production well fields; 3) drying and packaging of yellow cake; 4) restoration operations at old well fields; and 5) land application areas (Faillace and others, 1997). Radionuclides may be found in liquid effluent from four waste streams: production bleed of groundwater extracted during uranium recovery, groundwater sweep at the end of an operation, wastewater from yellowcake processing, and reject brine from reverse osmosis treatment of contaminated water. This effluent may be disposed through onsite evaporation, release in surface waters, onsite land applications, and/or injection into deep wells. Groundwater and surface water monitoring are required to ensure that harmful levels of radioactive effluent do not travel off site. Post-reclamation and decommissioning radiological surveys are required to monitor groundwater for decontamination and for removal of structures and equipment. There are also cleanup criteria for radium, uranium, and thorium levels in soils. These procedures are regulated by the NRC according to the provisions in 10 CFR 20 and 40, and by EPA in 40 CFR 440. Contact the NRC for guidance on radiation standards for closure of an in-situ uranium mine on BLM land. Their website is www.nrc.gov.

5. Reclamation of Surface Disturbance

To the extent practicable, confine regrading within the limits of the areas existing footprint. Remnants of ore piles, ore around loadouts, and other higher radioactive material must be identified and selectively buried. Millable ore may be consolidated, emplaced and fill-encapsulated in a recoverable location.

6. Ore piles, Sub-Grade and Scattered Material

Radioactive mine wastes and stockpiled ore should be covered with not less than 6" of soil with upper radiation limits of 5 picoCuries/gram (pCi/g) above background. 1½' or 2' of such cover preferably should be used. Soil cover below 6" depths may have radiation limits of up to 15 pCi/g.

7. Run on - Run off, Groundwater

Radioactive material should not be situated where run-off is likely to transport radionuclides off site through surface waters or through potable groundwater. Run-on may be related to such run-off, or any of several groundwater scenarios. The least invasive is where the naturally concentrated radionuclides are transported by groundwater toward the redox zone, leading to a redeposition approaching a natural state when they reach a reducing environment. Consequently design considerations for run-on and groundwater effects are on a case-by case basis. If hexavalent uranium ore or other significantly soluble mineralization is present it must be located so that it will not contaminate surface or groundwater.

F. BAT GRATING CONSIDERATION

___1. Installation

Install bat gates in competent rock at a distance several tunnel diameters back from the mine mouth. This allows the bats to pass through the grates without being subject to high predation. If the rock between the grate and the mine mouth is unstable or could become unstable, long-term stabilization is required. Such stabilization may include emplacing large size concrete or galvanized steel culvert in the mine opening. Any space between the culvert gate and mine wall is sealed with foam or grouted rock. Allow for drilling anchor holes in incompetent rock.

Declines or adits with significant highwall hazards could experience post reclamation burial of the tunnel opening. To avoid this, bat gates should be constructed on the inner end of a section of culvert which extends 10 feet out of the opening resting on natural ground or compacted fill material. The rest of the culvert section should rest on the adit or decline floor. Culvert diameter should closely match the excavated opening size to preserve existing air flow.

Culvert length should also be sufficient to interfere with predator vision at the grate location. Predators often can see better in a decline than in an adit because a decline will admit more light from the twilight or night sky. After the gate is welded to the end of the culvert and set in place, the decline above the culvert is backfilled with mine waste. The space between the culvert and mine wall (at the opening) is sealed with foam or grouted rock to minimize potential water pathways into the mine.

G. WORKER SAFETY MEASURES

1. Dosimeter Use

Dosimeters are formally designated as Thermal Luminescent Dosimetry Badges (TLDs). Dosimeters may be worn by individual reclamation workers to document radiation dosage, or when they enter a high radiation area (ie: mine-mouth entrance). Reclamation contractors may also need to give workers a quarterly urine sample to document high dust exposure in a radioactive environment. TLDs only register gamma exposure and urine samples are only valuable in a dusty environment. As stand alone tests they undercount exposure levels. A 0.1 rem dose is the occupational yearly limit. .

2. Avoidance of High Radon Areas

Unless secured from most radon incursion (i.e., by the inflated balloon technique) workers should not enter past the lip of any abandoned uranium or other mine with high radon values (see dosemeter use discussion). Entrance into mine workings is required for bulkhead and grating closure installations. The radon exposure to contractors doing this work can be minimized by: 1) the use of respirators; and 2) limiting the work to the period when the mine is inhaling outside air, after the work area is secured from most radon incursion by balloon or barrier wall located behind the closure work location.

3. Dust Suppression

Areas under reclamation should be subject to dust suppression methods. Dust abatement generally is accomplished by spraying water or a chemical solution on work areas and adjacent roads. Equipment should be washed subsequent to project use.

References

U.S. Nuclear Regulatory Commission, 1997, Draft standard review plan for in situ leach uranium extraction license applications: NUREG Report 1569, Division of Waste Management, Office of Nuclear Material Safety and Safeguards, NRC, Washington D.C.

Faillace, E.R., LePoire, D.J., Chen, S.Y., and Yuan, Y., 1997, MILDOS-AREA: An update with incorporation of in situ leach uranium recovery technology: Appendix C to NUREG Report 1569, Division of Waste Management, Office of Nuclear Material Safety and Safeguards, NRC, Washington D.C.

CHAPTER 13. SOILS

A. INTRODUCTION: A common reclamation measure is to strip the surface of the soil, sometimes called the topsoil, from 6 to 12 inches deep, and replacing it on reclaimed surfaces prior to reseeding. This topsoil is usually the most fertile portion of soil, often containing the most nutrients, microorganisms, seeds, and roots which will enhance the chances of re-establishing vegetation on the site. Topsoil salvage and replacement are therefore important steps in reclamation planning.

B. SOIL CLASSIFICATION: Soils develop over time from the alteration of land surface from plant growth, climate (including moisture and temperature effects), drainage, macro- and microorganism activity, and topographical position. These soils are characterized by the properties they inherit from the weathering and alteration process on the land surface. This results in a sequence of chemically and biologically differentiated layers of from one to four master horizons. From the surface downward these horizons consist of the A, B, and C horizons (the soil profile) and the R horizon which consists of the underlying consolidated rock.

1. The A horizon extends from the ground surface downward. Typically, weathering may result in partial removal and leaching downward of constituents like iron and aluminum oxides and silicate clays. Contributions from the decay of plants and their roots, however, results in an accumulation of organic matter in the A horizon. The A horizon is what is most often identified as the most fertile portion of the soil for salvage.

2. The B horizon lies immediately below the A horizon and is sometimes referred to as the subsoil. It is a zone of more moderate weathering in which there is an accumulation of many of the products removed from the A horizon, such as, iron and aluminum oxides and silicate clays. In arid regions, these accumulations may also consist of calcium carbonates or calcium sulfate. These accumulations of clay and calcium carbonate or sulfate accumulation may be so great as to make this horizon nearly impermeable to water movement and root penetration.

3. The C horizon consists of the unconsolidated material underlying the A and B horizons and may or may not be the same as the parent from which the A and B horizons formed. The C horizon usually lies outside the zones of major biological activity and is usually little affected by soil-forming processes.

C. PLANNING SOIL SALVAGE: Salvaging topsoil and replacing it on areas upon final reclamation is well understood to enhance revegetation success. In general, this means salvaging the A horizon, usually the top 6 to 12 inches of soil, however, the depth of stripping and salvage could be much less or more depending on the types of soils located in the project area.

Some soils may be very shallow to bedrock and yield very little to virtually no material for salvage. Some soils may contain elevated levels of salts which will inhibit plant growth and of questionable value for use later. In some areas though, the soils may contain very desirable material for salvage to a depth of several feet or more.

D. <u>SOIL SUITABILITY DETERMINATIONS:</u> Factors effecting soil suitability for revegetation include its texture (percentage of sand, silt, and clay), water holding capacity, pH, and salinity or electrical conductivity (EC). Table __ provides guidance in determining what portion of the soil profile should be salvaged.

Ideal pH levels range from 6 to 8, with a minimum usable value around 4.5-5 and a maximum limit of 8.5-9. At these extremes, revegetation options may be limited, and care must be taken to use plant species tolerant of such levels. Higher salinity levels also limit species options, especially as electrical conductivity approaches 12 or more millimhos/cm. There are numerous species adapted to high salt and alkalinity levels, though, and these should be selected for such sites. Where boron may be present, the soil should be tested to ensure that levels are below 5 ppm water soluble. Selenium at levels of 0.1 ppm in soil are also problematic. Soil texture is important.

Sandy loams are generally most suitable for revegetation, although even very rocky material can be used provided there are adequate fine materials intermixed. Sandy soils are very prone to wind erosion and have little water holding capacity. Clay soils are challenging because of their ability to bind water and their instability during shrink/swell cycles and should be avoided when possible.

Because most plants have rooting depth greater than 12 inches it is also important to make sure the material below the topsoil is not injurious to plant growth. Table 1 can be used as a guide in assessing the suitability for plant growth for the substrate below the replaced topsoil. In some situations, the waste rock or overburden, heap leach material, or tailings which are to reclaimed may be so noxious to plant growth that a sufficiently thick cap is required to prevent plants and their roots from intercepting the noxious material.

E. <u>SITE INSPECTATIONS/SOIL SURVEY:</u> For small operations or disturbances, all that may be needed to determine how deep to salvage the soil is a shovel and a little basic knowledge about soil/plant relationships. For example, in the Great Basin low sagebrush (<u>Artemisia arbuscular</u>) is typically found on soils which are often shallow to a very clayey subsoil. The clayey subsoil restricts downward water movement and rooting depth and is not very suitable for soil salvage, and the surface horizon above may only be a few inches thick. The presence of big sage (<u>Artemisia tridentata</u>), however, would indicate a rather deep soil, free of horizons which would restrict water movement or rooting depth. In these areas, the salvageable soil may be a few feet in thickness.

For large operations, a soil inventory of the project area may be helpful in determining baseline conditions and the thicknesses and quantities to which the soil could be salvaged. The soil map would provide information on individual soil units; their extent, depth, location and the types of plant communities adapted to the different types of soils. A soil survey follows the methods, standards and procedures described in Title 430-VI of the National Soils Handbook, (USDA-NRCS 1993), Soil Survey Manual (USDA-NRCS 1993), and Keys to Soil Taxonomy, 7th ed. (USDA-NRCS 1998). The information obtained during the survey is used to create a soils map of the site on a scale of about 1:15,000 or larger.

F. <u>REPLACEMENT OR SUBSTITUTE SOIL:</u> In some cases, there may be insufficient quantities of topsoil available for salvage to adequately cover the surfaces upon final reclamation and revegetation. There then is the need to find suitable replacement or substitute growth media; this may include using subsoils or strata deeper within the overburden with suitable characteristics for plant growth as outlined in Table ___. Deficiencies in the replacement or substitute soil could be made up by using soil amendments, which will be discussed later in this section.

G. <u>STOCKPILING AND DIRECT HAUL:</u> The salvaged soil can than either be stockpiled for later use or used immediately over regraded surfaces which are ready for final reclamation. The latter option sometimes called direct or live haul is preferable over stockpiling since the soil microbes, bacteria, viable seeds, and plants that can take root are at their most abundant, and would lead to better revegetation. Stockpiling of the soil for long periods results in the loss or elimination of these beneficial characteristics. This is especially so where soils are stockpiled more than several feet in height and biologically activity is diminished from lack of oxygen.

While direct hauling of soil to its final destination may be feasible in some cases, it is more typical for the soil to be stockpiled, often for years, before final placement. In such cases, the soil should be protected from erosion and weed invasion. This is accomplished by positioning the stockpiles to minimize exposure to wind and by immediate seeding of the piles, to reduce erosion, provide competition for weed species, and to maintain viability of the soil fungi and microbe communities. Since diversity and sustain ability of this community are not concerns, exotic perennial bunchgrasses such as crested wheatgrass or other low cost perennial cover crops are appropriate. However, where the growth medium will be stored for several years before use, it may be useful to seed with species appropriate to the final reclamation goal in order to establish a soil seed and vegetative material bank which will persist after the final use of the soil.

H. <u>SOIL AMENDMENTS:</u> Where the use of soil amendments is contemplated, it should be in response to a specific identified problem and should be thoroughly tested on a small scale for several years at the site before large scale use.

1. Fertilization:

The use of fertilizer should not be routine in the reclamation of arid sites in the west. These areas are typically at high risk of invasion by exotic annual weeds, almost all of which are favored by higher levels of nitrogen. Native western species are well adapted to the low fertility of soils in these areas. There are many cases of severe weed infestations which are directly attributable to addition of nitrogen. In any case, the nutrient needs of most native aridland species are unknown, which makes supplementation highly problematic. If there is doubt about the potential efficacy of fertilization, test plots should be established well in advance, with both fertilized plots and unfertilized controls, to determine whether the reclamation species are enhanced, and whether the weeds will be a problem. Since weed problems may not manifest themselves for several years, especially where the climate is highly variable, these plots should be placed at least four years before major decisions are based upon their performance. In addition to the considerable cost incurred, the routine use of fertilizer may well trigger problems with undesirable annual invaders which can be essentially impossible to correct. In grasslands, wetter areas, and in areas for which reforestation is planned, fertilizer application rates should be determined in consultation with local authorities in the Cooperative Extension Service, The Natural Resources Conservation Service, or on the basis of previous local experience. In arid areas where excess nitrogen frequently causes problems, it may still be desirable to add phosphorus, either by itself or in some cases with very low levels of nitrogen.

2. Mulch

As with fertilizer, mulch should be used only where there are specific indications for its application, and not as a routine element in reclamation. While it may be useful in wetter areas where severe erosion potential exists, in drier areas there are a number of potential problems. These include: wicking of soil moisture leading to increased evaporation, alteration of carbon:nitrogen ratios, attraction of rodent and invertebrate seed and seedling predators, and plant competition from grain seeds in the mulch. Where mulch is used, it is imperative that it be retained either by mechanical crimping, application of a tackifier, or with netting. These materials and the time required for their application add substantially to reclamation costs. Thus they should be tested in small scale test plots before being widely applied.

3. Gypsum:

Although expensive to incorporate, gypsum may be useful as an anti-crusting agent or to raise pH of acidic soils, although limestone derivatives are more commonly used to control acidity.

4. Biosolids:

Sewage biosolids have been used as soil amendments with some success, especially in soils devoid of fine and organic material. Their use on public lands requires special treatment and documentation. Even where possible, there may be problems with excess metals and nitrogen.

5. Manure:

In addition to increasing nitrogen levels, which may cause problems with annual weeds, manure frequently contains viable weed and other seed. Therefore it is rarely used in arid land revegetation.

6. Polymers:

Water retaining polymers have found some use in arid areas, but are generally too costly for large scale use.

CHAPTER 14. REVEGETATION

A. INTRODUCTION:

The goal of revegetation is to stabilize the surface from erosion, establish productive post-mining land uses, and restore visual resource integrity. Thus revegetation should be planned at the onset of mining activity in view of projected post-mining land use plans and goals. It should result in a self-sustaining diverse community of perennial vegetation which either represents or is projected to evolve into a stable, productive component of the ecosystem.

1. Early considerations:

2. Documentation of pre-disturbance vegetation:

When possible, the vegetation on the site should be documented before disturbance begins. Parameters to be considered may include species composition and cover, and in some cases species density (number of individuals of each species present). In many cases, this may serve as the reference standard for evaluation of post-mining reclamation success. It also provides valuable information for use in developing the reclamation species mix. The monitoring methodology is described below.

3. Documentation of revegetation:

A central file for the keeping of all records related to the revegetation effort should be established at the beginning of the process. Information which should be included is discussed in the Documentation section below.

4. Determination of final standards for release:

The standards by which revegetation adequacy will be determined should be established as early as possible in the mine life cycle. The elements include: Choice of reference areas or other standards for comparison, level of vegetative cover or density which will be considered adequate (e.g. revegetated cover equal to or greater than 100% of the cover of the reference area), stipulations about species composition and/or plant life forms (tree, shrub, grass, forb) to be re-established, and controls on noxious weeds or annual species.

5. Growth medium salvage

Topsoil in many areas, especially arid sites, is frequently in short supply and of poor quality. Many sites, however, have suitable growth medium in the overburden and/or waste material which is removed early in the ore extraction sequence. This material should be salvaged and stored for reapplication after mining. Parameters for testing and techniques for storage are discussed below. In general, growth medium is in short supply at reclamation of most western mines, therefore all potential growth medium encountered during the life of the mine should be assessed and saved if suitable.

6. Plant salvage

Where large or unusual specimens, especially of cacti, yuccas, certain trees, or sensitive species, are found, they may be removed at this point for replacement after mining.

7. Recontouring

Final land for the planned post-mining land uses should be considered in the initial stages of mine planning.

Considerations include: provision for wildlife migration routes, optimization of final slopes and aspects for revegetation goals, hydrologic patterns and creation/preservation of potential riparian zones, and reduction of visual disturbances by blending post-mining land forms into the surrounding topography. In some cases it is desirable to maximize certain aspects (such as cooler ones in hot-summer areas, or warmer ones where cold winters limit plants or wildlife) even if the resulting area of the footprint of disturbance is increased. It is also important at this stage to ensure that the planned slopes are not too steep to revegetate.

8. Preservation of islands of natural perennial vegetation:

Where possible, the mine plan should provide for the preservation of existing desirable natural plant communities. In addition to reducing the area of reclamation after mining, these provide excellent seed sources for natural revegetation and may serve as reference areas for the evaluation of post-mining revegetation success. They also contribute to diversity in the mosaic of age classes of communities, which is ecologically desirable.

9. Seed mix selection and ordering:

Seed mix components should be selected, and if possible ordered, at least one year prior to anticipated use. Because many of the demands upon the seed supply industry are erratic and unpredictable, and because supply is quite variable for many species, lead time is needed to ensure that the desired seeds are available when needed. Ideally, operators or agency personnel should establish contact with one or more seed suppliers early in the reclamation process, keeping them appraised of the projected need for seed.

10. VRMs Band seed selection:

Consideration of visual integrity of the post mining landscape should include choice of reclamation seed mix. It may be desirable to include a mosaic of shrubs and grasslands, and to include created talus slopes or rock outcrops for visual relief. Monocultures of certain species may at some times of year present an obvious visual anomaly which defines the mining disturbance on the post-mining landscape for years or decades. One example is the use of forage Kochia, especially on drill roads or small pads. In fall and winter, these communities are bright red or orange, and stand out against other dormant vegetation very graphically. Pure stands of grasses seeded in shrub or woodland areas may have a similar effect.

11. Wildlife considerations:

Because mine reclamation frequently represents the best opportunity to create wildlife habitat from scratch, consultation with both game and non-game wildlife personnel is imperative early in the reclamation process. Considerations should include not only species selection, but also the creation of structural diversity, a mosaic of appropriate plant communities, establishment of species which will support a prey base for raptors, mammals, and reptiles, the potential for creation or reestablishment of migration corridors, water sources, and nest sites. Many wildlife species, such as Sage Grouse, are limited by factors which can be readily provided in the post mining plant community, provided that these special needs are met in appropriate locations and proportions. The section on pit and highwall reclamation discusses other options for creating top quality wildlife habitat.

12. Fencing/trespass control:

Lack of protection from domestic and /or feral livestock is a major cause of revegetation failure. Before site release, it is normally imperative for the operator to maintain adequate controls on livestock usage, in order to allow maximum plant growth for bond release. However, at the conclusion of reclamation, fences are typically removed. This is usually unfortunate, especially in cases where the vegetation on the reclaimed site is superior to that of the surrounding un-mined area, as is very often the case. Domestic and feral livestock invariably concentrate heavily on these areas, resulting in the rapid deterioration of the reclaimed plant community. The option of maintaining fences to allow appropriate grazing management of reclaimed sites should be explored early in the reclamation planning process.

13. Test Plots and concurrent reclamation:

No characteristic distinguishes successful revegetation efforts from failures as accurately as the early installation and careful interpretation of small scale test plots and/or concurrent reclamation efforts. These are especially important in areas where there is little prior revegetation experience, and where edaphic and climatic conditions are variable or extreme. While careful record keeping is important, statistical analysis is not usually needed, since successes and failures are quite obvious. Test plots are useful in the evaluation of seed mixes, growth media, seed application method, fertilization, mulching, slope, aspect, and almost any other element of the revegetation process. They need not be large or elaborate, but should represent potential final conditions as accurately as possible. As successful materials and methods are identified, they can be scaled up to concurrent reclamation of areas which are no longer being actively disturbed. Not only does this smooth the learning curve, but it also results in an earlier return of portions of the disturbance to post-mining productivity, decreases manpower needs at the end of the mining life cycle, and allows earlier return of portions of the reclamation bond, or frees portions of that bond for application to new areas of disturbance. The importance of documentation of every element of the tested technique cannot be overemphasized. Because information will continue to emerge from these plots for years, the original conditions and monitoring of progress must be available long after the plots are established. It is also very important to clearly and permanently mark plot locations and treatments. Vast amounts of information are lost, and much time and money wasted, because plot markings were not identifiable as the plots matured. Ideally, plots would be marked by GPS (Global Position System), as well as by permanent monuments on the ground. Survey stakes or laths are not adequate, as they are too easily dislodged, decayed, or overgrown. Steel fence posts with permanent markings are acceptable on secured sites, but are vulnerable to theft and may pose safety hazards on unsecured sites. Claim post markers may be sufficiently visible and durable.

14. Irrigation

While irrigation is rarely practical on large sites, it may have some applications where it is not possible to seed during the ideal planting window of the wet season. Initial germination is often higher with supplemental irrigation, although this may result in problems of high seedling densities which cannot be sustained under natural conditions later. There is also the risk of increasing competition from weeds. Irrigation is not typically appropriate past the first growing season. Sprinkler or drip irrigation, while expensive to setup and maintain, avoids problems with traffic and compaction that result when water trucks or other mobile systems are used. Most plans stipulate that release of revegetated areas cannot be considered until at least three growing seasons have elapsed since planting AND cessation of irrigation. Thus irrigation results in a delay of final release consideration. Where irrigation is used on heap leach operations, it should not include spent leach solution unless the irrigated surface is later recontoured, since the nitrogen resulting from cyanide solution breakdown will usually cause problems with invasive annuals.

a. Species selection and seed mix calculations:

Species selection:

Species selected for revegetation should include a diverse mix not only of individual species but also of life forms appropriate to the area. A variety of species increases chances of success under variable site and climatic conditions. Species would typically include shrubs, forbs, and grasses, and in some cases trees. Only perennial species should be used, except in the rare cases where a green manure or cover crop is an intermediate step to final revegetation. Species should support the projected post-mining land use and should be capable of reproducing on the site. Federal regulations mandate the use of native rather than exotic species except where there is a compelling argument for the use of non-natives. In such cases, the reasons for their inclusion must be documented as detailed in BLM Manual 1745. This documentation must include a detailed description of the proposed introduction, along with applicable regulations and issues, a description of habitat, potential impacts, potential for hybridization and disease, displacement of native species, planned mitigations, comments from interested agencies and adjacent landowners, and supporting NEPA and scientific documentation.

In general, the use of non-natives is discouraged. Seed mix selection should be guided not only by experiences in similar locations, but also by observation of the natural undisturbed vegetation typical of the area. Constraints of soil type and climate, as well as special wildlife or visual requirements should be addressed.

Harvesting of local seed:

Plant species commonly display considerable site adaptation and variability. Thus seed collected far from its eventual planting site often does less well than seed of the same species collected closer to the planting site. Most professional seed suppliers record the collection site, and it may be possible to choose seed that is from locally adapted plants. If such seed is not available, the possibility of contracting with collectors to obtain local seed should be investigated. Some mines have had excellent success with seeds collected from previously revegetated sites. Others have used backpack vacuums to collect seed locally.

Determination of Pure Live Seed (PLS) ratio:

Before a seed application rate can be determined it is necessary to determine the percentage of pure live seed (pls) in the supplied seed. Seed may contain weed seed, seed of other species, chaff, sand, and other inert material, and broken seeds. The PLS rate is the percent of pure seed times the germination percentage rate divided by 100. It is the PLS which is actually used to determine planting rate and seed cost. For example, a seed lot with 90% germination and 99.50% purity has a pls rate of 89.55. (90 X 99.5) 100).

Less expensive seeds with lower purity and germination may actually cost more on a PLS basis than more expensive seed. The weed content and composition of the seed mix should also be carefully reviewed. While it is often impossible to obtain native, wild-collected seed which is certified weed free, every care should be taken to reduce the possibility of introducing undesirable or noxious species accidentally in the seed mix. The information needed for these evaluations is contained on the seed tag, which should always be saved in the permanent record.

Seed rate calculation:

Determine the desired number of seeds per square foot. In most cases this would be around 20. Where the seed is being broadcast and there are concerns about the ability to adequately cover it, this may be doubled.

Determine the desired percentages of the plants that make up the mix.

Determine the number of seeds per pound for each species in the mix. (From the Natural Resources Conservation Service [NRCS} or seed company references)

Multiply the desired number of seeds/square foot by the percent of that species in the mix to give the number of seeds of the species per square foot.

Multiply that product by 43560 (the number of square feet in an acre) to yield the number of seeds of that species per acre.

Divide that product by the number of seeds per pound for the species to get the number of pounds of that species per acre.

Multiply that result by the number of pounds of bulk seed required to yield one pound of pure live seed (PLS)

Repeat the process for each species in the mix.

Seed storage:

If seed is not immediately planted, it should be carefully stored under dark, low humidity, cool conditions. Seed viability decreases rapidly under improper storage conditions, especially when exposed to heat, high humidity, and rodent or insect pests. Some commonly used species, such as Winterfat and Kochia, have very short seed life, and should be planted the same season they are purchased.

Inoculation:

Most legume seeds should be treated with commercially available *Rhizobium* inoculants to ensure that they are able to make best advantage of their capabilities for nitrogen fixation. Other soil inoculations, as with soil fungi and microbes, may be of benefit, but this possibility has not been adequately tested on large scales, and there are many examples of successful revegetation on virgin growth media which have not received such inoculation.

Seeding methods and calibration of seeding rate

The most common revegetation methods include:

Broadcast seeding

Drill seeding

Aerial seeding

Hydroseeding

Transplanting

Timing of Revegetation Work:

Timing of revegetation is critical to the success of the work. In nearly all cases, including exploration disturbances, revegetation should occur as quickly as possible, in order to maintain soil nutrients, discourage weed invasion, and control erosion. In most areas of the arid west, reseeding and transplanting should be timed to coincide with the season of greatest precipitation. This often means fall or winter. If revegetation occurs too early, seeds are subjected to unnecessary exposure to seed predators and spoilage. If it occurs too late, seeds and plants may encounter insufficient moisture to germinate and survive, and will be faced with higher competition from annual invasive weeds. Careful planning is required to revegetate within the window of opportunity since site access and workability may deteriorate rapidly once seasonal precipitation begins.

Broadcast:

Broadcast seeding is the most versatile and inexpensive method of seeding most large mined sites. Provided that the surface has been properly roughened, usually by ripping, and that the seed is promptly covered, usually by dragging, excellent results can be cheaply obtained in a wide variety of environments.

Calibration of broadcast seeding rates is difficult to accomplish with precision. Methods involve either loading a known quantity of seed and applying it to a known area to adjust seed rate by trial and error, or by spreading sheets, tarps, or seed trapping sticky boards to determine seeding rate and need for adjustment.

Aerial:

Aerial seeding requires special equipment and is highly vulnerable to weather conditions. A disadvantage is that seed is not covered after application. Calibration of aerial seeding rates also involves trial and error as described above under broadcast seeding. Again, tarps or sticky boards may be used, but these should be colored and located as inconspicuously as possible to avoid human bias over visible calibration sites. The capture devices should be located on level or nearly level sites and in windless conditions. Mixers or agitaters are usually needed to prevent the seed mix from sorting and settling during operation.

Drill seeding:

Drill seeding covers the seed in one pass, and is therefore the most efficient method in terms of seed consumption. Drill seeding equipment is relatively expensive and is usable only on gentle terrain. Seed drills are calibrated by taping plastic bags to the seed tubes and then pulling the drill over a measured distance. The seeds collected in the bags are then counted or weighed to determine the seeding rate over the known distance. The drill is then adjusted as necessary to obtain the desired seeding rate. Because seed settles in the drill seeder during operation, some sort of agitater is often needed to maintain the original proportions of the seed mix. It is also difficult to distribute different sizes and forms of seeds unless multiple seed boxes and drills are available.

Hydroseeding:

Hydroseeding is problematic in arid environments because of the importance of seed/soil contact. In addition to suspending seed above the soil,the associated mulch wicks water away from the surface, increasing evapotranspiration. Problems associated with alterations of the carbon:nitrogen ratio may also occur. Many seeds are also damaged in transit through the pumping system. Where hydroseeding is practiced in arid areas, it should be done in two steps, with the seed being applied first without mulch, and the mulch applied after.

In wetter areas, hydroseeding may be practical, especially on steeper, erosion-prone slopes inaccessible to other equipment. The mulch type should be chosen with consideration of fertilization and biodegradability.

Transplanting:

Tubelings:

While expensive to purchase and plant, tubelings are a reliable method for the establishment of shrubs and trees. As with seeding, the planting time should coincide with the beginning of the moist season where possible. Plants must be acclimated to the site carefully before planting and should be from locally collected plant or seed material when possible. It is often necessary to protect the seedlings from rodents (by means of plastic or metal collars or sleeves) and from grazing. Fertilizer tabs or pellets may be added to the planting hole. Gas powered augers and digging bars are usually used to make planting holes.

Bare root seedlings:

These are the most cost-efficient materials for most transplanted species, but without very careful handling, survival rates may be very low. Planting should be done only in early spring, when soil temperatures approach 45 degrees F. Seedlings must be carefully acclimated on site, after storage in sealed paper bags at 32-33 degrees F. in high-humidity chambers. Acclimatization occurs on site, ideally in a sprinkler-equipped tent. Wet seedling roots are individually dipped in vermiculite, then jelly-rolled in bundles of fifty. The following day the bundles are placed in acclimatization boxes, such as fire camp beverage coolers, and moved to a shady place onsite. The jelly-rolled plants must be placed in the ground within 1\2 to one hour after removal from the boxes, so only one or two rolls should be carried at a time. Individual seedlings are removed from the rolls with care so that roots are not damaged, and are kept shaded while roots are positioned straight down in the planting hole, which is then carefully tamped around the roots.

Standards for release:

The criteria for evaluation of reclamation success and the standards for its release should be established early in the mining life cycle. These usually include final contours and slopes, identification of sources of growth medium, determination of the post mining land uses, selection of the post-mining plant community, and the identification of reference areas or standards for evaluation of vegetative cover. When possible, the plant community of the site before disturbance is often an appropriate reference for evaluation of reclamation success. Most common, however, are areas of adjacent undisturbed vegetation which support the post mining land use. Other reference areas may include test plots, successful concurrent reclamation, and in rare cases Ecological Site Indices or Range Site Descriptions. Data on perennial vegetative cover is collected from the reference site(s) or document and compared to the cover of the reclaimed site. For example, a release standard may state that the reclaimed community will include a diverse mix of shrubs, forbs, and grasses, with a minimum of 100% of the plant cover of the reference area and statistical assurance that the sampling was adequate to ensure 90% confidence that the sample mean is within 10% of the true mean of the sampled area.

Monitoring/statistical adequacy:

There are a variety of methods for quantification of vegetation. These are well described in the Interagency Technical Reference Sampling Vegetation Attributes (BLM/RS/ST-96/002+1730, 1996). In shrublands, the most reliable and easiest method is generally the line intercept method, which provides quantification of vegetative cover. Line point methods are less reliable, unless cumbersome and expensive frames or laser point projectors are used, and these require far larger sample sizes to achieve the required accuracy. Density counts are used in forested areas, or where information about the actual number of plants is required in special cases, such as number of tree seedlings established on a site to be reforested.

Federal regulations require that sampling be adequate to ensure that on shrublands the sample estimate is 80% certain to be within 20% of the true mean of the vegetation parameter measured. On grasslands, this is increased to 90% certainty that the estimate is within 10% of the true mean. The required number of samples to obtain this level of confidence is easily obtained via the equation given below. Typically about five or six line intercepts are done, then the initial results are plugged into the equation to determine the final number of samples needed. CAUTION: If only a couple of initial samples are done, the equation will indicate a grossly inflated number of samples required.

An equation to determine sample adequacy-

$N = (t^2 s^2) / (\text{mean of samples X } 0.2)^2$

Where: N = required number of samples

t = the value from the t distribution (t table) for (n-1) degrees of freedom and alpha = .80

s = the standard deviation of the preliminary samples

The equation can be adjusted for other confidence levels as follows:

To change the probability of 80% certainty, use the appropriate alpha level from the t table. To change the probability of being within 20% of the true mean, change the .2 in the equation appropriately e.g to 0.1 for 90% certainty, or .05 for 95% certainty. In normal shrublands, no more than 7 samples are usually required to achieve sample adequacy.

The vegetation of the reclaimed area is then expressed as a percentage of the reference area or description vegetation to determine whether the standard has been met.

Documentation:

At a minimum, the following information should be collected on revegetation work. If not available at the conclusion of reclamation, the determination of bond release, adequacy of work, cost, and reasons for possible failure will be difficult or impossible.

Earthwork:

- Number of acres scheduled for revegetation
- Number of acres regraded and method
- Final slope angles and aspects after regrading and method of determination
- Number of acres receiving topsoil, growth medium, fertilization, soil amendments, etc.

- Depth and source of topsoil/growth medium and method of application.
- Results of any soil analysis/observations, especially salinity, pH, boron, selenium

Revegetation:

Number of acres reseeded or planted

Seed bed preparations used

Seeding/planting methods

Seed Mix and seeding rate (PLS)

Seed source

Seed tags from all seed lots

Date of reseeding and other activities, including seed bed preparation, irrigation, fertilization, mulching

Revegetation monitoring and sampling:

Location and/or description of reference area or other reference

Sampling method

Number of samples taken on revegetated and reference sites

Statement of methodology including sample size, statistical adequacy of samples, determination of location of sample points.

Records of sampling for revegetated and reference sites, including all perennial species and weed data.

Sampling dates and names of samplers.

Typical mistakes: Certain mistakes in revegetation are common enough to list here. They include:

Using salty, silty, and/or hydrophobic soils because they were the top layer at the site.

Lack of record keeping during all phases of revegetation

Using very dark soils on sites and aspects which overheat during the growing season

Inadequate roughening of growth medium prior to seeding

Failure to promptly cover broadcast-seeded areas

Improper seed storage

Inappropriate timing of seeding

Failure to control livestock trespass

Unwarranted addition of nitrogen fertilization, mulches.

Inadequate regrading of slopes

Inappropriate choice of seedmix components

Lack of sufficient fine materials in growth medium

Inadequate marking of seeding sites

Failure to conduct early test plot trials

Special problems:

Allelopathy/competition:

Some commonly used species inhibit the germination and growth of other species either by direct competition (e.g. Crested wheatgrass) or by chemical processes (barley, sagebrush). Even in concentrations as low as 10% in a seedmix, crested wheatgrass may greatly reduce the establishment of other species. Therefore the use of highly competitive or allelopathic species should be carefully considered before inclusion. Annual cover crops, such as grains and other annual grasses, should be used only where there is a need for immediate vegetative establishment, or where they will be tilled into the surface before planting with perennial species. Most grain crops also persist by seed for several years, and frequently attract birds and rodents which hamper the establishment of a longterm perennial plant community.

Fire-prone communities

Where wildfire is anticipated, it is important to make every effort to control the establishment of fire-prone annuals. This involves immediate establishment of perennial plants to preclude establishment of weeds. The selection of perennial species may either include less flammable species such as bunchgrasses and forbs, to retard fire, or species that are resilient to fire and will quickly resprout from roots or crowns after fire, such as many grasses and shrubs. Local fire and conservation authorities should be consulted to determine which strategy is appropriate, and which locally adapted species might be used.

Weeds (noxious vs obnoxious) (Persistent vs temporary)

Weeds are very common invaders of disturbed sites in most mining areas. Noxious weeds are a special case legally designated species for which control efforts are mandated. (See the Weeds chapter). Lists of designated noxious weeds for each state are widely available. Reclamation sites should be carefully monitored for their presence, since control is difficult or impossible once they become established. Most problem weeds are annual species. If the growth medium source supports large numbers of these, direct hauling to the final use site should be avoided, since the seeds present in the medium will quickly establish. In most cases, weeds are only a temporary problem provided that the site is seeded immediately, (before a growing season has elapsed) with competitive perennial species. Even though the weeds may appear to dominate the site, the perennial species will establish and out compete them within two or three seasons. The addition of nitrogen fertilizer will greatly favor most annual weeds and may delay or preclude the establishment of desirable perennial vegetation. If disturbed sites are not immediately replanted, weeds may establish to the point where revegetation must be preceded by mechanical or chemical elimination of weeds and their seeds.

Sagebrush

Unlike most reclamation species, sagebrush seed must be applied on top of growth medium without covering. Thus where it is a component of a seed mixture, it is applied in a second pass, after other seed has been broadcast and dragged. Due to major losses of sagebrush habitat and associated wildlife in recent years, restoration of sagebrush is a high priority in many areas. Another method of

Roads and Dust Palliatives:

Problems associated with roads include steep cut/fill slopes, compaction, and compounds such as magnesium chloride applied to reduce dust. Roads, especially haul roads, require deep and careful ripping before application of growth medium. Cut and fill slopes need to be regraded to 2.5 or 3:1 to ensure stability and establishment of plants. Dust control compounds, especially chloride based rather than organic, may require either a deep layer of growth medium or establishment of salt tolerant species.

Heaps:

Leach heaps pose several problems for revegetation, due to their engineered porosity and residual levels of nitrogen, and in some cases salts. After regrading, heaps may require application of a relatively impermeable liner of clay or other barrier, followed by rock and as much growth medium as is available. Since the plants will be constrained by the barrier and rock from establishing roots deeply, the quality and quantity of growth medium is important. Where it is not important to restrict the input of meteoric water into heaps, they have been successfully revegetated with regrading and application of a thinner layer of growth medium, after which they are drill or broadcast seeded. The use of vegetation to intercept meteoric water by design has several as-yet unresolved problems. One is that most arid species are capable of developing deep root systems which will eventually penetrate the liner material and establish pathways for infiltration. Depending on the climate, plants may not be actively transpiring water during the precipitation season. Permanent fencing may be required to prevent overgrazing and subsequent plant removal. Wildfire may remove the vegetation at any time, or convert the community to annual species with little potential for long term evapotranspiration.

Tailings:

Due to their fine texture and frequent metal contamination, tailings typically require armoring with rocky material before application of growth medium and seeding. They may also pose problems for adjacent vegetation, since wind erosion may Asandblast@ plants. The use of plants tolerant of sandy conditions may be considered for either interim or final stabilization of heaps where metal and salt contamination is not problematic. Addition of limestone or acidifying agents may be needed to adjust pH to levels tolerated by plants.

Sandy sites:

Wind erosion and lack of moisture retention require the use of species specially adapted to sandy conditions. These include shrubs, forbs, and grasses. Wind may also transport sand to the detriment of vegetation, either by burying or exposing it, or by abrading stems and leaves. In such cases, it may be necessary to armor the site and apply a more stable growth medium before vegetation can be established.

Saline sites:

Highly saline sites greatly restrict revegetation options. Irrigation may also concentrate salts in the growth medium by evaporation. In such cases, a rock barrier layer and application of a non-saline growth medium may allow establishment of vegetation. Where this is not feasible, options are limited to the use of salt-tolerant vegetation. In general, electroconductivity (EC) values of 8 millimhos/cm or higher require careful choice of species. Above 12, only a few halophytic species may be usable.

High elevation sites:

Harsh climatic conditions and short growing seasons complicate revegetation of high-elevation disturbances, but there are typically a number of locally adapted perennial species suitable for use. Mulches may be used to improve the microclimate and stabilize the surface, but great care must be taken to ensure that the material is free of weed seeds or other undesirable plant material. Best results at such sites often come from transplanting appropriate plant material, especially those shrubs, forbs, and grasses which have a mat or cushion growth form and spread vegetatively, rather than exclusively by seed, to stabilize the surface.

Acidic sites:

Although there are reclamation species tolerant of acidic conditions, sites with pH of 6 or lower may require either isolation or neutralization of the growth medium if vegetation is to be established.

Wind effects:

Where wind erosion is expected, vegetation may be used to stabilize the surface and reduce particle transport. However, it is important to either select plant material adapted to sandy, unstable, well drained conditions, or to apply growth medium more suitable to plant growth. Wind scour may also damage or destroy vegetation, even if the particles originate on adjacent sites. Burying or exposure of plants by drifting is also common, and may require the use of drift fences to prevent.

Cryptogamic crusts:

These are crusts, typically on silty arid soils, which are composed of lichens, mosses, fungi, algae, and bacteria. Little is known of their role in nutrient cycling, but they are extremely valuable in the prevention of wind erosion in many arid areas. They are extremely sensitive to disturbance, especially crushing and trampling. Techniques for their re-establishment are still in infancy, but center around the collection of them from intact sites and respreading of them in disturbed areas.

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CHAPTER 15. NOXIOUS WEEDS

A. INTRODUCTION:

The following is a list of management actions that can be pursued by BLM Solid Minerals Reclamation in the effort to control invasive plants. Many of them are relatively easy to implement and are preventive in nature. Most of these came from various states' weed prevention schedules which most programs in the BLM probably are not aware of.

B. MANAGEMENT OPTIONS:

1. Include noxious weed prevention and control in all right-of-ways, leases or permits, and acquisition. Benefitting party will be financially responsible for monitoring and controlling weeds. Consider bond requirement to ensure weed control is accomplished.

2. Assure permits that involve soil-disturbing activities have provisions for sanitizing equipment prior to entering BLM lands.

3. Evaluate all potential acquisitions for noxious weeds.

4. Inspect gravel pits and fill sources regularly to identify weed infestations and sources of weed-free fill. Treat as necessary.

5. Require certified weed-free seed and mulch in site reclamations, include followup monitoring.

6. Retain bonds for weed control until the site is returned to desired vegetative conditions. Require weed control plan be part of surface restoration plan. Ensure company submits Pesticide Use Proposal to BLM if herbicides are going to be used.

7. Keep active road construction sites which are in relatively weed free areas at moderate or high-ecological risk to weed invasion, closed to vehicles that are not involved with construction.

8. Have BLM project inspectors check to be sure noxious weed-free seed is being used by contractors for all reclamation work; check seed bag label.

9. Require all heavy equipment be cleaned of soil, seed, etc. before moving into project area, then again before leaving project area.

CHAPTER 16. WIND

A. INTRODUCTION:

The driving force of wind increases as the square of wind velocity. Wind effects from this force can degrade reclamation efforts during and after reclamation. Wind effects also include loss of stockpiled soil for reclamation cover. Effects are most pronounced with silt or silty soil. With such material in a dry state, soil movement in the form of dustiness may become noticeable with as little as 10 mph winds. Gustiness can increase movement dramatically. Vehicle and machinery movement can initiate dustiness and airborne soil movement in lesser winds. If susceptible material is non-uniform in size erosive wind action will decrease with time. Windiness increases transpiration and dessication.

B. MECHANICAL REMEDIES TO LESSEN WIND EFFECTS:

1. Cover with clayey, sandy or loamy soil (permanent),

2. Cover with gravel or rock (temporary or semi-permanent),

3. Crimp straw into surface (temporary),

4. Mulching (temporary),

5. Furrow across prevailing wind (temporary),

6. Erect plastic snow fence across prevailing wind, preferably in multiples (temporary) or

7. Water or chemically treat (polymers) roads and vehicle movement areas (brief or temporary).

C. BIOLOGICAL REMEDIES TO LESSEN WIND EFFECTS:

1. Soil pile revegetation with grass (temporary),

2 Plant pioneer species which may include non-propagating or non-invasive exotics (temporary Or permanent) or

3. Establish grass or shrub windbreaks upwind of germinating surfaces (permanent).

D. THINGS TO CONSIDER:

1. Standard windbreaks are linear or single crescent design. Better protection and more natural appearance results from using a multiple crescent design.

2. Maximum wind speed occurs on ridge crests, open flat areas and occasionally in canyons. Rock or grass cover usually works effectively on ridge crests. Most options are usable on flat areas and low angle canyon areas.