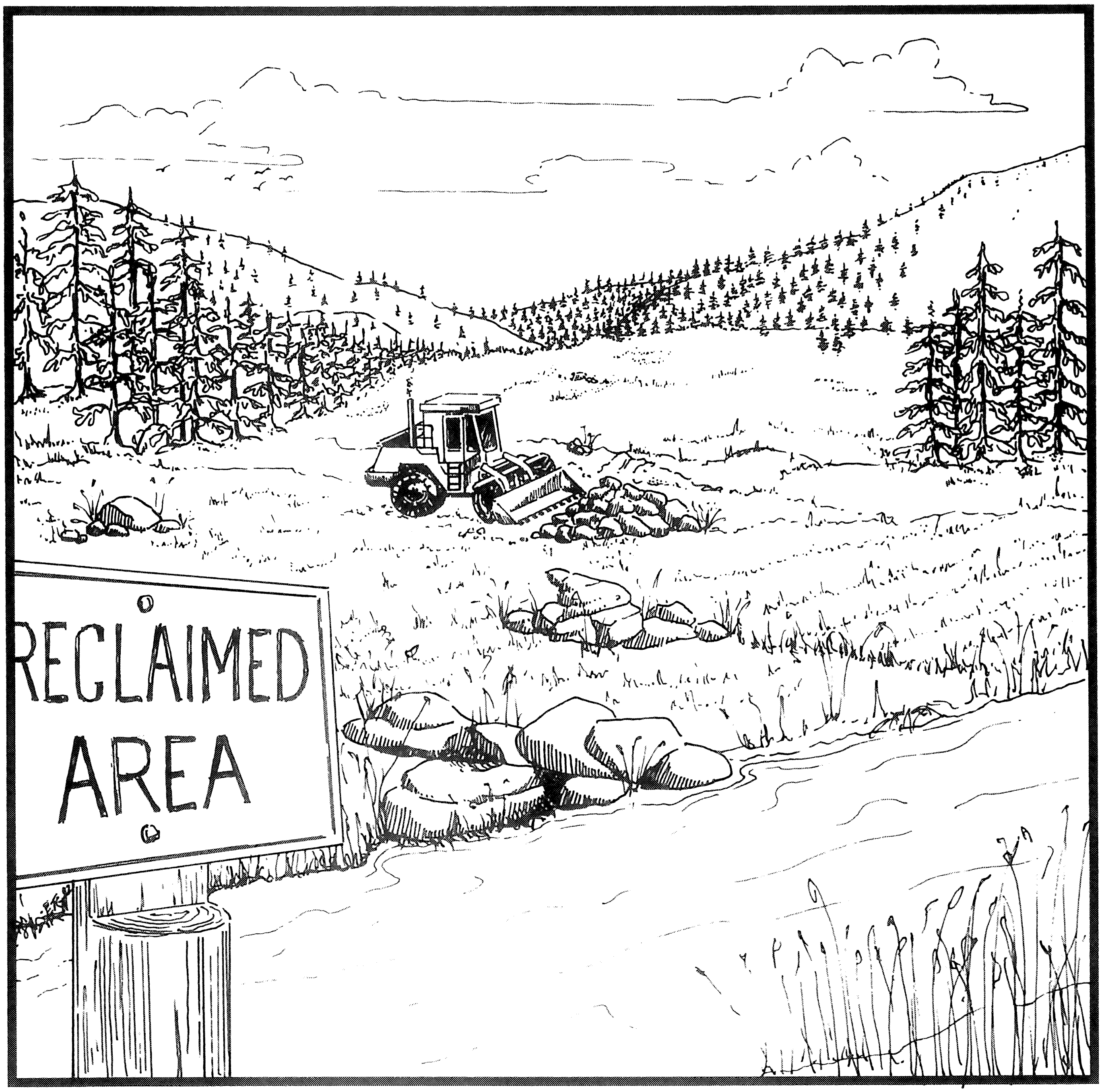
U.S. Department of the Interior
Bureau of Land Management
Solid Minerals Reclamation Handbook



noncoal leasable minerals, locatable minerals, salable minerals

BLM Manual Handbook H-3042-1

H-3042-1 - SOLID MINERAL RECLAMATION

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Form 1221-2
(June 1969)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

MANUAL TRANSMITTAL SHEET

Release	3-275
Date	2/7/92

Subject

H-3042-1 Solid Mineral Reclamation Handbook

1. Explanation of Materials Transmitted: This release transmits a new Handbook on the above subject. This handbook contains the nationwide guidance for solid mineral reclamation on Federal and Indian lands.

2. Reports Required; None.

3. Material Superseded: None.

4. Filing Instructions: File immediately after Manual Section.

REMOVE:	INSERT:
None	H-3042-1
	(Total: 112 Sheets)

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Energy and Mineral Resources

I. INTRODUCTION

A. BACKGROUND AND GENERAL INTRODUCTION

Multiple-use management is the central concept in the Federal Land Policy and Management Act of 1976 (FLPMA). 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."

Therefore, it is a statutory mandate that BLM ensure that reclamation and closure of mineral operations be completed in an environmentally sound manner. To accomplish this task, it is necessary to establish nationwide standards as a basis for development of site-specific reclamation requirements. The BLM professionals who establish site-specific requirements based on these nationwide standards, review reclamation plans and conduct inspection and enforcement on mineral operations will use these guidelines to judge the adequacy of the proposed and performed reclamation activities. In addition, they will inform operators of the standards by which their reclamation efforts will be judged.

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).

The BLM is providing in this H-3042-1 handbook, reclamation information and guidance that is readily available and applicable to various situations and conditions. The BLM's long-term reclamation goals are to shape, stabilize, revegetate, or otherwise treat disturbed areas in order to provide a self-sustaining, safe, and stable condition that provides a productive use of the land which conforms to the approved land-use plan for the area. The short-term reclamation goals are to stabilize disturbed areas and to protect both disturbed and adjacent undisturbed areas from unnecessary or undue degradation.

The purpose of this handbook is to provide consistent reclamation guidelines for all solid non-coal mineral activities conducted under the authority of the BLM minerals regulations in Title 43 of the CFR. The intent is to provide the user with clear guidance which highlights a logical sequence for managing the reclamation process and a summary of key reclamation principles.

B. AUTHORITIES

This handbook provides consistent reclamation guidelines for all surface-disturbing activities conducted under the authorities and implementing regulations listed in BLM Manual Section 3042. These authorities govern the exploration, development and mining of noncoal solid minerals as well as reclamation of lands disturbed as result of such operations. Additional State and Federal environmental statutes and regulations also provide authority for specific reclamation and mitigation requirements.

This handbook addresses reclamation for operations conducted under the provisions of the regulations at 43 CFR Group 3500 for the solid leasable minerals other than coal; 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.

Because of differences in the statutory authority granted the Secretary of the Interior and delegated to the Director of the Bureau of Land Management, the guidance in this handbook does not apply uniformly to all noncoal solid mineral operations on public lands. These differences are noted where they exist, and specific programmatic guidance in other BLM manuals and handbooks are cited as cross-references, where applicable. In most cases, the technical procedures are applicable to all types of operations, regardless of the authorizing authority.

C. POLICY

The policy governing land reclamation is set forth in numerous BLM Manual Sections. Of special note are Manual Sections 3042, 3590, 3600 and 3809.

D. RECLAMATION STANDARDS

The required reclamation standards shall not conflict with the Resource Management Plan, the Management Framework Plan, or other land use planning document objectives. An interdisciplinary approach shall be used to analyze the physical, chemical, biological, climatic, and other site characteristics and make recommendations for the reclamation plan. Where appropriate, consider the early development of test plots to determine the best local procedures and practices for revegetation. Revisions of the reclamation standards themselves may be made only with the consent of the operator. In order for a disturbed area to be considered properly reclaimed, the following must be complied with:

1. Waste Management. All undesirable materials (e.g. toxic subsoil, contaminated soil, drilling fluids, process residue, refuse, etc.) shall be isolated, removed, or buried, or otherwise disposed as appropriate, in a manner providing for long-term stability and in compliance with all applicable State and Federal requirements.

a. The area shall be protected from future contamination resulting from an operator's mining and reclamation activities.

b. There shall be no contaminated materials remaining at or near the surface.

c. Toxic substances that may contaminate air, water, soil, or prohibit plant growth shall be isolated, removed, buried or otherwise disposed of in an appropriate manner.

d. Waste disposal practices and the reclamation of waste disposal facilities shall be conducted in conformance to applicable Federal and State requirements.

2. Subsurface. The subsurface shall be properly stabilized, holes and underground workings properly plugged, when required, and subsurface integrity ensured subject to applicable Federal and State requirements.

3. Site Stability.

a. The reclaimed area shall be stable and exhibit none of the following characteristics:

(1) Large rills or gullies.
(2) Perceptible soil movement or head cutting in drainages.
(3) Slope instability on or adjacent to the reclaimed area.

b. The slope shall be stabilized using appropriate reshaping and earthwork measures, including proper placement of soils and other materials.

c. Appropriate water courses and drainage features shall be established and stabilized.

4. Water Management. The quality and integrity of affected ground and surface waters shall be protected as a part of mineral development and reclamation activities in accordance with applicable Federal and State requirements.

a. Appropriate hydrologic practices shall be used to protect and, if practical, enhance both the quality and quantity of impacted waters.

b. Where appropriate, actions shall be taken to eliminate ground water commingling and contamination.

c. Drill holes shall be plugged and underground openings, such as shafts, slopes, stopes, and adits, shall be closed in a manner which protects and isolates aquifers and prevents infiltration of surface waters, where appropriate.

d. Waste disposal practices shall be designed and conducted to provide for long-term ground and surface water protection.

5. Soil Management. Topsoil, selected subsoils, or other materials suitable as a growth medium shall be salvaged from areas to be disturbed and managed for later use in reclamation.

6. Erosion Prevention. The surface area disturbed at any one time during the development of a project shall be kept to the minimum necessary and the disturbed areas reclaimed as soon as is practical (concurrent reclamation) to prevent unnecessary or undue degradation resulting from erosion.

a. The soil surface must be stable and have adequate surface roughness to reduce run-off, capture rainfall and snow melt, and allow for the capture of windblown plant seeds.

b. Additional short-term measures, such as the application of mulch or erosion netting, may be necessary to reduce surface soil movement and promote revegetation.

c. Soil conservation measures, including surface manipulation, reduction in slope angle, revegetation, and water management techniques, shall be used.

d. Sediment retention structures or devices shall be located as close to the source of sediment generating activities as possible to increase their effectiveness and reduce environmental impacts.

7. Revegetation. When the final landform is achieved, the surface shall be stabilized by vegetation or other means as soon as practical to reduce further soil erosion from wind or water, provide forage and cover, and reduce visual impacts. Specific criteria for evaluating revegetation success must be site-specific and included as a part of the reclamation plan.

a. Vegetation production, species diversity, and cover (on unforested sites), shall approximate the surrounding undisturbed area.

b. The vegetation shall stabilize the site and support the planned post-disturbance land use, provide natural plant community succession and development, and be capable of renewing itself. This shall be demonstrated by:

(1) Successful onsite establishment of the species included in the planting mixture and/or other desirable species.

(2) Evidence of vegetation reproduction, either spreading by rhizomatous species or seed production.

(3) Evidence of overall site stability and sustainability.

c. Where revegetation is to be used, a diversity of vegetation species shall be used to establish a resilient, self-perpetuating ecosystem capable of supporting the post-mining land use. Species planted shall include those that will provide for quick soil stabilization, provide litter and nutrients for soil building, and are self-renewing. Except in extenuating circumstances, native species should be given preference in revegetation efforts.

d. Species diversity should be selected to accommodate long-term land uses, such as rangeland and wildlife habitat, and to provide for a reduction in visual contrast.

e. Fertilizers, other soil amendments, and irrigation shall be used only as necessary to provide for establishment and maintenance of a self-sustaining plant community.

f. Seedlings and other young plants may require protection until they are fully established. Grazing and other intensive uses may be prohibited until the plant community is appropriately mature.

g. Where revegetation is impractical or inconsistent with the surrounding undisturbed areas, other forms of surface stabilization, such as rock pavement, shall be used.

8. Visual Resources. To the extent practicable, the reclaimed landscape should have characteristics that approximate or are compatible with the visual quality of the adjacent area with regard to location, scale, shape, color, and orientation of major landscape features.

9. Site Protection. During and following reclamation activities the operator is responsible for monitoring and, if necessary, protecting the reclaimed landscape to help ensure reclamation success until the liability and bond are released.

10. Site Specific Standards. All site-specific standards must be met in order for the site to be properly and adequately reclaimed.

II. 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 reclamation methodology and expected reclamation condition of the disturbed lands and should be periodically reviewed and modified as necessary.

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.

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. SURFACE DISTURBING ACTIVITIES

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

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

Exploration 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.

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Development and mining or mineral processing 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 authorizations.

TABLE II-1
Summary of Activities and Authorizations

SURFACE-DISTURBING ACTIVITY	LOCATABLE AUTHORIZATION	SOLID LEASABLE AUTHORIZATION	SALABLE AUTHORIZATION
Prospecting	Generally casual use, no BLM authorization (43 CFR 3809.1-2)	Generally casual use, no BLM authorization	Generally casual use, no BLM authorization
Exploration	3809 Notice sent to BLM 15 days before starting operations of 5 acres or less-no BLM authorization (43 CFR 3809.1-3). Approved Plan of Operations for greater than 5 acres or "special areas" (43 CFR 3809.1-4). Plan generally required in Wilderness Study Areas (43 CFR 3802.1-1). Bonds are required for Plans of Operations, not for Notices. See current 3809 bonding policy.	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)
Mining or Milling	Same as Exploration. See current 3809 bonding policy.	43 CFR Part 3590 covers operations. The AO must approve mining 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).

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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 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.

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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.

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 and issue a decision.

III. INSPECTION AND ENFORCEMENT

A. INTRODUCTION

The requirements of the reclamation plan and the appropriate regulations are enforced through regular inspections of the operation, both 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 shall 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 the applicable laws, regulations, terms and conditions of leases, licenses, or permits, 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 shall determine whether unnecessary or undue degradation of the land is occurring and the AO shall take appropriate enforcement action when such determination is made.

Field personnel shall 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, allow for oversight of the adequacy of the resources dedicated to I&E, and avoid the use of unqualified personnel for I&E functions. A variety of disciplines may be needed to conduct inspections of reclamation activities, e.g., engineers, geologists, hydrologists, soil scientists, 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 for:

1. Determining whether the operation is in compliance with the reclamation plan and other established requirements.

2. Determining whether concurrent reclamation, as planned, is taking place.

3. Identifying deficiencies in the reclamation plan and recommending appropriate modifications to the operator.

4. Identifying any noncompliance.

5. Taking appropriate enforcement action if noncompliance is identified.

6. Monitoring reclamation success and completion.

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

BLM personnel shall observe plugging of underground mine portals in front of the seals to assure that openings are properly plugged. Similar observation should 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 shall 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 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 surface and underground mining operations; and shall 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 may be worn during inspections, as appropriate. Other protective clothing and equipment shall be worn when necessary.

If possible, inspections shall 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 shall 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) shall 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 shall be issued by the authorized officer. A continuing violation shall 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 shall undertake proceedings to cancel the lease, license, or permit. Any required enforcement action involving Indian lands shall 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 shall be issued if the operator does not correct the violation after consultation. If the operator fails to take action following the NON, the AO shall 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 shall 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 shall issue a trespass notice. If the violation involves a failure to reclaim or meet other stipulations, a NON shall be issued. Failure to comply with the NON or trespass notice shall 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 may 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 shall 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, shall 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 shall 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 shall submit a written report to the AO. Upon concurrence by the authorized officer that the noncompliance has been corrected, the operator shall 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 or accidents causing 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 shall 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 shall 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 shall 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 shall 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 should 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 should 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 shall 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 shall 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 shall recommend that the appropriate period of bonded liability be terminated.

IV. RECLAMATION OF SITE ACCESS

A. INTRODUCTION

Roads, railroads, and other types of site access are common to virtually all phases of mineral development. Careful consideration of the access requirements is crucial to a thorough analysis of any proposal. Access can often be one of the major surface impacts related to exploration and mining activity.

B. TRANSPORTATION AND TEMPORARY EXPLORATION ACCESS

1. Roads

Determine before construction if the road is to be retained or reclaimed. The road construction method determines the amount of disturbance which needs to be reclaimed. Consult Bureau Manual Section 9113 for road construction guidelines for all roads, especially those which will be retained and incorporated into the Bureau road network.

2. Road Location and Construction Guidelines

a. Access routes should be planned for the minimum width needed for safe operations and should follow natural contours where practicable, to minimize cut and fill. If suitable for reclamation purposes, excess material from cuts should be appropriately stockpiled. Salvage topsoil during construction, and store uphill if possible.

b. Select routes which minimize surface disturbance. Use existing access where appropriate to minimize surface disturbance. Criteria considered during route location should reflect concerns discussed in the RMP or other land-use planning documents.

c. Select routes which are stable and dry. When wet areas cannot be avoided, consider the use of geotextiles, mattes, planking, or rock to improve the subbase and minimize rutting and erosion.

d. Avoid sustained grades greater than 10 percent and side slopes greater than 45 percent. Short sections of steep grade may be preferable to long sections of low grade in some locations. Ridgeline and contour roads provide the flattest slopes.

e. Drainage structures or energy dissipators should be used where appropriate on all roads. Use filter windrows at the bottom of cut and fill slopes to help limit erosion. Use design storm events as described in Chapter VII of this handbook.

f. When possible avoid areas where snow drifts stay late into the spring. These areas may be unstable and difficult to revegetate.

g. Where roads cross intermittent drainages, dips in the roadbed may be used to allow drainage across the road.

h. Most roads should be crowned and include ditches or sloped roadbeds. See Figure IV-1.

i. Fill and cut slopes shall be constructed to ensure slope stability and erosion control. Maintain a sufficient distance from the toe of the fill to streams depending on hillside slope and anticipated maximum stream flow. Placement of fill in excess of two feet to construct roads or other earthen structures shall be compacted in accordsnce with acceptable geotechnical and civil engineering standards and practices.

3. <u>Road Reclamation Guidelines</u>

a. Remove all surfacing (i.e. pavement) from the road surface.

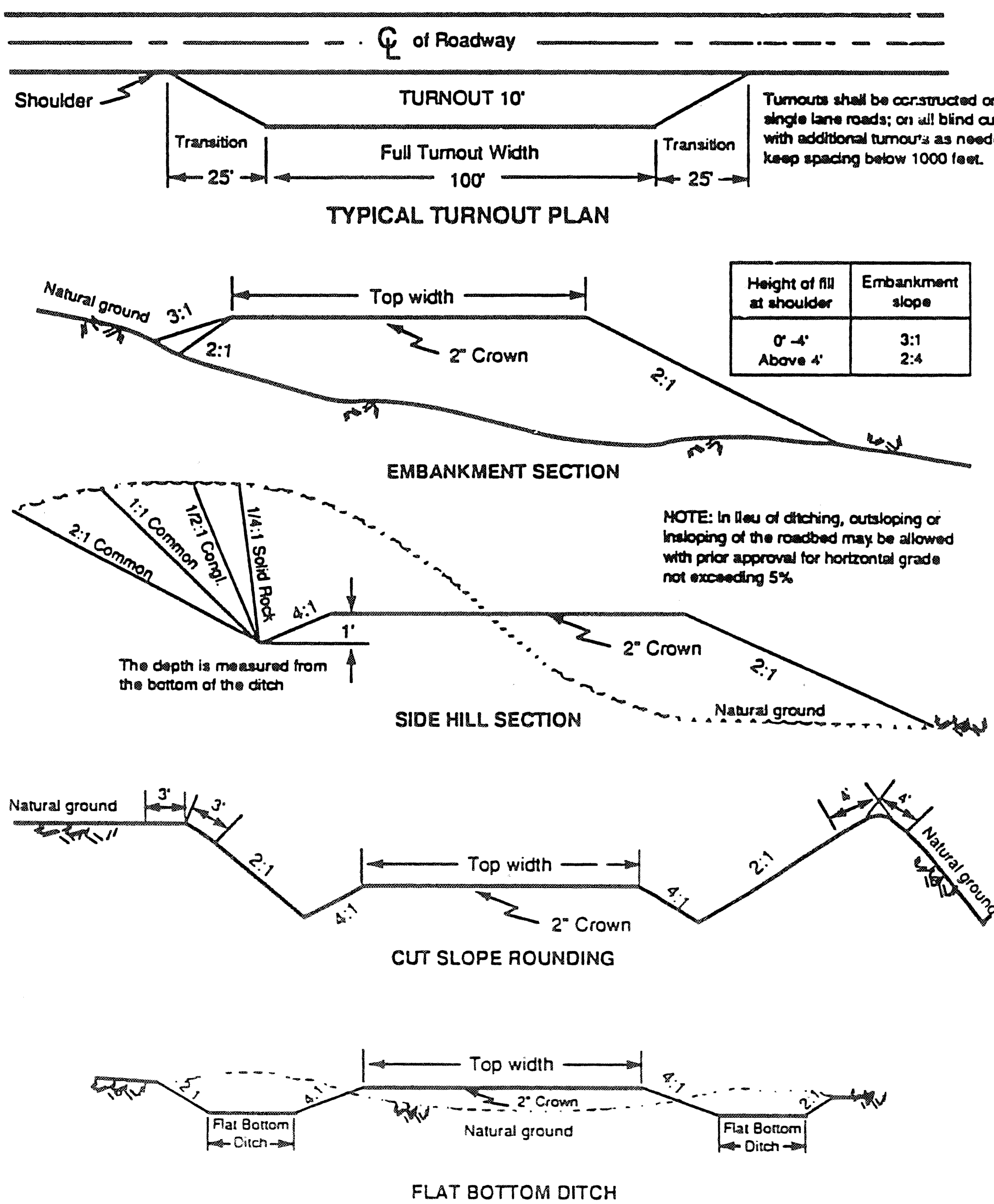
b. If roads are to be utilized for more than one year, mulching and seeding of cut and fill slopes should be completed immediately after disturbance to control erosion and establish vegetative cover. Seed types, fertilizer, and rates of application can be found in the revegetation section.

c. Remove culverts and restore drainage to its pre-disturbance configuration.

d. Shape roads and associated disturbance in conformance with the reclamation standards included in this handbook and Manual Section 3042.

e. Roads should be ripped to reduce compaction.

Figure IV - 1
Typical Road Section



f. Shaping and grading can range from only outsloping the road surface to full restoration of the disturbance to the original contours. At the minimum, pull the berm back into the road prism, outslope the road surface, spread topsoil or other suitable growth medium, and scarify the surface prior to revegetation.

g. On wide roads where a travelway is to be retained, locate it on the outside portion of the existing road and reclaim the remaining road width.

h. Mitigate the visual impacts whenever possible by reducing the cutslopes and introducing trees or shrubs to the reclaimed road sites. Consider hydromulching cut slopes to reduce the long term visual impacts.

C. <u>EXPLORATION ACCESS</u>

1. <u>Location Guidelines</u>

Use existing access or consider cross country travel whenever possible. Where there is no existing access, use the following guidelines:

a. Follow natural terrain wherever possible to minimize cut and fill.

b. If access is located in dry intermittent drainage way, do not alter the drainage way so as to impede free drainage. Do not channelize drainage way.

c. Keep side cast material as far as possible from perennial water and riparian zones (seeps, springs, etc.). Sidecast material should not be placed in ephemeral or intermittant drainages.

d. Crossing perennial water should be discouraged, however, if necessary, BLM should work with the operator to develop guidelines for each water crossing on a site-specific basis.

e. For exploration access, a minimum of center line staking and on-site examination prior to construction is required.

f. The management of surface water drainage shall be addressed for all roads constructed on public lands.

2. Reclamation Guidelines

When post-exploration alternatives permit, exploration access should be stabilized and conditioned for those alternative uses. Exploration access roads which will not be a part of post-exploration use should be reclaimed in a timely manner. Exploration-related roads should be completely reclaimed when no longer necessary.

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 uses.

V. RECLAMATION OF DRILLING OPERATIONS

A. INTRODUCTION

Many types of exploration activities have the potential for significant impact on the surface and other resources. As a part of the required plan, notice or license, the operator must include provisions for reclamation and abandonment of drill holes, drill pads, and other surface and subsurface disturbances created by the exploration activity. Specific requirements for reclamation of exploration activities must acknowledge and consider that activities conducted in areas which will be mined within one year may need minimal reclamation.

Drill holes and other excavations for exploration, development, or prospecting must be completed in a manner consistent with applicable state and Federal regulations. Methods of reclamation shall be approved in advance by the AO in a reclamation plan, and may include backfilling, regrading, revegetation, cementing or other plugging, and capped casing, or combinations of these, or other methods, as applicable.

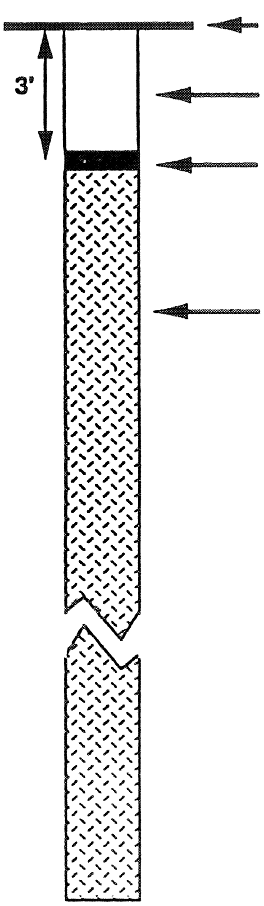
B. DRILL HOLES

The proper abandonment of drill holes will be achieved when (1) all aquifers are adequately cemented or otherwise isolated to prevent the migration of liquids or gases, (2) the surface hole is properly plugged to prevent injury to the public, livestock, and wildlife, and (3) the surface is properly cleaned up and reclaimed according to the approved reclamation plan.

All holes drilled for the purpose of mineral exploration should be plugged, sealed or capped in a manner consistent with the state regulations. These activities must be conducted in order to prevent adverse changes in ground water quality or quantity. Capping of the drill holes shall be designed to ensure the safety of people, livestock, wildlife, and machinery in the area. In the absence of state requirements, or when state requirements are less stringent, the standards in this chapter apply.

If water is not encountered, plugging, sealing, or capping will not be required if development of a mine or a mine expansion occurs within one year of the drilling activity. However, the hole must be securely covered in a manner which will prevent injury to persons or animals, or damage to equipment and generally filled with cuttings or drilling mud. See Figure V-1.

Figure V-I
Drill Hole Plugging Requirements When No Water Is Encountered



Guildelines

1. Backfill hole with cuttungs or bentonite gravel to 3' below ground level.

2. Install a non-metallic plug with approved company identification.

3. Backfill and tamp final 3' with cuttings or use cement plug.

4. Spread excess cuttings to no more than 1" above original ground level.

If static water is encountered a preferred method is to fill the hole to the surface with bentonite pellets. Any bentonite drilling muds used to seal exploration drill holes must meet the following specifications, as provided in the latest edition of the American Petroleum Institute (API) Standard Procedures for Testing Drilling Fluids: 1) ten minute gel strength of at least 20 lbs./100 sq. ft., and 2) filtrate volume not to exceed 13.5 cc. If the drill rig is no longer on the site when the hole is plugged, the use of bentonite gravel is a suitable alternative. See Figure V-2.

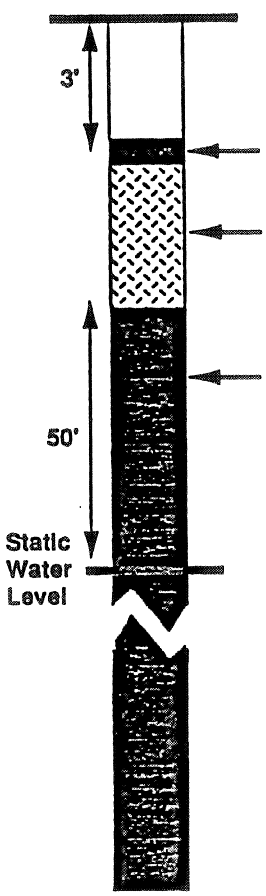
If artesian water is encountered, the hole should be plugged to the surface with cement meeting API standards. Alternatively, bentonite may be used to plug the hole if it is able to contain the flow of water. See Figure V-3.

Drill holes for development which will not be mined through within the next 12 months shall be abandoned to the satisfaction of the AO by methods approved in advance by the AO and in a manner to protect the surface and, for leasable minerals, not to endanger any present or future underground operation or any deposit of oil, gas, other mineral substances, or water strata. In all cases, the AO must have for the records a sketch or description of the actual plugging procedure used.

If there are no state requirements, at a minimum, aquifers and mineralized zones within 500 feet of the surface should be cemented 50 feet above and below and through the zone. All aquifers and mineralized zones greater than 500 feet in depth need to be cemented through and 100 feet above and below the zone. These are minimum standards and may be increased by the AO as necessary by local conditions to include total cementing from the surface to total depth, as in the case of mineral deposits that are soluble in water. See Figure V-4

At a minimum, all drill holes to be permanently abandoned require a 3-foot cement surface plug. In cultivated fields, the top of the surface plug may be set 2 feet below the surface and backfilled with compacted earth. For future reference, a brass or aluminum plug with identifying hole number and company name or initials or some other permanent marker set in the cement is desirable. See Figure V-5.

Figure V-2
Drill Hole Plugging Requirements When Static Water Is Encountered



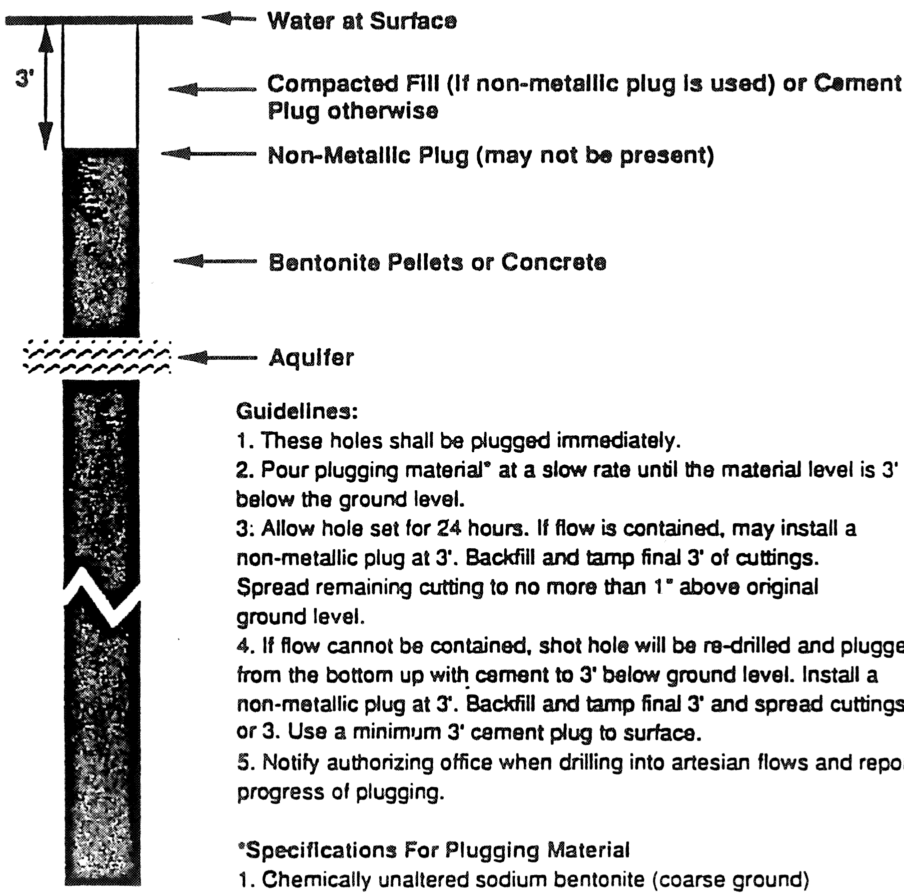
Guidelines:
1. Place plugging material* from bottom of hole to above the static water level.
2. Backfill hole with cuttings to 3' below ground level.
3. Install a non-metallic plug with approved company identification.
4. Backfill and tamp top 3' with hole cuttings or 3. Use a minimum 3' cement plug to surface.
5. Spread excess cuttings to no more than 1" above original ground level.

*** Specifications for Plugging Material:**
1. Chemically unaltered sodium bentonite (coarse ground)
2. Physical sizing: 3/8" minimum, 3/4" maximum
3. Moisture content: not more than 17% ± 2%
4. Inert solids: not more than 15% (in package)

Hole Sizes and Volumes Table

Hole Diameter Inches	Hole Volume cu/ft/foot	Pounds Material to Fill One Foot	Feet Filled by One 50# Bag	Bags to Fill 100 ft.
3 1/2	0.067	4.8	10.4	9.6
5 1/2	0.165	11.9	4.2	23.8
10	0.545	39.2	1.3	78.4

Figure V-3
Drill Hole Requirements When Artesian Water Is Encountered



Guidelines:

1. These holes shall be plugged immediately.
2. Pour plugging material* at a slow rate until the material level is 3' below the ground level.
3: Allow hole set for 24 hours. If flow is contained, may install a non-metallic plug at 3'. Backfill and tamp final 3' of cuttings. Spread remaining cutting to no more than 1" above original ground level.
4. If flow cannot be contained, shot hole will be re-drilled and plugged from the bottom up with cement to 3' below ground level. Install a non-metallic plug at 3'. Backfill and tamp final 3' and spread cuttings or 3. Use a minimum 3' cement plug to surface.
5. Notify authorizing office when drilling into artesian flows and report progress of plugging.

*Specifications For Plugging Material

1. Chemically unaltered sodium bentonite (coarse ground)
2. Physical sizing: 3/8" minimum, 3/4" maximum
3. Moisture content: not more than 17% ± 2%
4. Inert solids: not more than 15% (in package)

Hole Sizes and Volumes Table

Hole Diameter Inches	Hole Volume cu/ft/foot	Pounds Material to Fill One Foot	Feet Filled by One 50# Bag	Bags to Fill 100 ft.
3 1/2	0.067	4.8	10.4	9.6
5 1/2	0.165	11.9	4.2	23.8
10	0.545	39.2	1.3	78.4

Figure V-4

Figure V-4
Drill Hole Plugging Requirements For Leasable Minerals Soluble In Water

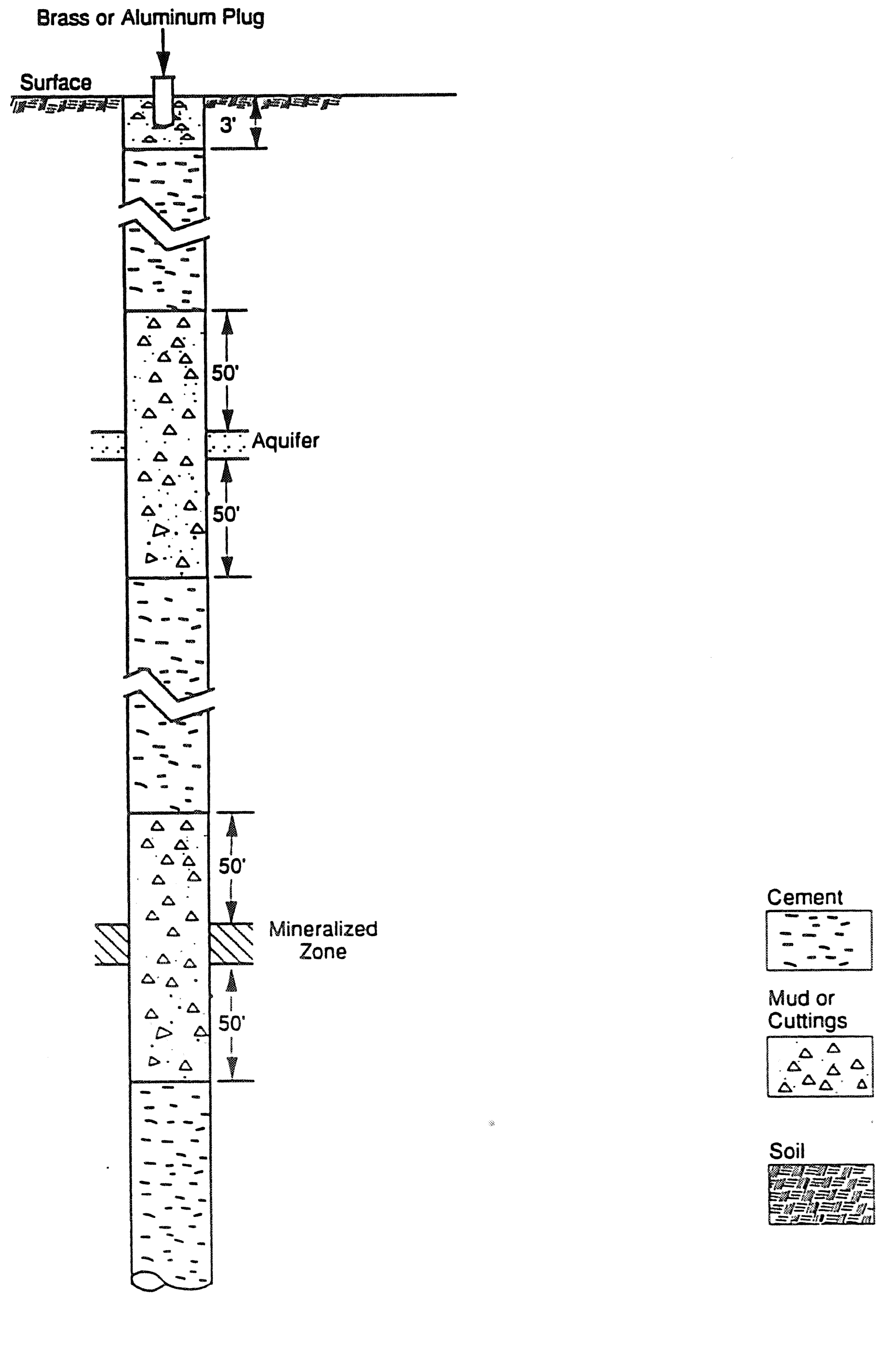
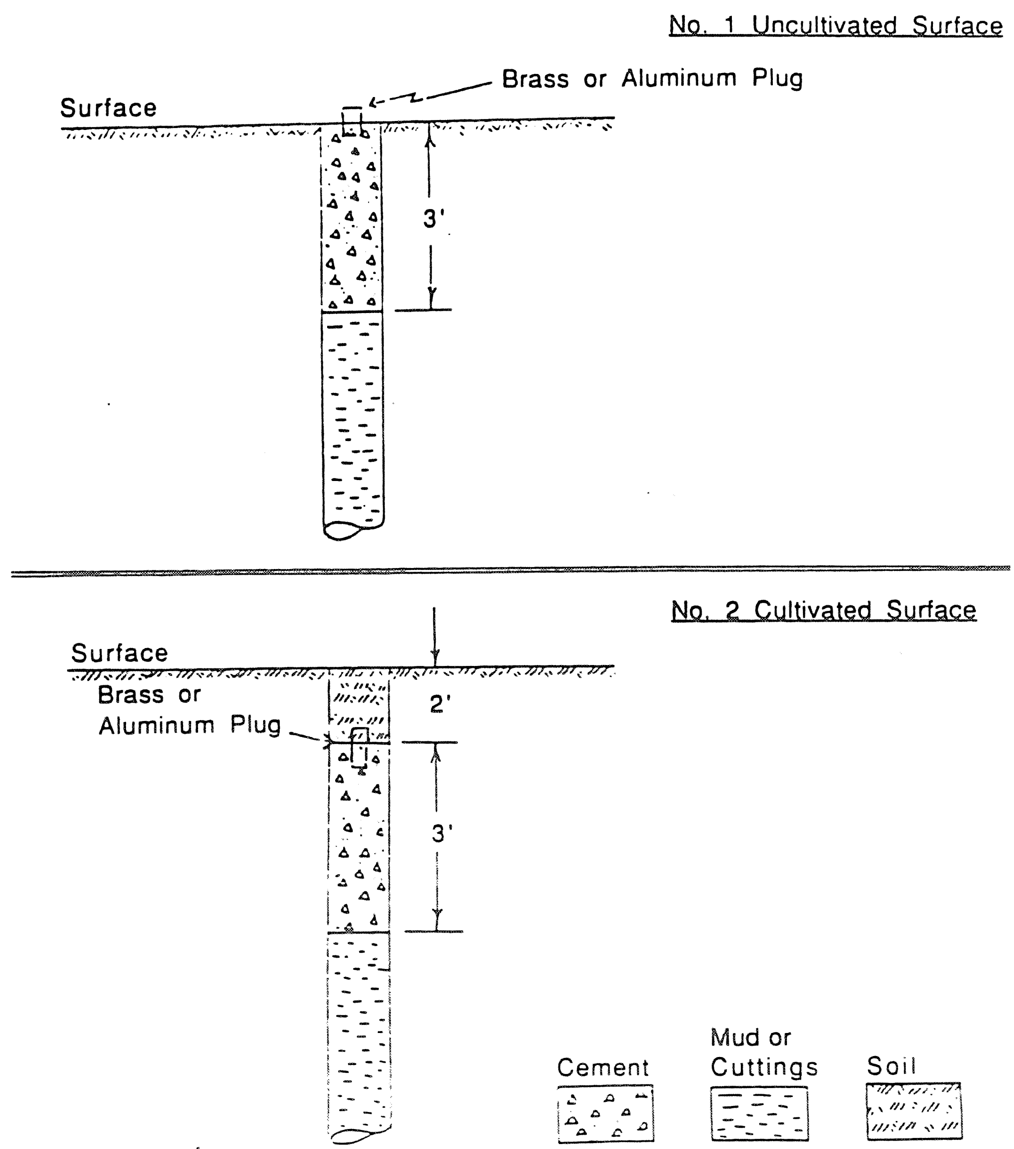


Figure V-5
Drill Hole Surface Plugging



Accordingly, upon completion of each drill hole, the operator will (1) properly plug and abandon the hole, or (2) condition the hole for use as a water well, or (3) condition the hole for retention as a monitoring well.

1. Utilization of Drill Holes for Water Wells

Some drill holes may be converted to water wells subject to the acceptability of parameters such as water quality, aquifer protection, hole stability, etc. Upon receipt of a written request from the surface owner or the appropriate surface management agency other than BLM, or a BLM-generated request, the AO may approve the conversion of an exploratory drill hole for further use as a water well. Approval of such conversion will be accompanied by a corresponding transfer of responsibility for any liability for damage and eventual plugging. When BLM is the party requesting the conversion to a water well, the BLM must agree to accept responsibility for ultimate reclamation of the drill hole. Nothing in this handbook supersedes or affects the applicability of any State law requirements with respect to such transfer.

The BLM will cooperate with and assist other Federal agencies and SMA's or surface owners that desire to obtain and convert drill holes for use as water-source wells. The BLM's primary responsibility is to ensure that the drill hole is properly abandoned. Any entity desiring to obtain such drill holes as water-source wells, including BLM, must take liability for any work on the drill hole not directly attributable to normal plugging and abandonment and must assume, by written agreement, future liability for such drill hole.

Conversion of drill holes to water-source wells and their subsequent operation may be subject to State laws, BLM regulation and/or special permits or stipulations set forth by the appropriate surface management agency. Accordingly, whoever obtains or operates such a well is responsible for familiarizing themselves with and abiding by such laws or restrictions as may be appropriate.

Every release of liability for conversion of such drill holes must be signed by either the surface management agency or the surface owner, as appropriate. Other agencies or individuals desiring use of such wells must make appropriate arrangements with the party accepting liability.

2. Use of Drill Holes for Water Monitoring

The operator may utilize exploration drill holes or surveillance wells for the purpose of monitoring the effects of subsequent operations on the quantity, quality, or pressure of ground water or mine gases only with the approval of the AO in consultation with State Agencies and/or the surface owner, as applicable. Approval for such use will continue the liability for eventual plugging, reclamation and abandonment. Nothing in this handbook supersedes or affects the applicability of any State law requirements.

C. DRILL PADS

When drill pad construction is required, the pad should be of minimum size required to accommodate the drill rig and associated equipment. Topsoil or other suitable growing medium should be segregated and stockpiled for spreading on the pad once the hole has been properly abandoned (see revegetation section).

Reclamation of the drill pad involves reshaping to prevent erosion and to establish contours which are consistent with the drainage patterns of the adjacent undisturbed areas. The visual impacts of any drill pad disturbance must also be mitigated. Excess drilling mud and drill cuttings, as well as any reactive or toxic materials uncovered during or created by drilling, shall be properly disposed of. Revegetation of the drill pad may be required to properly reclaim the site (see Revegetation, Chapter XII). If the drill site is on an exploration access, the site may be reclaimed concurrently with reclamation of the access. See Figure V-6.

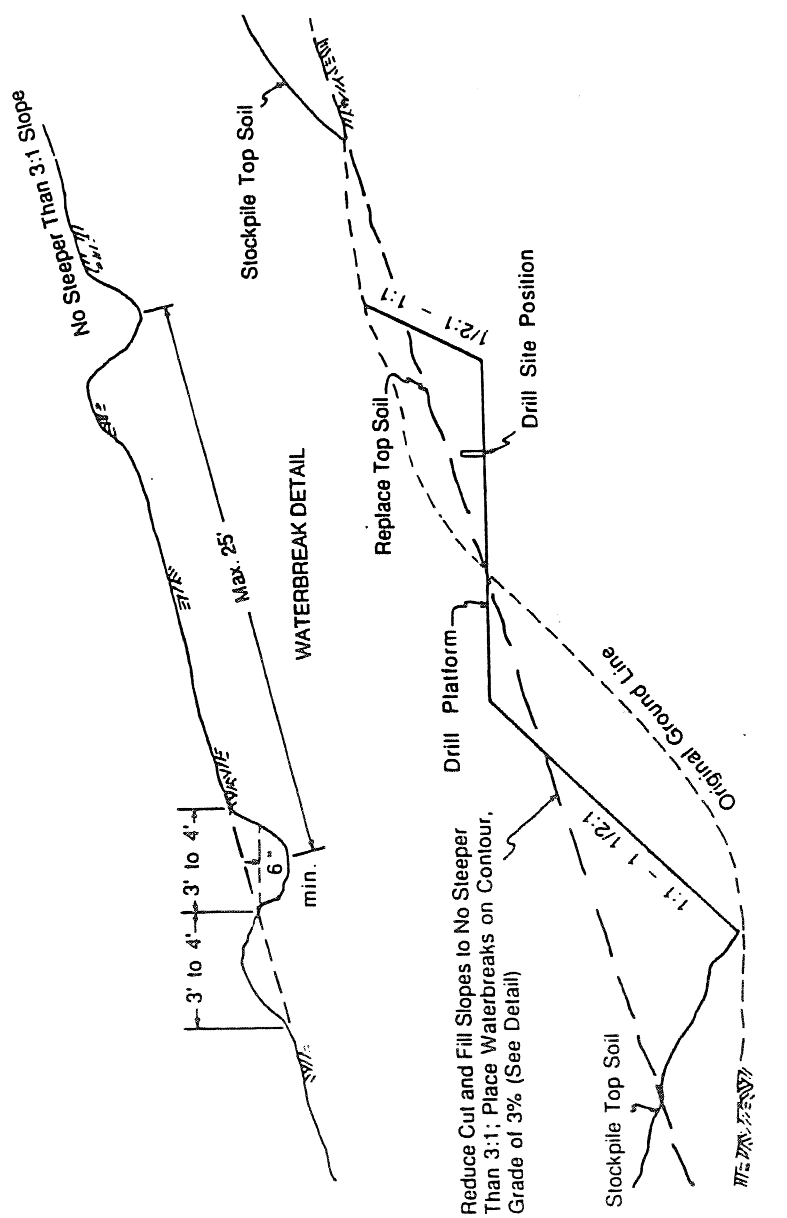
D. MUD PITS

Mud pits or reserve pits are usually constructed adjacent to or on the drill pad. These pits are generally constructed without a complete assessment of the subsurface conditions, such as groundwater hydrology, soil mechanics, etc., of the specific location. Such pits shall be used only for disposal of drilling fluids and produced waters from the drilling operation. Where the potential for groundwater contamination exists, these pits should be constructed with a suitable liner to ensure protection of the environment.

In all cases, these disposal or holding pits must be reclaimed. Any hazardous substances in the pits must be removed and disposed of in a proper manner (see Chapter VIII on waste disposal). Once the material in the pits has sufficiently dried, the area should be reshaped, topsoil or other suitable growing medium shall be spread over the pit and the area revegetated.

Figure V-6

Figure V-6
Drill Pad Reclamation



VI. OTHER EXPLORATION-RELATED RECLAMATION

A. INTRODUCTION

Proper reclamation of lands disturbed by exploration activities is designed to prevent unnecessary or undue degradation, prevent waste and damage to the mineral-bearing formations (43 CFR 3591.1), and protect the health and safety of the public, wildlife, and livestock. This will be accomplished by adherence to reclamation standards and guidelines. These guidelines are intended to be general in nature and provide the necessary flexibility for each specific case, taking into consideration the geologic setting, hydrology, topography, types of mineral present and other appropriate factors.

B. SURFACE DISTURBING EXPLORATION ACTIVITIES

1. Trenches

To minimize potential hazardous situations, all exploration trenches should be backfilled and reclaimed as soon as practical. Ideally trenches should be reclaimed immediately after the needed samples or other information has been collected. If it is necessary to keep trenches open for a specified period, the sides of the trenches should be stabilized by reducing the slope angle to avoid caving. Any trench that cannot be reclaimed immediately must be designed to prevent erosion and water impoundment. In addition, all open trenches must be fenced to reduce the hazard to the public, livestock, and wildlife. Additional safety measures may be necessary under OSHA or other Federal or State requirements. When trenches are excavated, topsoil or growing medium should be segregated and stockpiled. Upon abandonment, trenches will be filled and reshaped. The stockpiled growing medium will be spread over the fill material and the area will be revegetated as necessary.

2. Exploration Mines

In some situations, exploration mines, including test pits and small underground operations, may be approved as part of an exploration operation. These test mines should be reclaimed and closed as soon as practical. If the exploration mines are to be used in later operations, interim stabilization and reclamation for a specified duration will be required in accordance with the reclamation plan.

3. Bladed areas

Bladed areas include all areas disturbed by mechanized earthmoving equipment for various purposes during exploration. Final reclamation of exploration should be based on resource values. In cut-and-fill areas, reshape to a compatible slope. Replace side cast material into disturbed areas. All culverts should be removed and drainages reclaimed or reestablished. Round off berms and establish water bars or roughen the surface as necessary. Rip roads to reduce compaction and aid revegetation.

VII. DRAINAGE AND HYDROLOGY

A. INTRODUCTION

As a consequence of exploration, surface mining, and other mineral activities, disturbed areas may be subject to accelerated erosion of unstabilized soils and other materials. The potential for sediment production is highest between initial disturbance and final physical stabilization of the site. Erosion losses from unvegetated disturbance can be affected by weather conditions, type of materials, and slope factors (angle and length). Without controls, this soil could be carried by surface run-off into the natural waterways. The threat of siltation from the mine disturbance degrading downstream water quality is one of the most important issues confronting mine planners.

The hydrologic portion of the reclamation plan shall be designed in accordance with all Federal, State, and local water quality standards, especially those under the Clean Water Act National Pollutant Discharge Elimination System (NPDES) point source and non-point source programs.

The baseline survey should be conducted to identify the quantity and quality of all surface and subsurface waters which may be at risk from a proposed mineral operation. All aspects of an operation which may cause pollution need to be investigated, so that every phase of the operation can be designed to avoid contamination. It is better to avoid pollution rather than subsequently treat water. The diversion of water around chemically reactive mining areas or waste dumps must be considered during the planning stage. Site selection for waste dumps should be conducted to minimize pollution.

Reclamation plans should be prepared to include a detailed discussion of the proposed surface water run-off and erosion controls including how surface run-off will be controlled during the ongoing operations, during interim shutdowns, and upon final closure.

Reclamation plans should also include a properly designed water monitoring program to ensure operator compliance with the approved plan. The purpose of the monitoring program is to determine the quantities and qualities of all waters which may be affected by mineral operations.

Operators should consider controlling all surface flows (i.e. run-on and run-off) with engineered structures, surface stabilization and early vegetative cover. Where the threat to the downstream water quality is high, the plan should provide for total containment, treatment, or both, if necessary, of the surface run-off on the project site. Sediment retention devices or structures should be located as near as possible to sediment source.

Common forms of sediment control include:

- Sediment ponds (siltation ponds/water retention ponds).
- Sediment barriers include both temporary and permanent structures, such as dams, brush barriers, silt fences, ditches, water spreaders, bales of straw, etc. See Figure VII-1.
- Shaping waste embankments and disturbed areas to reduce run-off velocities.

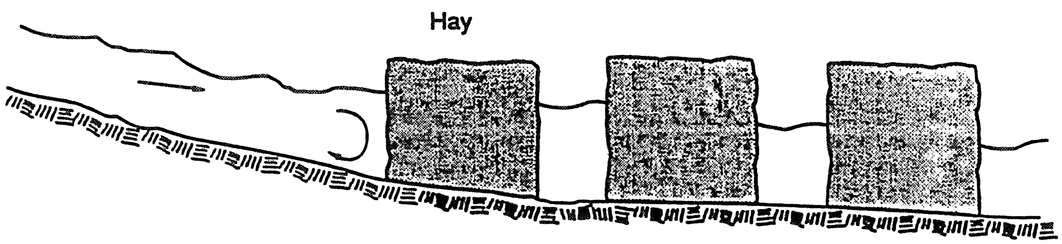
B. SEDIMENT PONDS

Good reclamation practices are essential to reduce the suspended solids content of surface run-off. Sediment ponds are one of the most effective means to capture or detain surface run-off from disturbed lands for the purpose of removing the suspended solids. The sediment trapping efficiency of a pond (i.e. the percentage of incoming sediment which remains in the pond) relates to the residence time of the water in the pond. Longer residence times increase the pond efficiency. The trapping efficiency of the sediment pond is dependent upon:

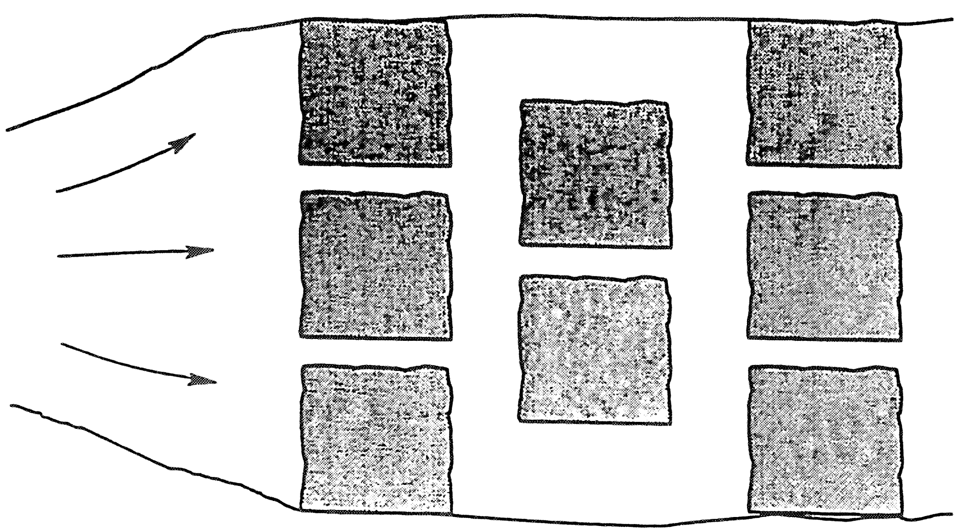
1. The surface area of the settling basin.
2. The rate of inflow.
3. The horizontal velocity of flow through the basin.
4. Settling velocity of the particles.
5. Depth of the water in the settling basin.
6. The flow pathway between the pond's inflow and outflow.

Figure VII-1

Figure VII-1
Example of Typical Sediment Barriers



Profile



Plan

Due to the importance of physically controlling contaminated surface run-off from entering natural water-ways the following sedimentation pond guidance is recommended:

- Prevent contamination of unpolluted surface flows by diverting water flows around the disturbed areas or sediment ponds.

- In locations where topographic confinements do not allow for the construction of ideally shaped ponds and the pond inlets and outlets are too close together, baffles can be used to prevent short-circuiting. Ponds should be deep enough to prevent hydraulic scouring and to provide for additional storage volume so the pond does not require frequent clean-out. The pond should be designed and maintained to ensure retention of the design storm event.

- Where there exists a high potential for contaminated run-off to impact natural waterways or fisheries, the pond should be designed for total containment of the project site run-off resulting from the design storm event.

- The integrity of the sedimentation pond must be ensured through the proper design and construction of the pond dam, standpipe system when used, and emergency spillway. Emergency spillways should not be constructed in fill material. The sedimentation pond should be a non eroding structure designed to safely discharge the volume of water and sediment in excess of the design storm event. Emergency spillways should be protected with coarse rock or 1/2 round culvert to resist erosion during design storm events. Where standpipes are installed, anti-piping barriers and rock stilling basins (energy dissipating devices) should be constructed at the discharge of the pipe. See Figures VII-2, VII-3, and VII-4.

- All sediment control structures such as ponds, ditches, dikes, etc. should be designed under the direction of and certified by a registered professional engineer. The design must be reviewed by the AO prior to construction. Design of these structures must address sediment capacity, the design storm event and other appropriate factors. These devices should be constructed prior to upstream surface disturbing activities.

Figure VII-2
Example Sedimentation Pond, Plan View

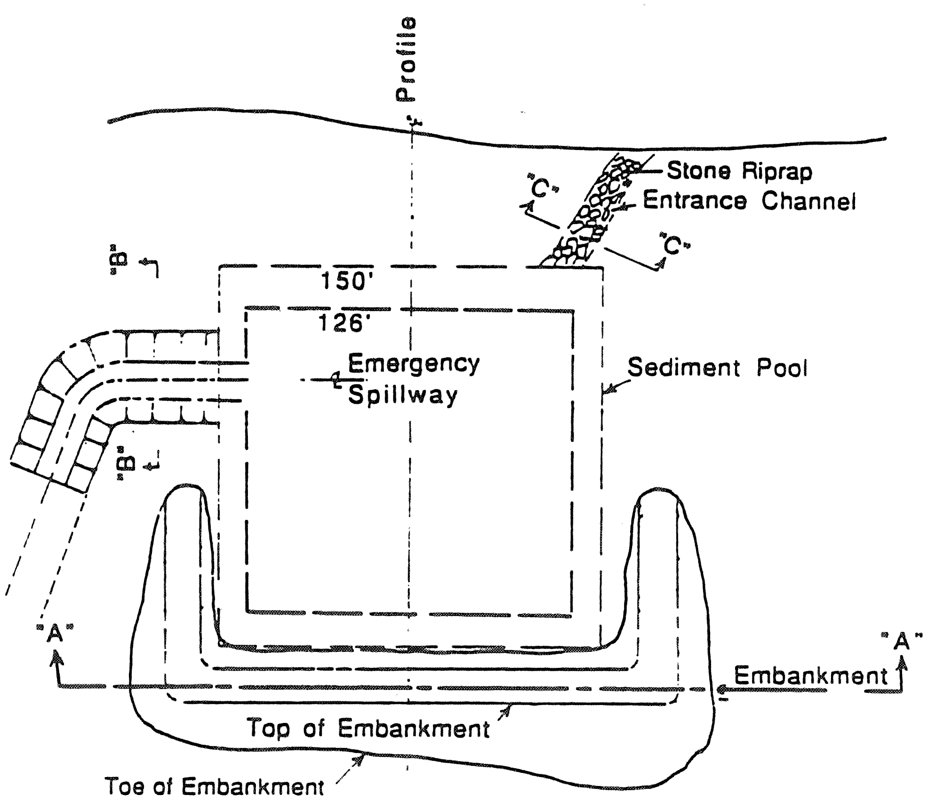


Figure VII-3

Figure VII-3
Example Sedimentation Pond, Profile and Cross-Sections

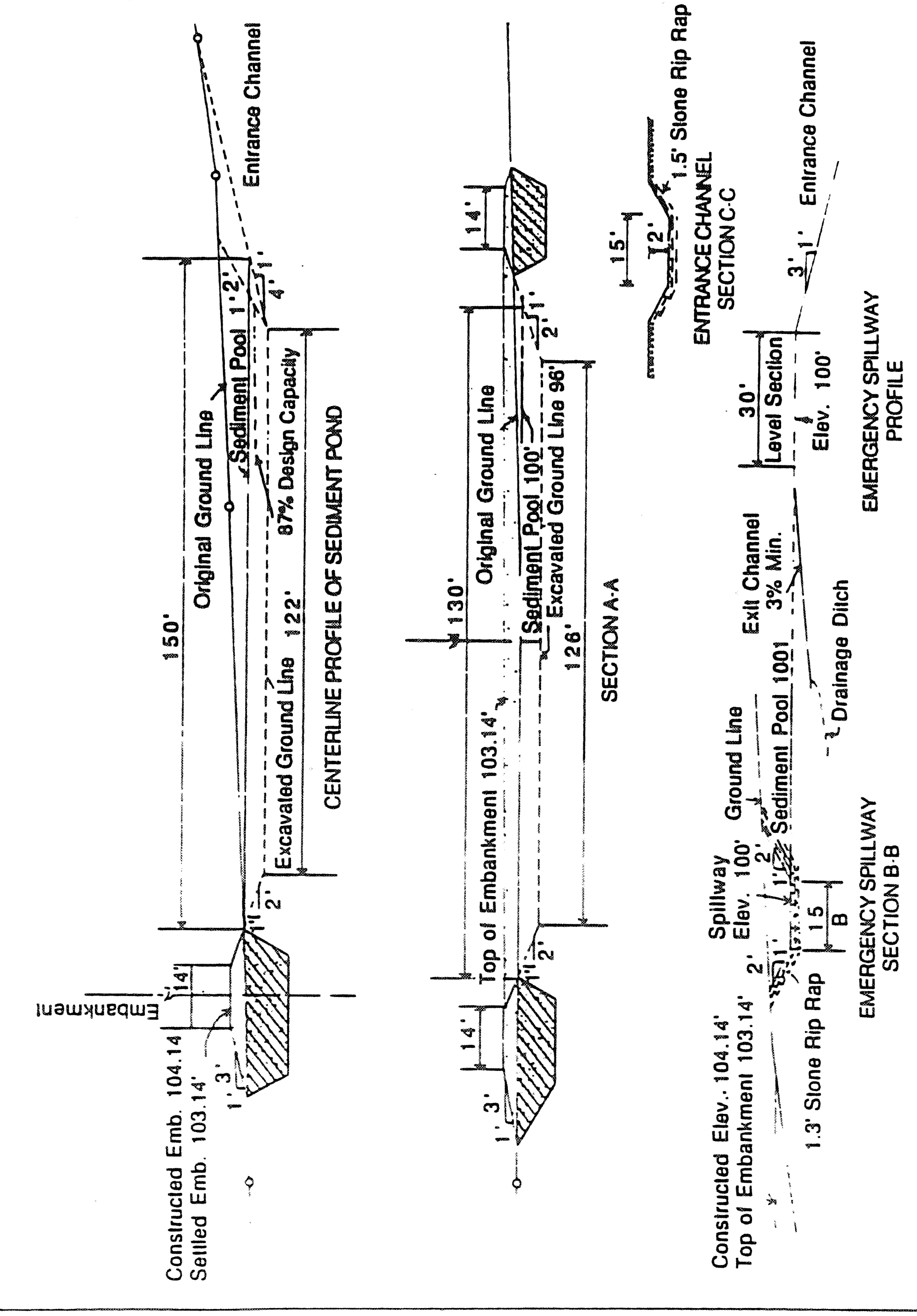
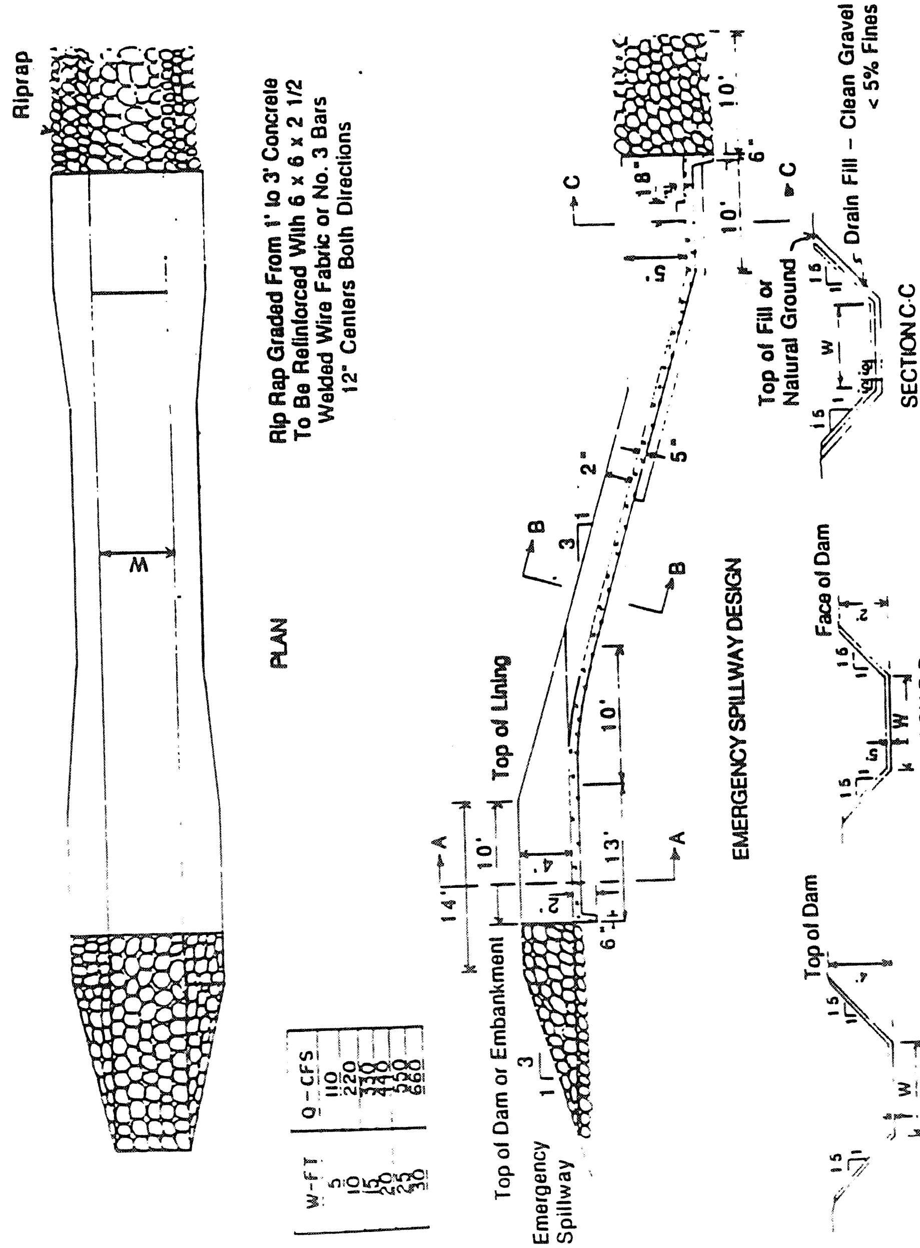


Figure VII-4
Example Sedimentation Pond, Emergency Spillway



W-FT	Q-CFS
5	110
10	220
15	330
20	440
25	550
30	660

- Sediment ponds shall not be constructed within permanent stream channels or on unstable slopes without the prior consent or approval of the AO. The operator shall ensure that all such structures are constructed and maintained according to the design, and are periodically inspected for safety and structural stability.

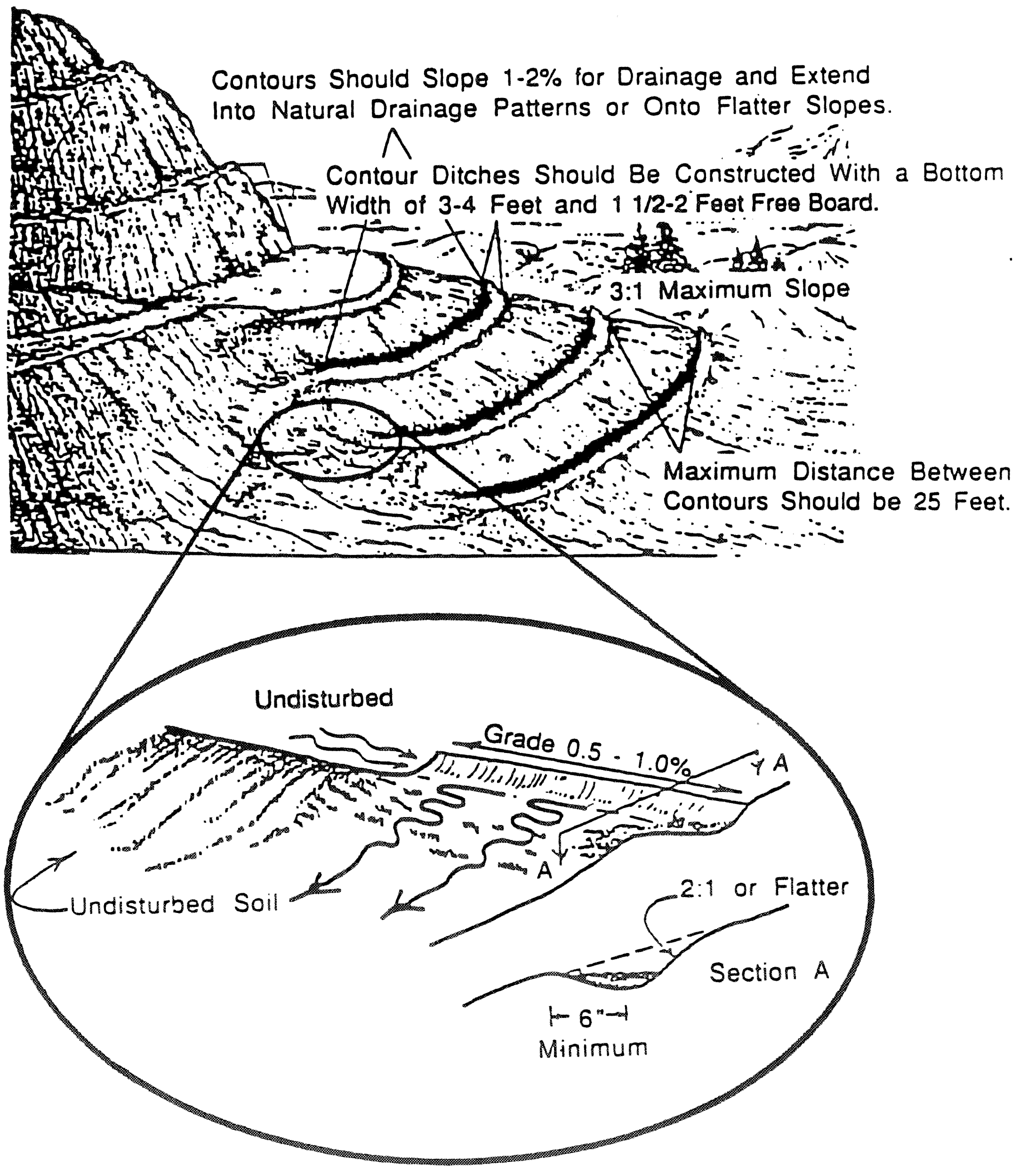
- The operator shall monitor existing sediment ponds for capacity and stability on a regular basis. Sediment ponds shall be maintained until the lands disturbed under a project have been reclaimed and the reclamation criteria have been met. Ponds may be reclaimed or retained in accordance with the reclamation plan.

C. EROSION PREVENTION AND CONTROL

Sediment control is an important feature of both mine operations and reclamation because of the high potential for erosion and sediment production. Erosion can be caused by both wind and water. Manmade slopes shall be designed to prevent sheetflow from run-off. Disturbed areas are susceptible to wind erosion when the particle size is 0.1 mm or less, wind velocity generally exceeds 12 mph, and the spoil surface is periodically dry. Higher wind velocities may erode larger particle sizes. Mill tailings are often extremely susceptible to wind erosion. Soil surveys of the site may provide additional information regarding the erodability of the soil from wind or water and soil loss tolerance.

The angle and length of the slope can adversely affect the amount of erosion caused by surface run-off. With steeper slope angles, the higher the velocity and the silt carrying capacity of the run-off. The longer the slope length, the greater the potential for erosion due to channeling. Where excessive slope lengths (>100 feet, depending on slope angle) are to be expected, consider the use of terraces, benches, or other slope breaks to minimize erosion. Terraces and benches should be designed to handle the expected peak flows and should be constructed wide enough to prevent overflowing during the alternate thawing and freezing weather conditions. The benches should be designed to drain properly into natural drainages and construction allowances should be made for settling of the spoils. See Figure VII-5.

Figure VII-5
Erosion Prevention Using Terraces and Benches



CONTOUR FURROW CROSS-SECTION

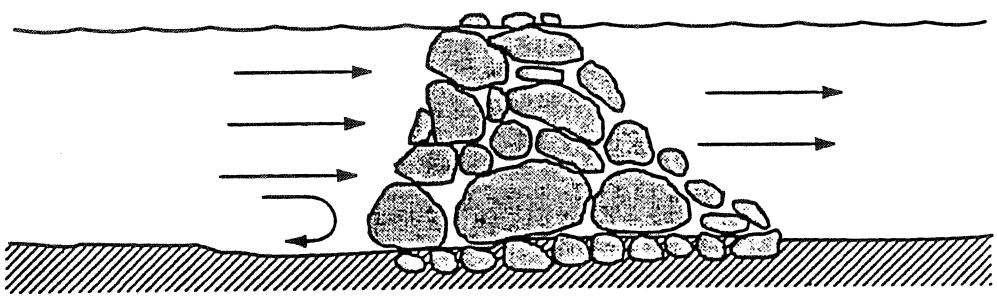
Appropriate mitigation measures for wind erosion must be taken. To reduce wind erosion, materials should be covered with mulch or matting and/or coarse waste rock and then topsoil, if available. A plant cover should be established if mulch, matting, or topsoil is used so long-term surface coverage is provided. Barriers, such as snow fences, oriented perpendicular to the prevailing wind may also be used to help reduce erosion until a good plant cover is established. If a plant cover cannot be established, the area can be covered with coarse rock (> 3 inches).

Erosion will increase with increasing storm intensity and duration, slope length, slope angle, material impermeability, and scarcity of ground cover. Ideally, natural means of erosion control are preferred. If erosion rates are relatively slow and time permits, revegetation should be used.

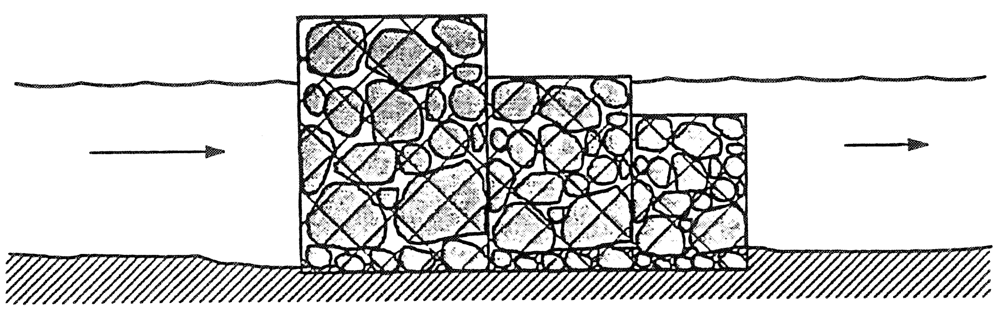
In most cases, some form of additional surface modification must be used to inhibit water flow. Flow can be impeded and infiltration increased by disking, furrowing, terracing, and/or deep ripping on the contour. Equipment may not be able to traverse the contour of a slope when it exceeds 2.5:1 (H:V) or 40%. Terracing can also be used to break up the overall slope length. Terrace width and spacing should be based on storm intensity and spoil permeability. In wet areas or where the spoil is impermeable, terraces need to be wider and spaced closer together. Berms constructed of windrowed rocks or brush are a means of breaking-up and slowing surface flow. In particularly critical areas, lined ditches can be used to intercept overland flow and channel it to more stable locations. Reshaping and grading can be used to reduce the slope and make the area more accessible for revegetation equipment.

Barriers should be used to reduce water velocity and minimize erosion. Sediment barriers are usually only effective for small volumes of run-off and sediment and may be as simple as strategically placed 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 flow.

Figure VII-6
Rock Filters



Rock Pile
Stream Centerline View
Keyed Into Bank and Streambed



Gabion Dam
Stream Centerline View

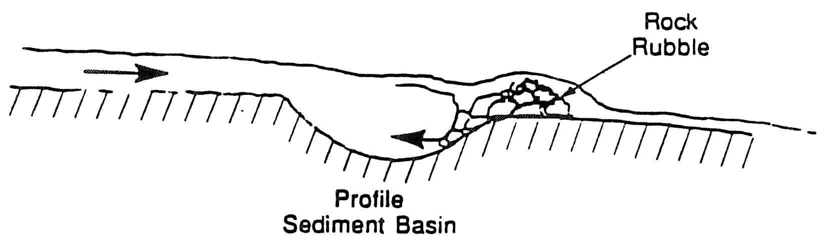
Brush barriers have been proven moderately effective when located at the toe of waste embankments or other elevated disturbance. Brush barriers placed in the drainages above sediment ponds will slow the inflow velocity of the run-off, thus reducing sediment input into the ponds. These structures may require periodic maintenance. See Figure VII-1.

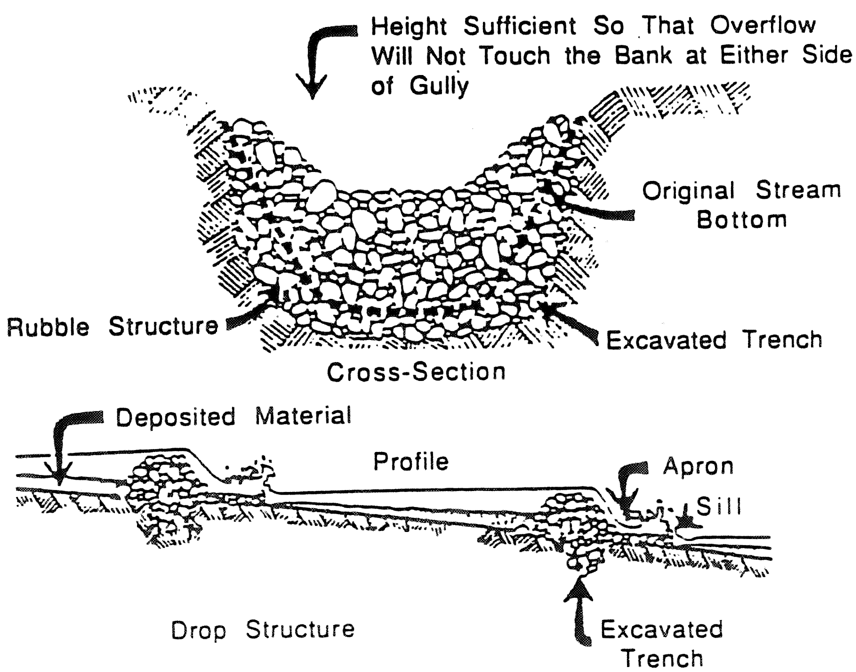
Rock filters can be effectively used in trapping sediments, and are simple to design and construct. The rock filter should be designed to handle the expected peak run-off flows in the area. Normally the rock filters are constructed using smaller rocks in the core to serve as the filter and coarse rock on the surface to protect the filter. See Figure VII-6.

Sediment traps or drop structures can be set-up within drainages to capture sediment after the particles have left the disturbed area. (See Figure VII-7). Such structures can be either porous or nonporous. These should only be used for short term control. Structures become ineffective if not properly maintained, and maintenance costs can be very high for long-term use. Structures should be placed within intermittent drainages, if possible. A series of traps down a drainage is usually more effective than a single large pond. Sediments should be removed when the trap is one-half to two-thirds full and properly disposed of.

Sediment traps or settling ponds function by reducing water velocity, and allowing suspended sediments to settle. Generally, the larger the settling pond, the more sediments will be trapped and the finer the size of the particles which will fall out. Settling ponds require the construction of an embankment or other structure. Local geology, groundwater hydrology, embankment design, and other geohydrologic factors must be considered in the overall design due to subsurface pore water pressure, seepage and piping concerns around, through, and beneath the structure.

Figure VII-7
Sediment Traps





Porous structures are of a simpler design and easier to build. Their efficiency in trapping sediments is generally less than that of nonporous structures. Loose rock can be used and reinforced by wire mesh, steel posts or other materials. Rock should be sized to withstand the anticipated peak flows of the area. Rock can be sized smaller within the core of the dam to filter out smaller sediments. Porous structures will often promote vegetative growth behind the dam. If the vegetation is protected, the vigorously growing plants will help trap more and finer sediments and provide for long-term stability of the structure. Spillways should be an integral part of any design, even using porous materials.

Nonporous structures utilize spillways or perforated risers as water outlets from the sediment traps. The stilling effect of the pond is greater than with porous structures. This may be a significant factor in using them where deleterious or harmful sediments are involved. Nonporous structures require stronger anchoring because of the water pressure behind the dam. The dam should be removed after it has served its function, unless designed and approved as a permanent structure.

D. <u>SHAPING AND GRADING</u>

Shaping and grading a disturbed site are fundamental reclamation measures for the purpose of creating a stable landform, providing for proper drainage control, reducing erosion, and preparing for revegetation (see Chapter XI on Landform Reclamation for more detail).

E. <u>REVEGETATION</u>

Soil protection or stabilization to reduce erosion is the first objective of revegetation. The establishment of an early vegetative cover is one of the most effective methods for controlling erosion and sedimentation. Disturbed areas are most susceptible to erosion between initial disturbance and revegetation. Timely revegetation of mine disturbance is critical. See Chapter XII on Revegetation for more detail.

F. <u>EROSION AND INFILTRATION CONTROL</u>

Infiltration into wastes can result from:

- Subsurface water movement
- Leakage from abandoned mines
- Downward percolation of surface waters and precipitation

The diversion of surface water around a chemically reactive mined area is highly preferable because it reduces erosion and generation of polluted water. See the Chapter VIII, Mine Waste Management and Pollution Control, for additional information.

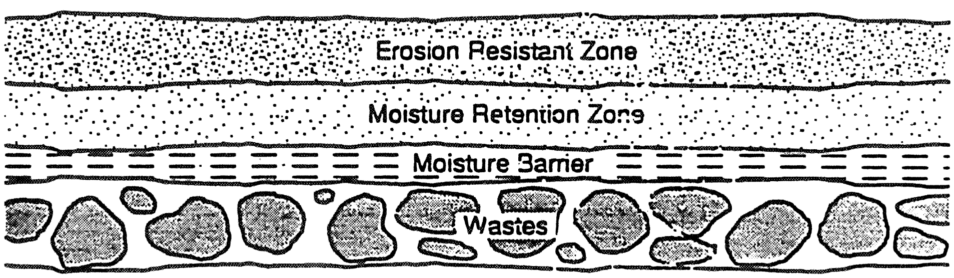
1. <u>Cover Systems</u>

Cover systems should be constructed over disturbed areas that contain material susceptible to leaching. See Figure VII-8. Together with the drainage system, the cover system forms a major component of mine water management and is a key factor in the limitation of infiltration and the support of vegetation. Minimizing rain and snow melt infiltration into chemically reactive, acidic, or toxic mine wastes reduces the formation and transport of pollutants out of mined areas. Furthermore, measures to reduce water infiltration can reduce the oxygen supply which reduces the rate at which acid, and possibly other pollutants are produced.

The criteria for an effective cover system are:

- The cover system should possess low permeability to minimize water infiltration and oxygen availability.
- The covers should have a shallow slope with a well drained surface, free from depressions and hollows which could contribute to the retention of water.
- The cover system should be of a suitable thickness compatible with the performance objectives.
- The construction of the cover system should be simple and should maximize the use of locally available materials without the need for processing those materials.
- The covers should be resistant to erosion along slopes before vegetation is fully established.

Figure VII-8
Cover Systems



- The cover system should support a vegetative cover in order to maximize the capacity of the upper soil zones to intercept infiltration and provide erosion resistance once the vegetation has become established.

- The cover system should be free from long-term maintenance requirements.

A cover system using these criteria results in a three zoned system, the construction of which differs between the top (flatter) surface of mined areas and external (steeper) slopes. Thicknesses of these zones will depend upon site-specific parameters. Additional information on this topic is referenced in the bibliography. These zones, from the bottom up, are described as follows:

Moisture Barrier

Once the top surface of the disturbed area has been reshaped to relatively flat uniform gradients an infiltration resistant layer is constructed. It is usually made from compacted clay material or other impermeable materials, such as manufactured textiles or membranes. Permeability after placement should be 10^{-6} to 10^{-7} cm/s. Mining wastes which do not involve acid or toxic materials subject to leaching may omit the moisture barrier zone.

Moisture Retention Zone

The moisture retention zone, directly above the moisture barrier, retains moisture to support vegetation during dry seasons and provides a moisture source to assist in the prevention of desiccation. This material is commonly a sandy clay loam.

Erosion Resistant Zone

This forms the upper layer of the three zoned cover system. In addition to providing resistance to erosive forces of rainfall and runoff this zone forms the seed bed for the vegetation and acts as a pore breaking zone (capillary break) to restrict moisture loss due to evaporation during dry seasons. A well-graded, gravelly sand usually works satisfactorily for this layer. Topsoil or other growth medium should be placed over this layer prior to revegetation.

Steep external slopes that cannot be reduced to less than approximately 3:1 (H:V) require a different type of erosion resistant zone. The erosion protection requirements for these areas are considerably higher than for gentler slopes. Consequently the material used commonly consists of competent crushed rock.

G. SUBSURFACE DRAINAGE SYSTEMS

Subsurface drainage systems can be constructed to intercept groundwater at the interface between contaminated and non contaminated zones. Depending upon the depth of influence, this can be achieved by a variety of methods ranging from under drains and cutoff trenches to drawdown wells.

In circumstances where water cannot be diverted laterally, underdrains can be installed at the base of valley waste fills to improve drainage, enhance waste stability, and minimize retention time and the resultant polluted water generated from reactive material. The underdrain fill should be composed of competent rock with a nominal size of one to two feet or larger, depending on site-specific conditions. The underdrain should be constructed with an overlying filter layer to prevent clogging. These systems require detailed engineering for design and possible effluent treatment. See Figure VII-9.

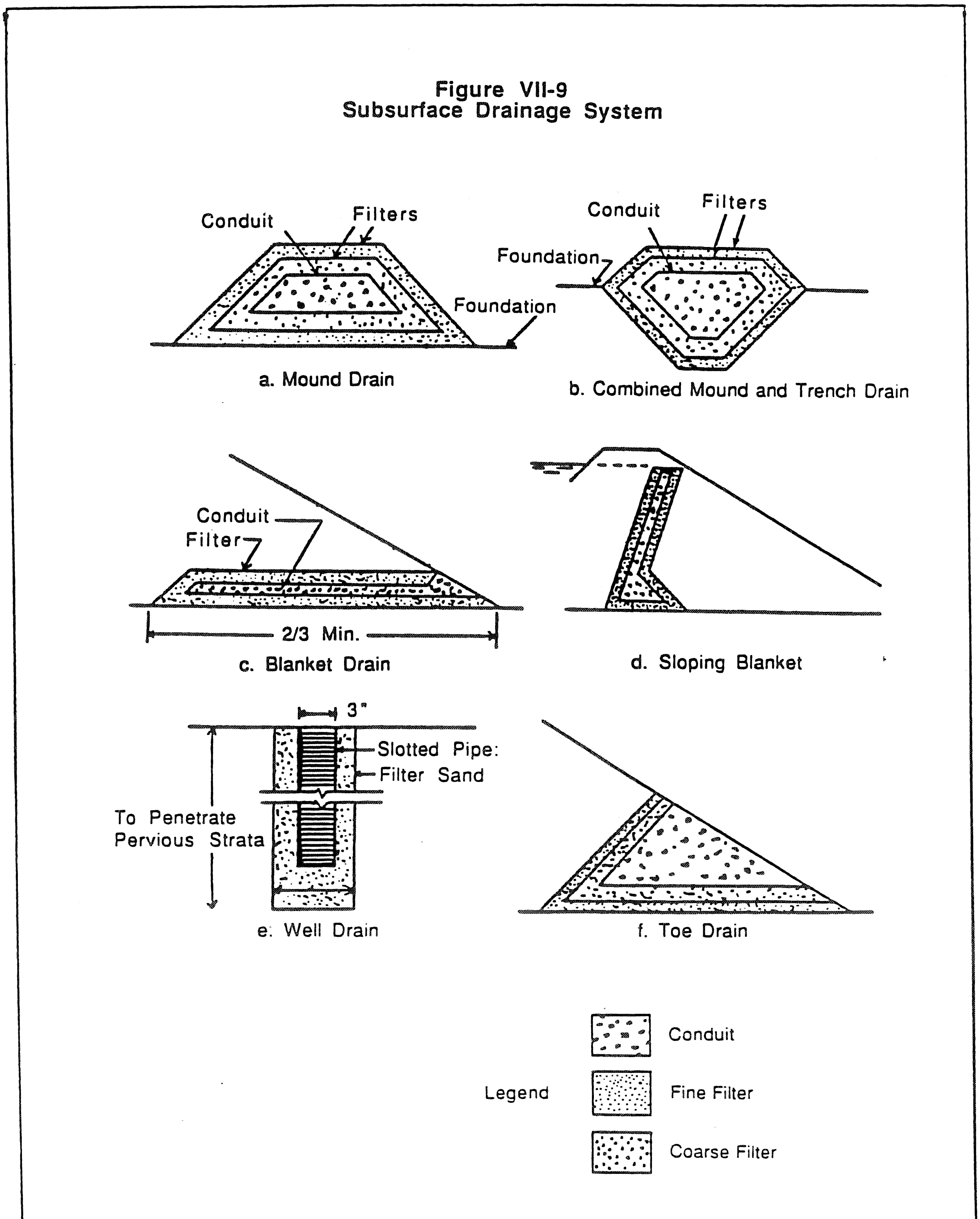


Figure VII-9
Subsurface Drainage System
Conduit
Filters
Foundation
a. Mound Drain
Conduit
Filters
Foundation
b. Combined Mound and Trench Drain
Conduit
Filter
2/3 Min.
c. Blanket Drain
d. Sloping Blanket
3"
Slotted Pipe:
Filter Sand
To Penetrate
Pervious Strata
e. Well Drain
f. Toe Drain
Legend
Conduit
Fine Filter
Coarse Filter

H. WATER DIVERSIONS

Stream diversions may be a necessary part of the operational plan. However, long-term diversions from original stream channels should be discouraged wherever possible. The justification for stream diversions as well as structures or ponds, etc., that might occupy the original area of the stream channel, should be closely examined. Check State and Federal laws or regulations controlling stream diversions. A Corps of Engineers 404 permit may be required. The following should be considered:

- Trans-basin diversions (where water is diverted from one drainage to another) are complex and should be discouraged. Discuss this with the State and Corps of Engineers for compliance and feasibility before approval.

- The longer a stream diversion is in place the greater the chance for failure or environmental damage. Diversions designed for shorter duration can be managed more successfully than long-term diversions.

- Construction of a new stream channel should provide for stability of the stream bed and stream banks; this might include heavy rip-rap or protective vegetation being established in the channel. See Figure VII-10.

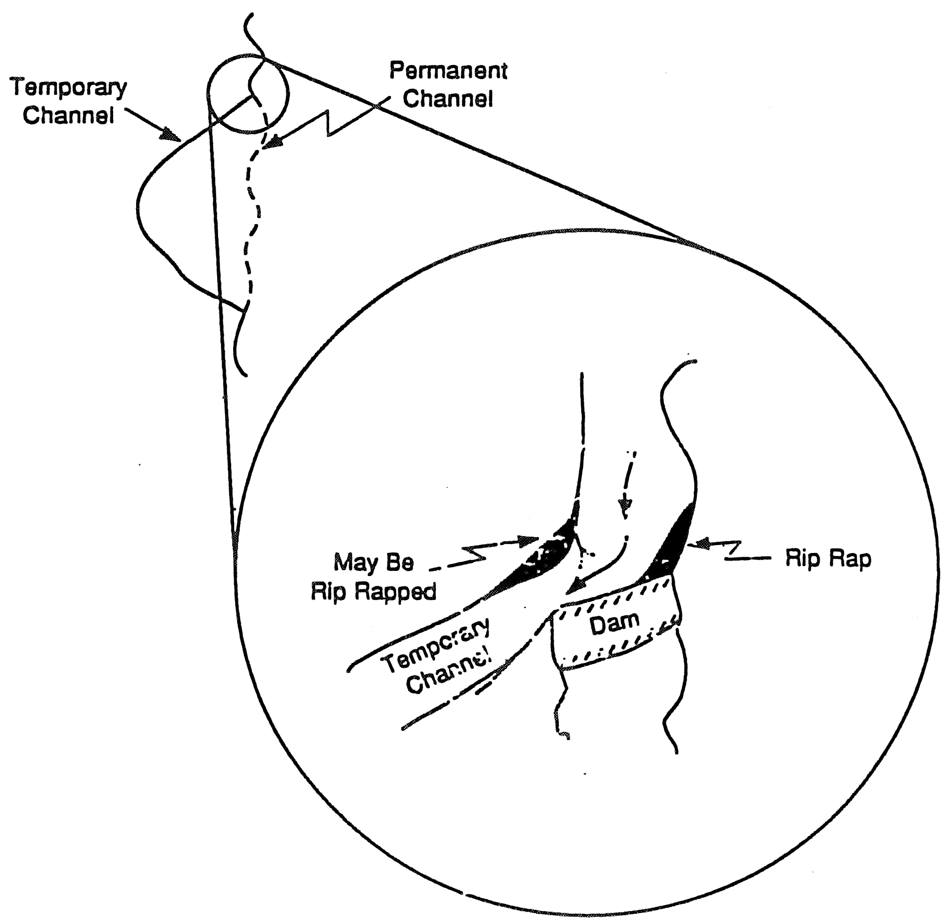
- The headgate, where the stream is originally diverted, should be of adequate size and construction to handle the flow of the design storm event.

- The stream gradient of the new channel must be designed to minimize stream bed erosion and bedload potential.

- The reclamation plan should specify how the stream channel will be reclaimed. All pipes or culverts should be removed from the area during reclamation.

- Constructed stream channel diversions that are no longer required, should be reclaimed.

Figure VII-10
Temporary Diversion of Stream Channel



I. AFFECTED BODIES OF WATER

Mining and related operations can impact water quality and quantity in onsite and offsite streams, rivers, lakes and wetlands.

1. General Procedures

a. During review of the reclamation plan and actual reclamation, premises should be inspected for potential water contamination problems.

b. If an actual or potential water contamination problem is evident, operator should plan and initiate containment measures and Federal and State environmental agencies should be consulted.

c. Post-reclamation resource values of the body of water should be consistent with the pre-disturbance values or the land-use plan.

d. Specific mitigation measures will depend on the specific problems encountered.

e. If reclamation efforts directly affecting a river, stream or wetland are proposed, an Army Corps of Engineers Section 404 permit or other State or Federal permits may be required.

J. DRAINAGE RECONSTRUCTION

When drainages have been altered during an operation, the following guidelines should be used when those drainages are to be reconstructed.

- Streams and drainages should generally avoid abrupt changes in the slope between undisturbed and reclaimed channels.

- Activities should not obstruct the natural flow of water either through gravels or force the stream to flow underground. Topsoil and mine wastes should not stored as a berm in the stream bank.

- Drainage areas, basin relief ratios, valley gradients, and drainage densities for all reclaimed drainage basins should approximate those that existed prior to disturbance.

- Reclaimed drainages should have similar geomorphic characteristics, including: channel depth, top width, stream gradient, cross-sectional area, bendway radius of curvature, length and overall sinuosity to those found in the predisturbance drainages. See Figure VII-11.

- The reclaimed drainages should have similar hydraulic characteristics, including: flow depth, water surface top width, cross-sectional area of flow, water surface slope, mean channel velocity, bendway shear stress, and in-stream vegetal retardance or surface roughness to those found in undisturbed drainages.

- Upon inspection, there should not be signs of head cutting, bank failure, channel avulsion, or other indications of instability.

- Overall basin drainage density should be similar to pre-disturbance, with the exception of pre disturbance Order 1 and 2 streams. They should generally be allowed to form on their own.

K. IMPOUNDMENTS

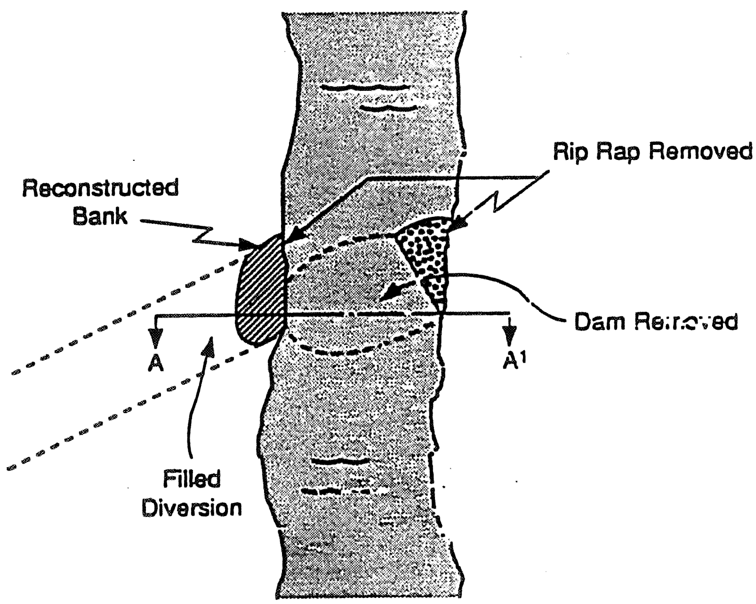
In some cases, the reclamation plan may include the permanent construction of a water impoundment or authorization to leave pit areas which retain water. This should only be approved under the following conditions:

- An impoundment must be a justifiable post-disturbance land use and be in conformance with the RMP or other land use plan.

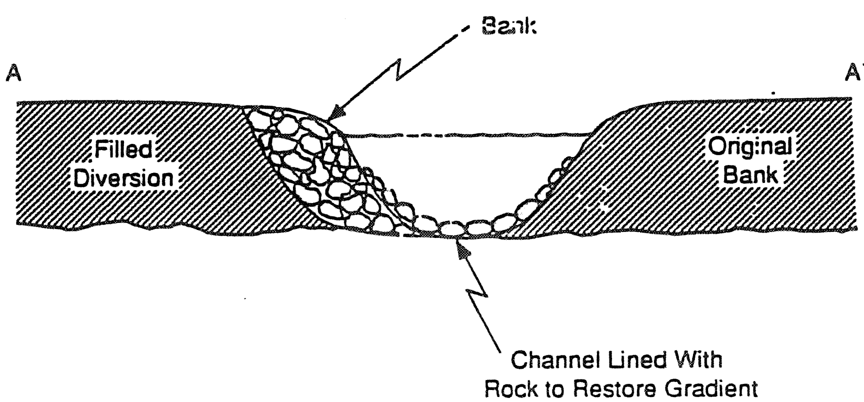
- There should be enough water to meet the requirements of the post-mining land use.

Figure VII-11

Figure VII-11
Reconstructed Drainage



Plan View



Section A - A1

- The water quality must be suitable for the proposed land use.

- The construction of the impoundment will not adversely impact ground or surface water hydrology on or off of the reclaimed area.

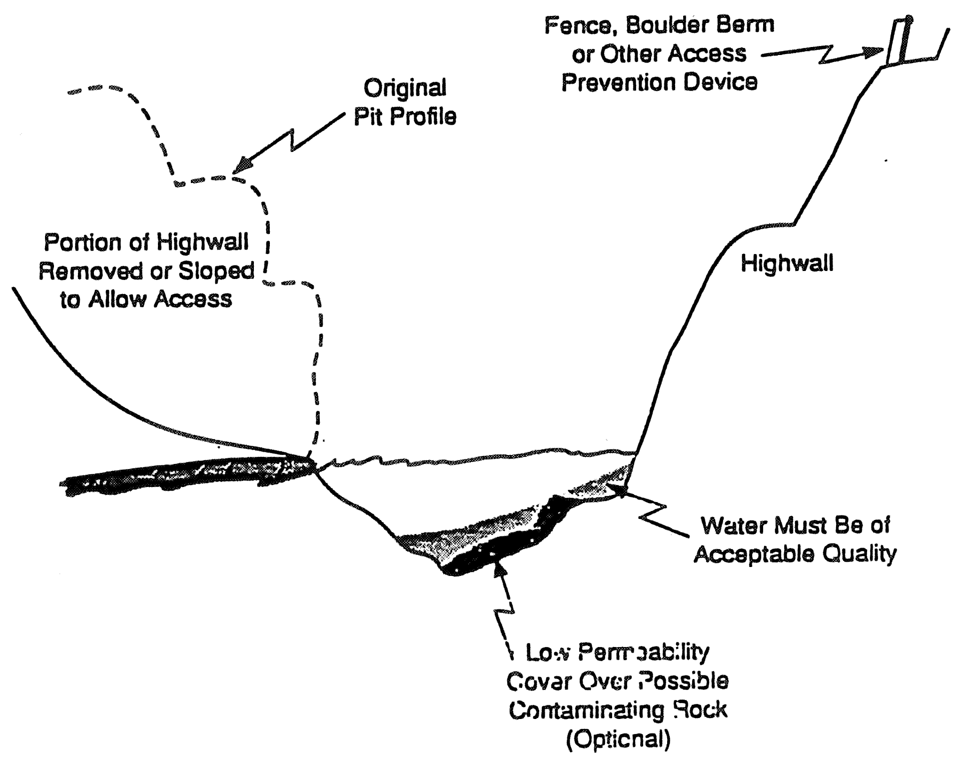
- Impoundment and embankment structures must be designed taking into account local subsurface geologic and hydrogeologic considerations.

If an impoundment is approved as a part of the reclamation plan, it must meet all applicable State and Federal requirements, and be constructed to provide for the planned function. Any exposed pit areas must be stabilized and constructed to provide for safe access to the impoundment for wildlife, livestock, or people. See Chapter XI for details. Stabilization of the shoreline using riprap or other means may be required to prevent erosion. See Figure VII-12.

L. MAINTENANCE

In general, reclamation practices should not involve long-term maintenance requirements. Where long-term maintenance of hydrologic structures, water treatment plants, fences, etc. will be necessary, some form of operator funding for maintenance will be required. Facilities requiring maintenance may prevent the termination of the period of liability and the release of the bond.

Figure VII-12
Acceptable Permanent Impoundment



VIII. MINE WASTE MANAGEMENT AND POLLUTION CONTROL

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 must 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 design of waste management practices must be conducted in cooperation with the State, the EPA, the BLM, other SMAs, and the operator.

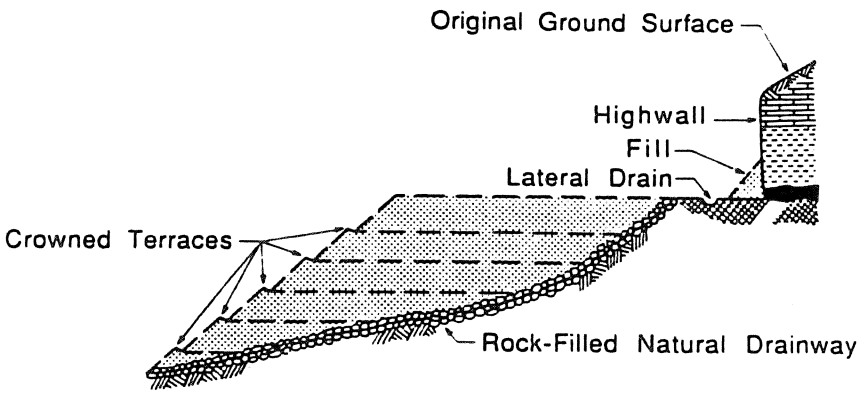
B. EXTERNAL WASTE DUMP DESIGN AND CONSTRUCTION

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. In the design and construction of large waste dumps it is important to consider appropriate reclamation performance standards for stability, drainage, and revegetation. Some guidance to consider during the mine plan review process includes the following:

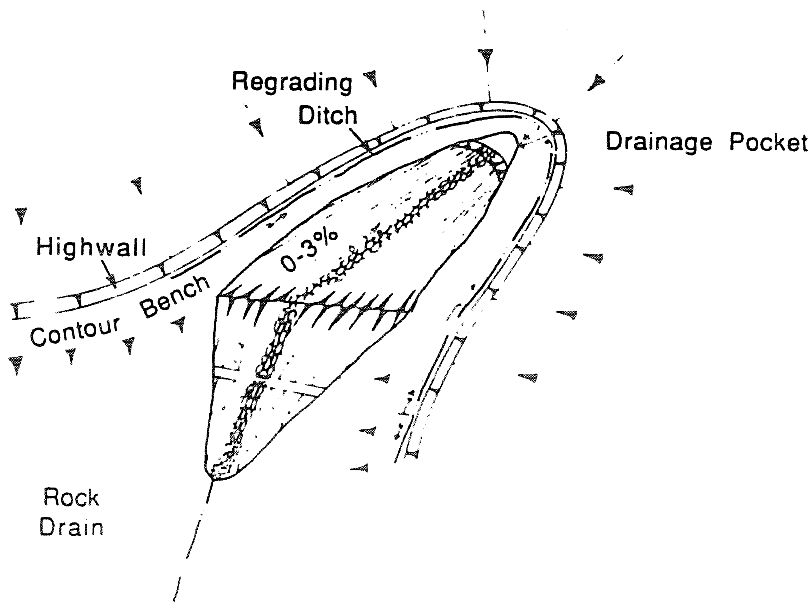
- Waste dumps should not be located within stream drainages or groundwater discharge areas unless engineered to provide adequate drainage to accomodate the expected maximum flow.

Figure VIII-1

Figure VIII-1
Examples of Types of Waste Dumps



Cross Section of Typical Head-of-Hollow Fill.



THREE DIMENSIONAL SKETCH OF VALLEY FILL

- 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.

- 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.

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

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

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

- 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.

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

- After the waste dump has been shaped, scarified, or otherwise treated to enhance reclamation, available topsoil or other selected subsoils should be spread over the surfaces of the dump as a growing medium. Grading and scarification may be required.

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

- 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.

- Waste dump benches should be bermed or 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.

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).

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

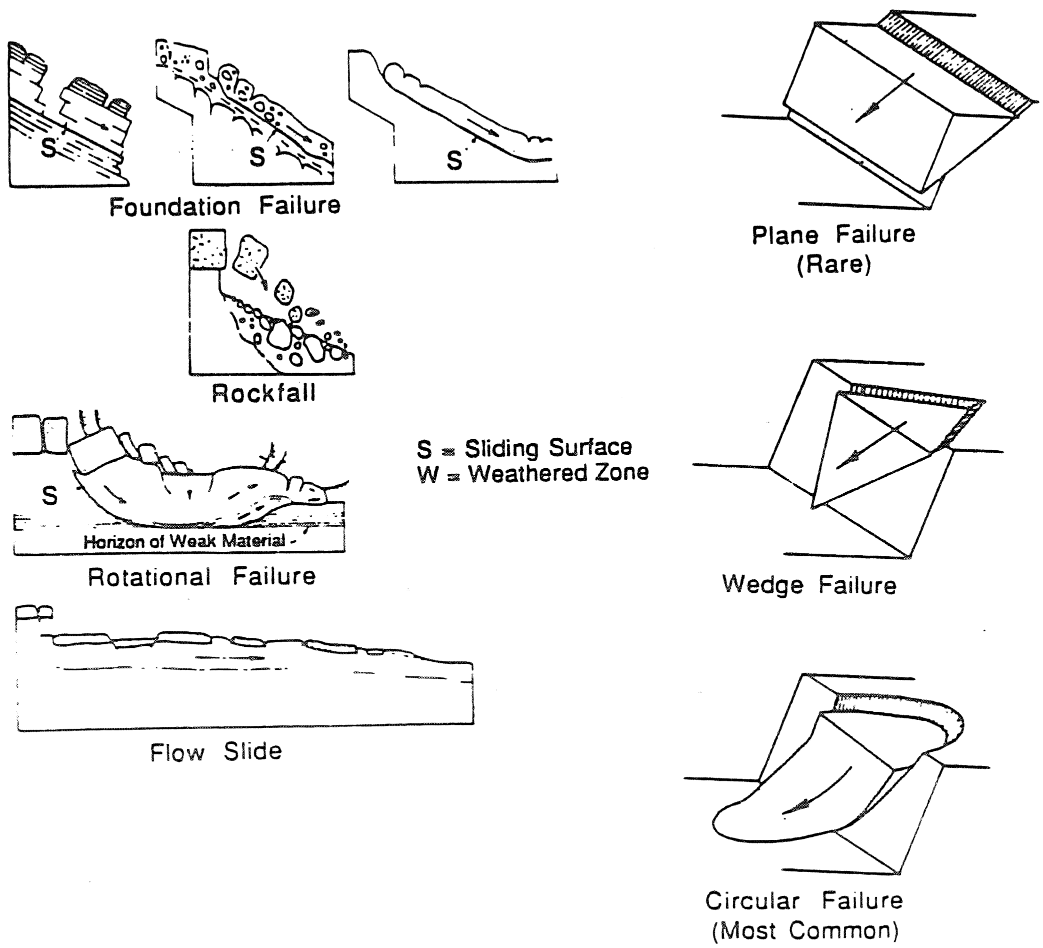
When a slope is at the point of failure F=1.

1. Waste dumps generally fail in three ways. See Figure VIII-2. The following minimum factors of safety are adequate to avoid specific types of slope failure under most conditions (after Vandre):

    a. Foundation slides F = 1.1
    b. Shallow flow slides F = 1.3
    c. Rotational slides F = 1.5

Figure VIII-2

Figure VIII-2
Types of Dump Failures



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

a. Foundation slope and competency
b. Dump slope angle and height
c. Cohesion, density, and saturation of dumped material (Internal design, particularly drainage design, affects saturation)
d. Compaction
e. End use of surface (ie. range vs. highway)
f. 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. Some dumps up to 60' high may have single angle of repose slopes, depending on material characteristics and other site-specific factors, such as hydrology and location.

b. Dumps higher than 60' may have angle of repose slopes interrupted by benches or terraces, if the slopes and benches collectively have an overall factor of safety of 1.5 or greater (the forces resisting sliding should exceed forces causing sliding by 50% or greater).

c. Dumps higher than 60' may have slopes steeper than 2.5:1 if the operator can design those dumps with an F of 1.5 or greater to the satisfaction of BLM or other appropriate regulatory agencies.

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:

(1) At least every 60' in elevation for angle of repose slopes
(2) At least every 100' in elevation for 2.5:1 slopes
(3) At least every 150' in elevation for 3:1 slopes
(4) At least every 200' in elevation for 3.5:1 slopes

g. Benching should be generally sloped gently inward and designed to accomodate the drainage of surface water.

5. Dumps should have an overall factor of safety of 1.5 or greater when:

a. Dump height exceeds 60'
b. Dump is above or supports a road
c. Dump is above a railroad (may require an even higher factor of safety due to vibrations generated by long trains)
d. Dump is adjacent to a stream
e. Dump is above or supports a building or powerline
f. Wherever the risk of failure, or the potential loss due to failure, is unusually high due to site-specific considerations.

6. 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

7. Proposals for revegetating slopes steeper than 2.5: 1 should be carefully evaluated. Revegetation on steep slopes requires committment by the operator and extensive monitoring to assure success.

8. 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.

9. 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.

10. Dumps should be designed for regional factors which may include:

a. High winds (when fines are present)
b. Snow
c. Flash flooding
d. Earthquakes
e. Poor foundation characteristics

11. 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.

12. 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 AO.

Some References for Factor of Safety Calculations

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.

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

C. SURFACE AND GROUND WATER MANAGEMENT

1. 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:

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

- 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.

2. 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.

3. 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.

4. 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 in Table VIII-1.

TABLE VIII-1
TYPICAL COMPONENTS OF A
WATER MONITORING PROGRAM

- 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.

5. <u>Water Re-Use</u>

If a closed-circuit system can be approached or attained, then discharge of effluent can be reduced or eliminated. The principal components of closed recycle systems are treatment ponds for mine water and mill effluent, and associated pumps.

Re-use is complicated by the quality of water required for mining and processing. For example, multi-stage milling circuits using flotation reagents in sequence, can suffer from reagent buildup interfering with the flotation process. Treatment of non-reusable waters must be addressed in the plan.

A technique predominantly used in arid regions is the use of evaporation ponds to reduce waste volumes. This can significantly reduce the volume to be treated by other means. Disposal of residues is an important consideration and may contribute to hazardous waste problems.

6. Specific Contamination Problems

Since most States have adopted water quality criteria, the design of sediment control structures should be based on the removal of solids to meet specific state water quality standards. The designs should be referenced to a specific storm event. It is recommended that at a minimum, sediment ponds should be designed with excess capacity to retain the volume of water and sediment contributed from a 24 hour-10 year precipitation event, or to State standards where the state requirements are more stringent. The various standards consider all or some of the following parameters as being important with respect to surface and underground mining activities:

a. Total suspended solids.

b. pH (acidity or alkalinity).

c. Total dissolved solids.

d. Inorganic pollutants (toxic materials and heavy metals).

e. Organic pollutants and toxic organic material.

f. Oils, greases, and solvents.

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

D. ACID MINE DRAINAGE

Most acid mine problems have the same origin: oxidation of sulfide minerals. Water entering mineralized zones by infiltration, and oxygen entering by diffusion and convection, support bacteriologically catalyzed chemical oxidation of the pyritic material. This 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 will engender a problem with heavy metals. 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.

Acid mine drainage (AMD) is generally related to the following:

- Any deposit containing sulfide minerals, particularly iron sulfides, or their salts is a potential source of AMD. There is some evidence that size affects reactivity, e.g. microscopic pyrite is more reactive than massive pyrite.Acidification can occur at virtually all points of mining and beneficiation, including mining, stockpiling of ore and overburden, run-off from disturbed areas and stockpiles, percolation through mined and reclaimed areas, leaching, and following initial success at reclamation.

- AMD formation starts when sulfide minerals react with oxygen or ferric iron and water. While the AMD formation process is the result of a number of chemical reactions, some of which are catalyzed by the bacteria *Thiobacillus ferrooxidans*, AMD formation can be represented by the following basic reactions:

  $$2FeS_{2(s)} + 7O_2 + 2H_2O \iff 2Fe^{2+} + 4H^+ + 4SO_4^{2-}$$

  $$FeS_{2(s)} + 14Fe^{3+} + 8H_2O \iff 15Fe^{2+} + 2SO_4^{2-} + 16H^+$$

  The oxidation of ferrous iron (Fe^{2+}) to ferric iron (Fe^{3+}) consumes oxygen and may remove dissolved oxygen from water.

Acidic water producing sites may be identified by the following:

- In more extreme 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 can grade from yellow-green to purple or black depending on other metals/minerals mobilized by the acid water and the state of oxidation. In some cases the water itself may be colored.

- Acid waters can be colorless, thus clarity is not always an indicator of low acidity.

- The presence of intermittent AMD in arid settings is usually most apparent following a precipitation event and may be indicated by appearance of:

  - mineral salt blooms in low places such as the toe of mined dumps and ore stockpiles;
  - 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.

- Acid producing soils and spoils may have no substantial vegetative cover and there may be a noticeable lack of insect or small mammal activity.

AMD impacts the receiving environment in the following manner:

- AMD 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 AMD. Below pH 5.0, acid waters are corrosive to metal and concrete structures. Low pH water mobilizes heavy metals increasing toxicity problems. Surface water pollution can be more easily treated than ground water pollution.

- AMD impacts receiving waters by altering, eliminating, or inhibiting diversity of aquatic organisms through either direct chemical effects or by coating stream beds with precipitates. Elevated total acidity, sulfate levels, iron, and total sulfur create a heavy demand for oxygen which rapidly depletes its availability to biotic organisms. Sudden changes in pH can aggravate the problem of base metal toxicity. Freshwater fish can usually survive in pH levels of 5.0 to 8.5, but waters below pH 4.0 are toxic.

AMD can be controlled, but usually not entirely eliminated, in the following manner:

- Mine wastes and ore stockpiles should not be placed in natural drainages. Surface drainages should be diverted away from mine and waste/stockpile areas. Waste materials should be tested for the presence of reactive materials. Pyritic wastes should be promptly buried to minimize oxidation. Wastes should be compacted, sealed with a low-permeability cap, blanketed with soil or soil-like material, and revegetated to reduce ingress of air, and limit infiltration of water while enhancing transpiration. The use of capillary breaks in the waste piles will also inhibit the migration of water and contaminated solutions. A vegetative cover will yield organic acids and matter to the waste providing a metal-complexing source. They also tend to inhibit bacteriological activity and restrict air infiltration. Other techniques, including the addition of a layer of road salt between pyritic wastes and the impermeable cap, or the use of surfactants and bactericides, such as Promac, should be investigated for extreme cases. Any leached salt tends to inhibit *Thiobacilli* activity. The work done at the Rum Jungle mine in Australia provides a good example of these techniques. (Ryan, Peter, "Rum Jungle Mine Rehabilitation - Northern Territory, Journal of Soil Conservation)

- Underground workings may be allowed to flood if subsequent ground water movement can be restricted and hazards are not created by doing so. Without the influx of additional groundwater, the flooded works will become a chemically reducing environment, which will inhibit pyrite oxidation. See Chapter IX on "Closure of Underground Mine Access" for more details.

- Constructed wetlands may provide some benefit in removing some of the iron in AMD and potentially add alkalinity to effluent as a result of metal uptake and acid consumption by the plants. The use of constructed wetlands to remove other metals from AMD is still in the research stage. Two of the important questions to answer involve bioaccumulation of toxic metals and toxicity of metals in the AMD to the bacteria involved in the treatment mechanisms.

- If possible, impound to contain, re-use after proper conditioning, or evaporation can be used to reduce volume of AMD. Untreated AMD can yield compounds upon evaporation which will again form AMD upon contact with water. Direct treatment of AMD usually involves the addition of alkaline reagents such as lime, soda ash briquettes, or sodium hydroxide, often followed by aeration. There are a variety of schemes and equipment that can be employed to treat AMD, ranging from the passive and relatively inexpensive to capital and operation/maintenance intensive methods. The final product of these treatment operations is a hydroxide and/or sulfate sludge that must be disposed of. The metals in these sludges have the potential to be redissolved upon pH depression. The stability of the sludges is dependent on the final disposal environment, as well as the process and alkaline reagent used to create them.

- It may take several years before beneficial effects of AMD control measures are reflected in reduced acid and heavy metal content in receiving waters.

- The Bureau of Mines has conducted years of AMD control research and should be consulted in developing mitigative actions.

E. ALKALINE AND SALINE MINE 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 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 materials 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.

F. HEAVY METAL POLLUTION

The heavy or base metals are those with a density greater than 5.0 and comprise 38 elements in total. Not all are significant to mining situations. Some of the elements of concern include zinc (Zn), copper (Cu), lead (Pb), cadmium (Cd), and mercury (Hg). At even extremely low concentrations, some metals are lethal if regularly ingested. Reclamation of the potentially toxic sites should include measures to stabilize the wastes and prevent both wind and water erosion.

Material that will comprise mine wastes should be sampled and analyzed for heavy metal content and mobility under anticipated weathering conditions and interaction with acid or alkaline materials. Heavy metal contamination of soils, spoils, surface waters, and ground water is associated with AMD. An acid problem often indicates a heavy metals problem.

In any specific mining situation, only some metals will be found at hazardous levels. Toxicity, however, may be synergistically enhanced, and should be evaluated through analysis during plan development. One or more metals will usually be present in concentrations high enough to cause concern if mine waters are acidic.

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

  1. Total phosphorous sample
  2. Total nitrogen analysis (nitrate and nitrite, ammonia total Kjeldahl (organic) nitrogen)
  3. Sedimentation rate assessment
  4. Lake flushing rate
  5. Concentration of chlorophyll A
  6. Other site specific analysis, as needed

- Eutrophication causes may be:

  1. Treated at the source
  2. Treated between the source and the affected body of water, or
  3. Mitigated in the body of water

- Some treatments of eutrophication source material at minesite are:

  1. Shaping, contouring, establishing topsoil, and revegetation to reduce siltation
  2. Establishing new wetlands to filter out undesirable nutrients, contaminants, and sediment
  3. Avoidance of over fertilizing for revegetation

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

  1. Establishing new wetlands
  2. Rock or sand bed filtration
  3. Overland flow through vegetated areas with similar filtering as wetlands, such as meander loops

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

  1. 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.)

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

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

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

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

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

H. 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.

    1. Oxygen supersaturation of surface water by day caused by algae

    2. Oxygen depletion of surface water by night caused by algae

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

    4. 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).

  1. Algae reduction techniques
  2. Flushing
  3. Pyrite buffering
  4. Possible elimination of bottom browsing fish

I. 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.

J. CYANIDE HEAP AND VAT LEACH SYSTEMS

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 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 includes cyanide detoxification of residual process solutions, ore heaps, tailings impoundments, and 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. <u>Cyanide Solutions</u>

A key to reclamation of cyanide facilities is planning for the solution neutralization process. The first step is to set a detoxification performance standard. This will have to 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. BLM may need to require more stringent standards if sensitive resources are present. 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, should be specified for detoxification of 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 waters. 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:

a. Natural Degradation and Fresh Water Rinse

If enough time is available, natural degradation has alot of advantages for detoxification of cyanide facilities. 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.

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.

b. Alkaline Chlorination

Alkaline chlorination is the most widely recognized destruction technique used in the mining industry in terms of engineering expertise and operating experience. 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 compounds present can be toxic to aquatic life and to vegetation in land application areas. Dechlorination of discharge waters may be necessary.

<u>Advantages of Alkaline Chlorination</u>

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

(2) Reaction reasonably rapid. Suitable for emergency use.

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

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

(5) Most metals complexed with cyanide are precipitated as hydroxides.

(6) Chlorine is readily available in several forms.

(7) System adaptable to either continuous of batch operation.

(8) Process can be used for slurries and for clear solutions.

Disadvantages of Alkaline Chlorination

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

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

(3) Complexed iron cyanides are not removed.

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

c. 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.

<u>Advantages of Sulfur Dioxide/Air Process</u>

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

(2) Suitable for batch or continuous treatment.

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

(4) Heavy metals are removed through precipitation.

Disadvantages of Sulfur Dioxide/Air Process

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

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

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

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

(5) Strict control of process pH is required.

d. 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.

Advantages of Hydrogen Peroxide Process

(1) Process relatively simple in design and operation.

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

(3) Heavy metals are significantly reduced through precipitation.

(4) The process is adaptable for batch and continuous treatment operations.

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

(6) Close pH control is not required provided an alkaline pH is maintained.

(7) The process does not produce high quantities of waste sludge.

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

Disadvantages of Hydrogen Peroxide Process

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

(2) High reagent dosages required to remove ammonia and thiocyanate.

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

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

e. 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).

Advantages of Ferrous Sulfate Complexing

(1) Reagent costs are low.

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

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

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

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

Disadvantages of Ferrous Sulfate Complexing

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

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

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

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

f. 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.

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).

g. 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 desireable, but difficult to acheive. 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. Retreatment 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 any 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.

2. <u>Spent Ore Heaps and Tailings</u>

a. 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 a 10 to 20 foot column test 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 material has a net acid generating capacity. If this is the case then the measures to prevent development of acid mine drainage need to be incorporated into the reclamation plan.

b. 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 detoxification 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.

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) are 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 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.

c. Shaping and Revegetation

After detoxification is complete, 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 cvanidated material. This could cause direct precipitation recharge and generate undesirable leachate from retained cyanide or metals that were not removed during 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. 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 Chapter XII for topsoil and revegetation guidance).

d. 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 are 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.

3. <u>Process Ponds</u>

a. Solution removal

Cyanide solutions are removed from the process ponds, treated, and disposed of as part of overall mine reclamation as discussed in item J1.

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.

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.

IX. CLOSURE OF UNDERGROUND MINE ACCESS

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.

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 or use the underground workings. The method of closure may need to be designed to allow for ingress and egress of small animals.

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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. 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.

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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. <u>Permanent Closure</u>

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 and according 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 reopened 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 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:

a. Detailed description of the proposed method of closing the shaft.

b. 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.

c. 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.

a. 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.

b. Hydrologic 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.

c. Engineering report of shaft construction inc all physical dimensions, (vertical cross sec plan view), materials, thickness of shaft li utilities present, obstructions, elevation o collar, total depth, and all landings, prese structural condition, and shaft pillar size.

d. Historical report of when construction began shaft, problems encountered, when it was com what its purpose was (e.g., ventilation, ore hoisting, supplies, man cage, emergency exit and location of other mines in the surroundi

After thorough investigation, the AO shall appro writing the method of closure after consultation with th management agency, the surface owner, the appropriate St agency, other Federal agencies and the operator. At a m the AO should require the following:

a. Incombustible fill material;

b. Isolation of aquifers;

c. Closures and caps of reinforced concrete anc competent rock by keying, or adequate mechan means; and,

d. A permanent brass or aluminum plug giving th case number, company name, and date of closu

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

D. SAFETY NOTES

Underground workings which are not actively being mined should only be entered when absolutely necessary. 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.

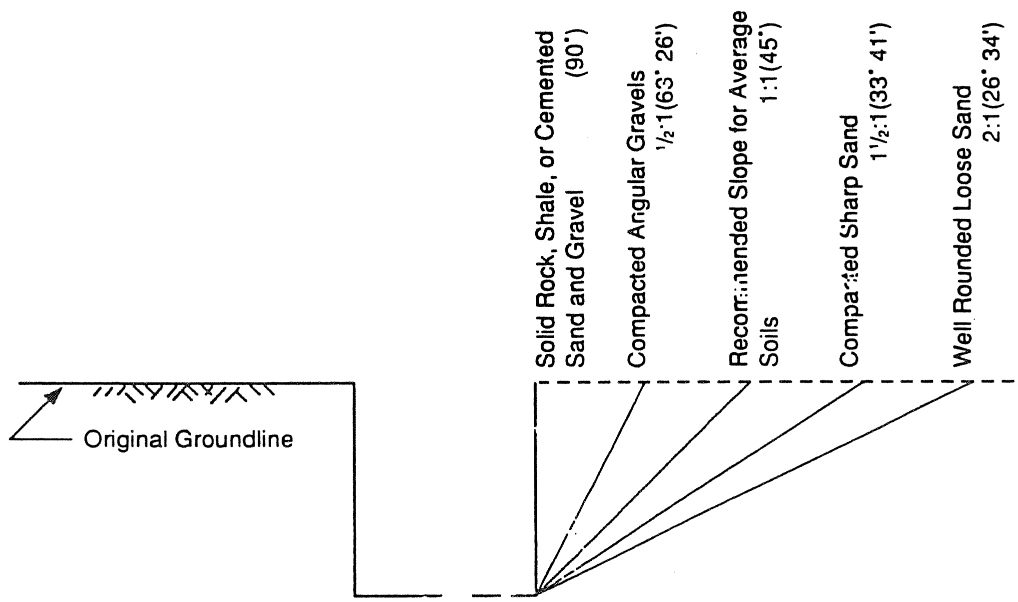
1. Personal Safety Precautions

Persons engaged in underground mine access closure projects or in searching for old shafts and workings should be ever mindful of their own safety. 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 should 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

At any open shaft it is necessary to provide fences or guards to protect personnel and plant from falling into the shaft and from other dangers (for example suction and blast during filling). In addition it is necessary to ensure that all operations are carried out from stable ground (Figures IX-1 and IX-2) and that any necessary precautions are taken to deal with possible mine gases.

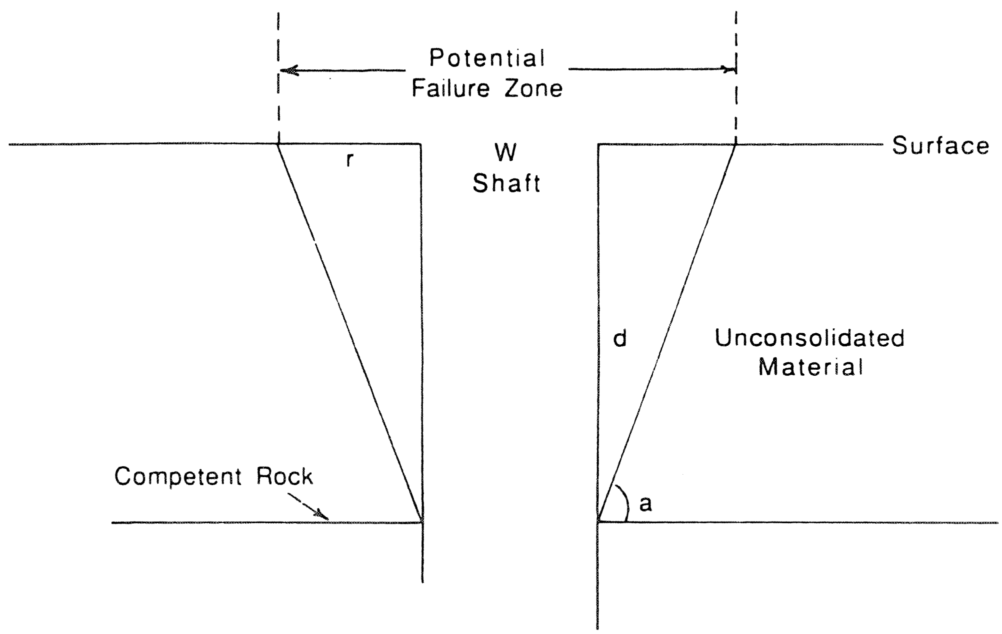
Figure IX-1
Approximate Angle of Repose for Sloping Sides of Excavations



Note:
The Angle of Repose is measured from the horizontal.

SOURCE: 29 CFR 1926.652

Figure IX-2
Use of the Angle of Repose for Determination of the Potential Failure Zone



Potential Failure Zone = 2r+W Where:

W = Average Width of Shaft
r = Failure Radius = d/tan a
d = Depth to Competent Rock
a = Angle of Repose For Material Type Present at Site

SOURCE: D. G. Simpson and M. Kuhns (1989)

3. Ground Stability

The factors influencing the stability include:

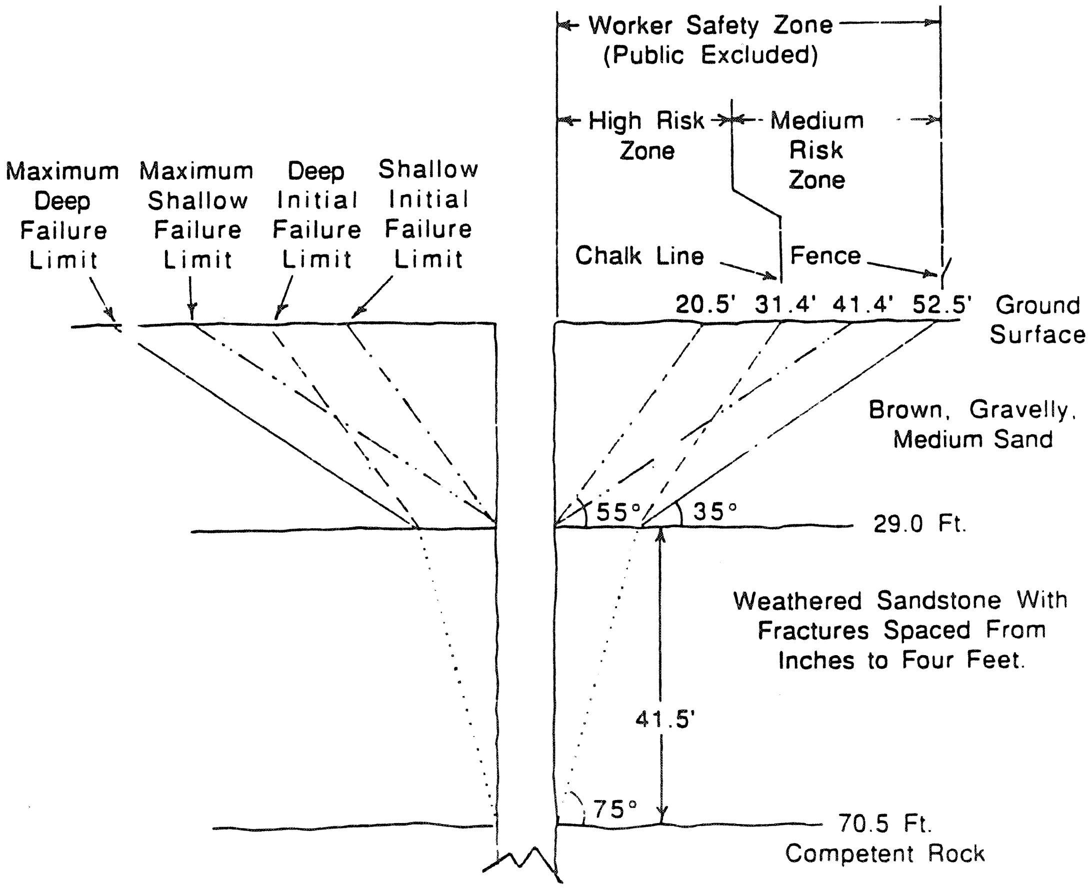
- nature of superficial deposits;
- groundwater levels;
- depth of firm bedrock;
- existence of shallow workings;
- other possible voids, for example, concealed ventilation drifts;
- strength and condition of the shaft lining.

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.

Figure IX-3
Worker and Public Safety Zone Calculations



<u>Calculations for Failure Limit:</u>

Shallow Initial Failure Limit = 29/tan 55° = 20.5'
Deep Initial Failure Limit = 41.5/tan 75° + 29/tan 55° = 31.4'
Maximum Shallow Failure Limit = 29/tan 35° = 41.4'
Maximum Deep Failure Limit = 41.5/tan 75° + 29/tan 35° = 52.5'

SOURCE: D. G. Simpson and M. Kuhns (1989)

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.

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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

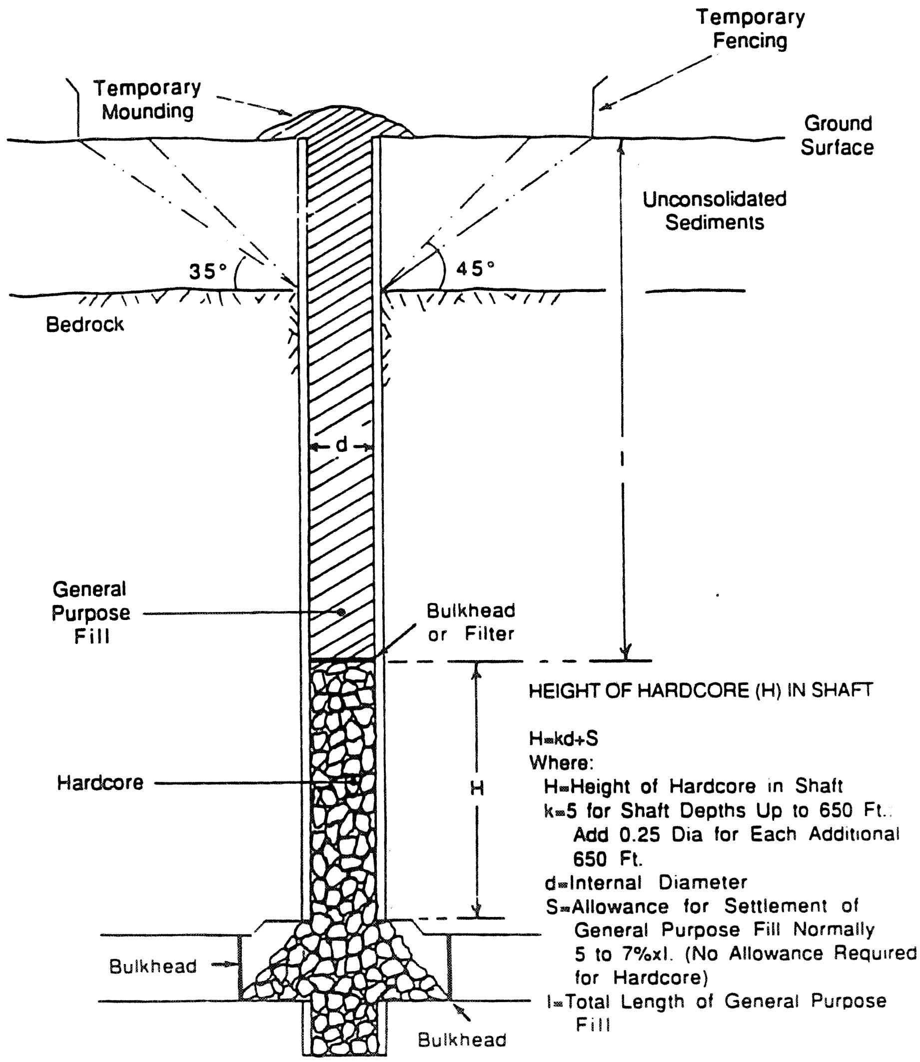
For shafts with shallow sumps, controlled filling should be commenced with hardcore and brought above the roof of the shaft bottom roadways to a height equal to not less than five diameters for shafts up to 650 feet deep. Additional fill equivalent 0.25 diameters for every additional 650 feet of depth 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.

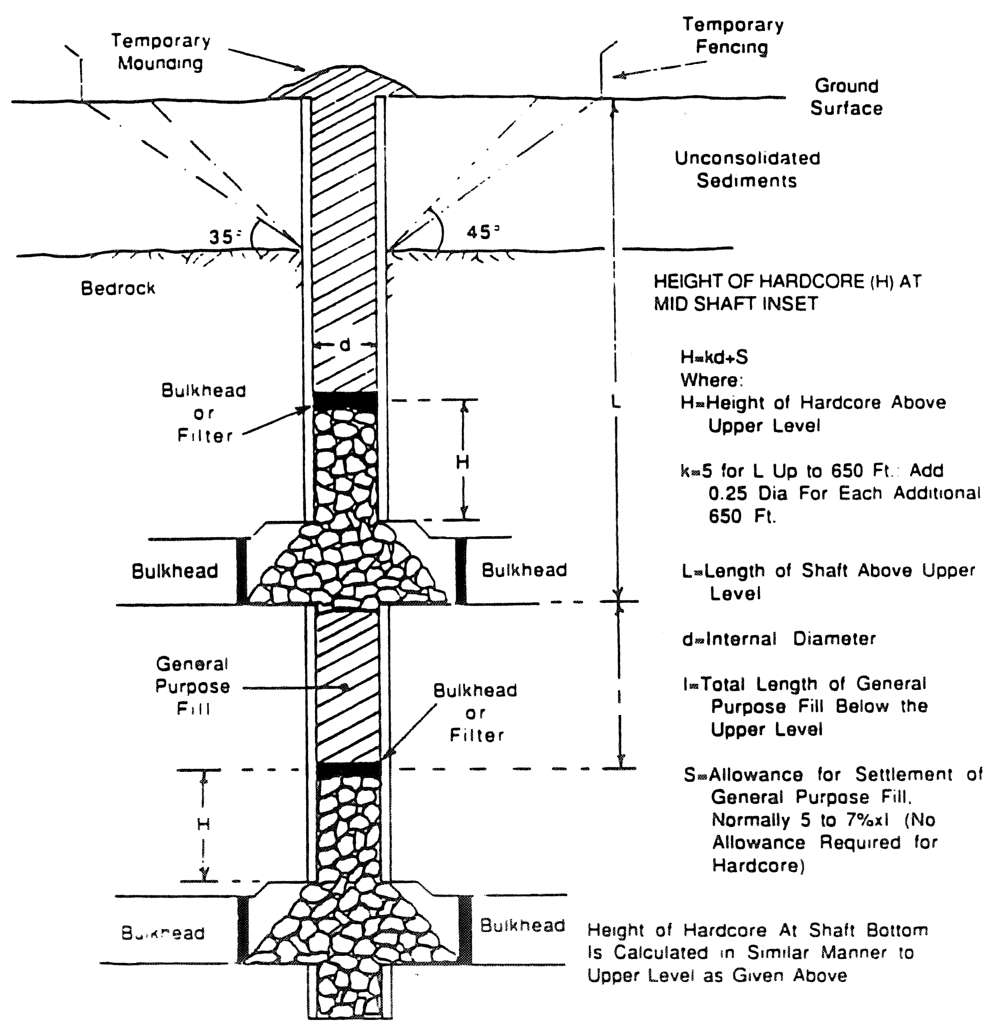
Figure IX-4

Figure IX-4
Controlled Backfill



Source: National Coal Board (U.K.)

Figure IX-5
Multi-Level Controlled Backfill



Source: National Coal Board (U.K.)

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. <u>Enclosures</u>

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. <u>Covers</u>

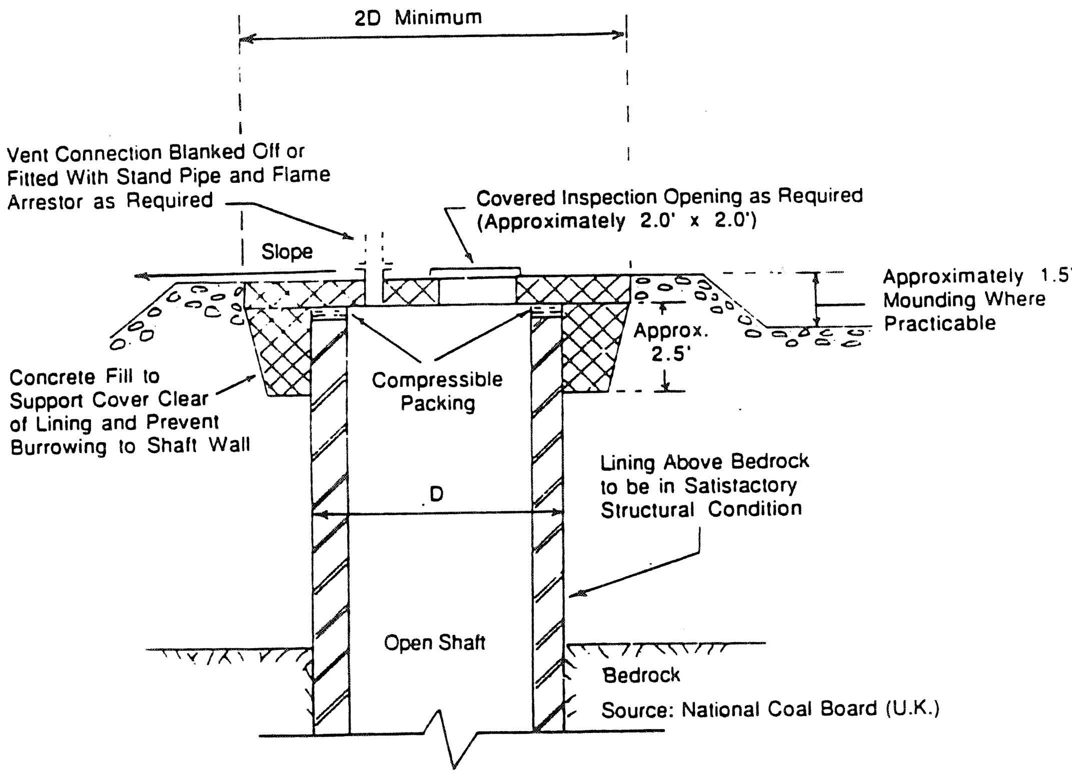
Covers are intended to prevent the accidental entry of persons and illegal dumping into an unfilled shaft but are not designed to protect the surface against subsidence by cratering. Generally, covers should not be used as permanent mine closures. Only backfilling will permanently support shaft lining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

Figure IX-6

Figure IX-6
Light Duty Shaft Cover



Typical Constructions (to Carry Superimposed Load of 270 Lbs./Ft.^{2})
For Covers to Be Used Only Within a Secure Enclosure
- In-Situ Concrete Slab Strength = 4350 psi
- Pre-Cast Concrete Beams and Topping
- Steel Sections and Plating (Limited Life)
- Steel Sections and Heavy Timbers (Limited Life)

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.

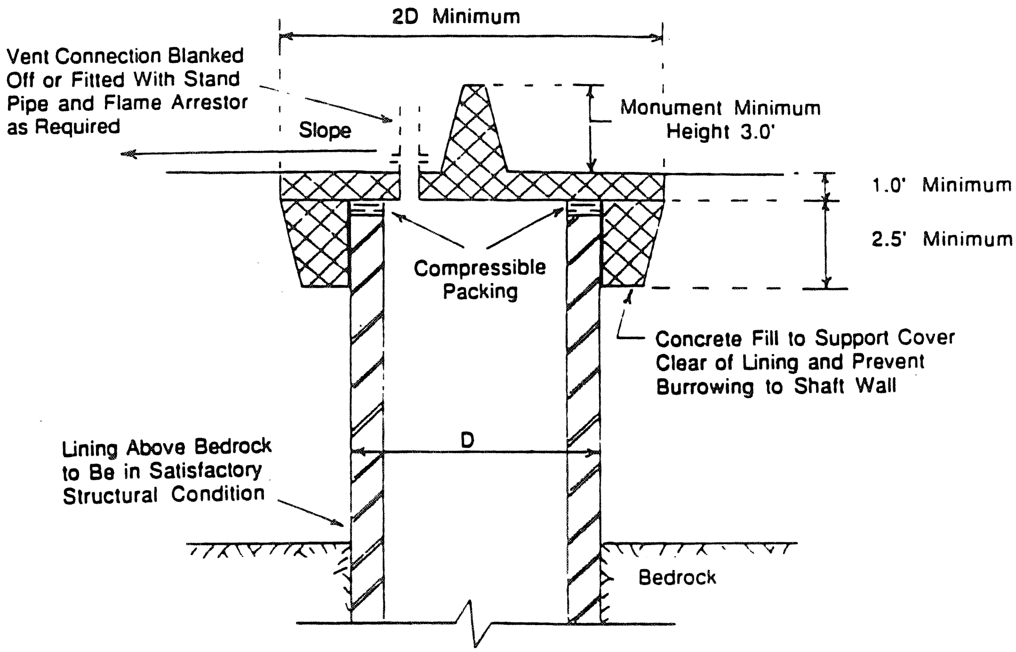
4. Caps

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).

Format Corrected in Chapter 9

Figure IX-7
Heavy Duty Shaft Cover

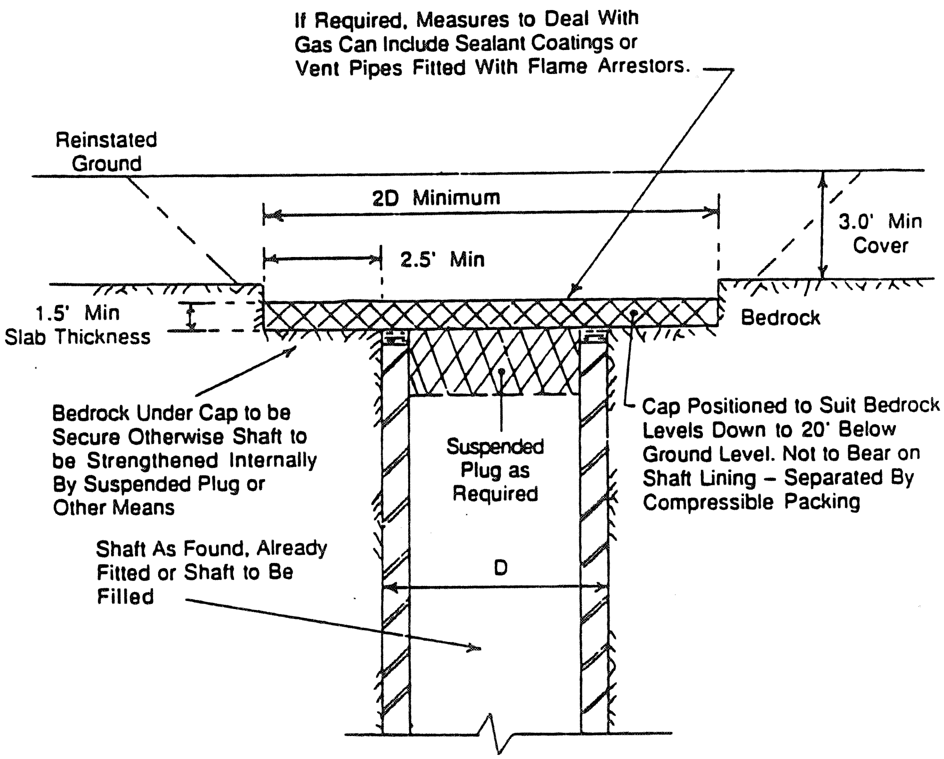


Notes:
- Cover Designed for Superimposed Load of 700 Lbs./Ft.^{2}
- Reinforced Concrete Slab Strength 4350 psi, Concrete Minimum Thickness 1.0'.
- Cover to be Marked With Shaft Reference Number Diameter and Depth, and Monument to be Positioned Centrally.

Source: National Coal Board (U.K.)

Figure IX-8

Figure IX-8
Shaft Cap, Shallow Bedrock



Notes:
- Cap Designed for Overburden Plus Superimposed Load of 700 Lbs./Ft.^{2}
- Reinforced Concrete Slab Strength 4350 psi. Concrete Minimum Thickness 1.5'.
- Reinforcing Bars to be Not Less Than 1 5/8" Diameter and to Have Not Less Than 4 Inches Cover.
- Cap to be Marked With Shaft Reference Number, Diameter and Depth, and Position of Shaft Centre.

Source: National Coal Board (U.K.)

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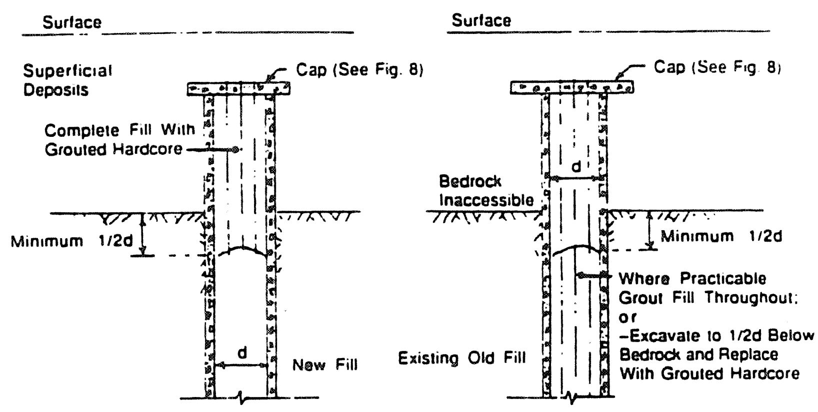
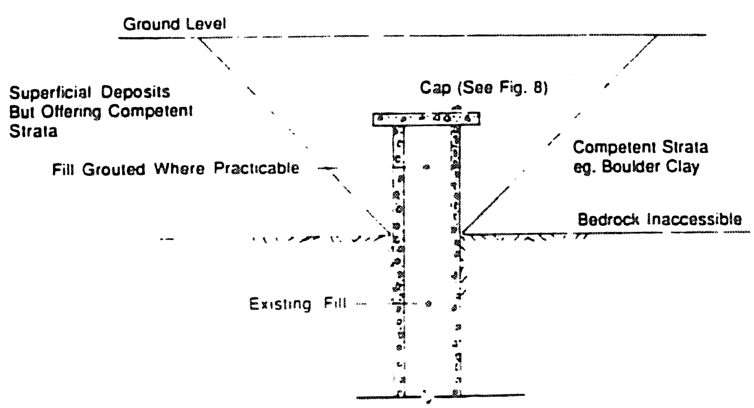
Figure IX-9
Shaft Cap, Deep Bedrock



(A) Untreated Shaft

(B) Old Filled Shaft (Possible Limited Disturbance of Site Acceptable)

d = Shaft Diameter



(C) Old Filled Shaft (Competent Strata Available Above Bedrock)

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.

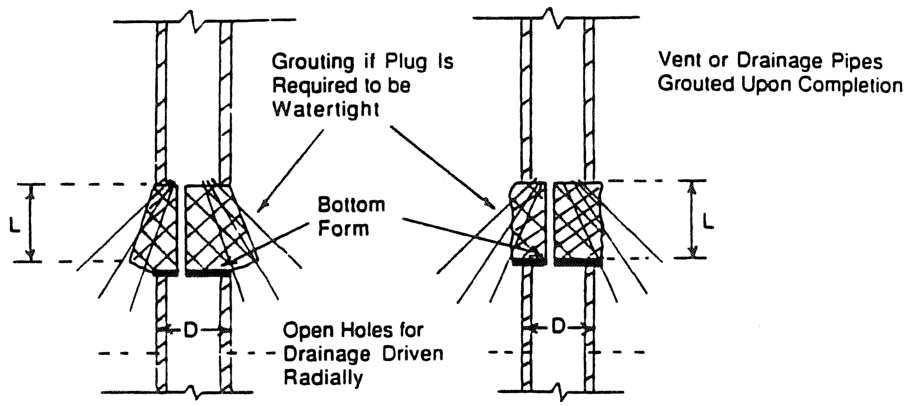
Figure IX-10 illustrates three types of shaft plugs for horizontal strata. Figure IX-10(A) shows the traditional conical shape where the load is carried by the strata in direct compression. The volumes of excavation and concrete needed and, if required, rock to be grouted are considerably greater than 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.

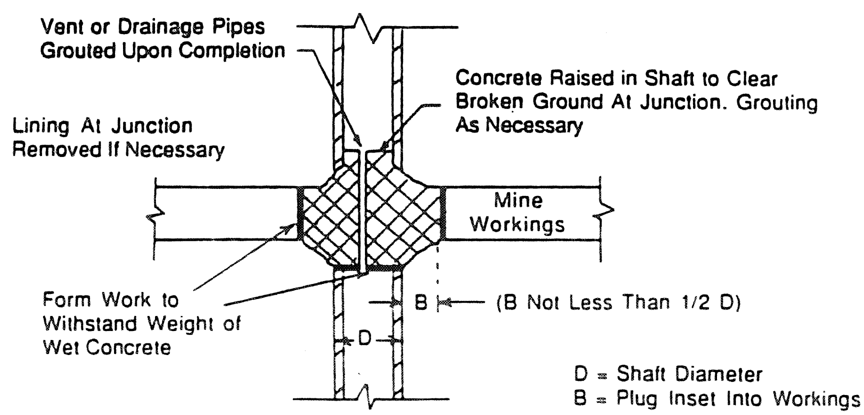
Figure IX-10

Figure IX-10
Shaft Plugs



(A) Conical Plug

(B) Parallel Plug



(C) Inset Plug

Notes:
- Length (L)=D But Need Not Exceed 12 Feet.
- Concrete Strength, 4350 psi, Reinforced As Required
- Ventilation and Drainage Pipes Provided As Necessary During Construction.

Source: National Coal Board (U.K.)

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.

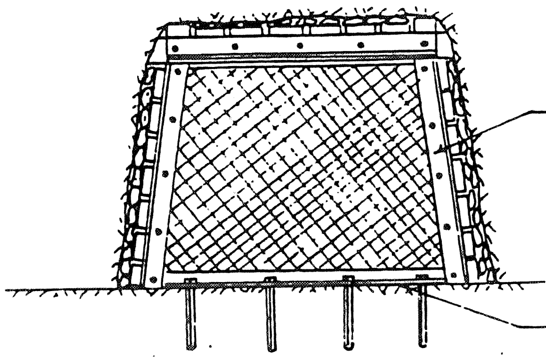
In some circumstances it may be necessary to design a plug for possible uplift pressures caused by water from the mine rising within the shaft.

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.

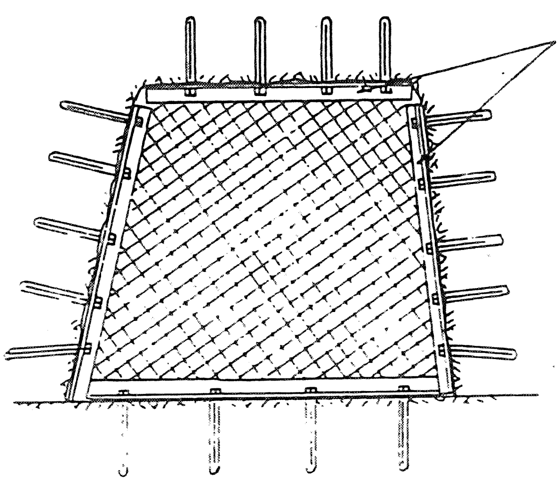
6. <u>Roadway Stoppings and Dams</u>

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.

Figure IX-11
Temporary Adit Closure



Typical Timbered Opening

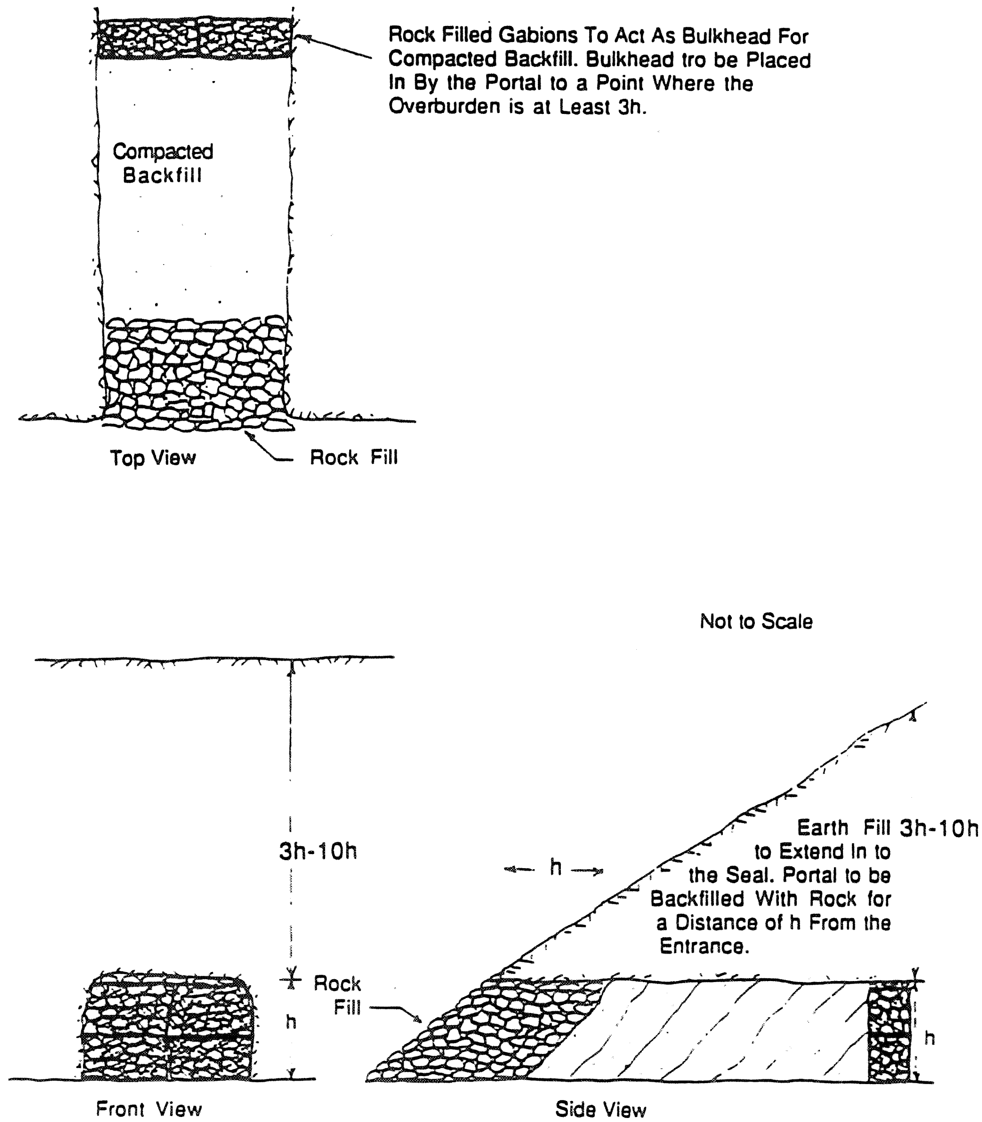


Not to Scale

Typical Non-Timbered Opening

Source: A. Vance, BLM Utah

Figure IX-12
Permanent Adit Closure



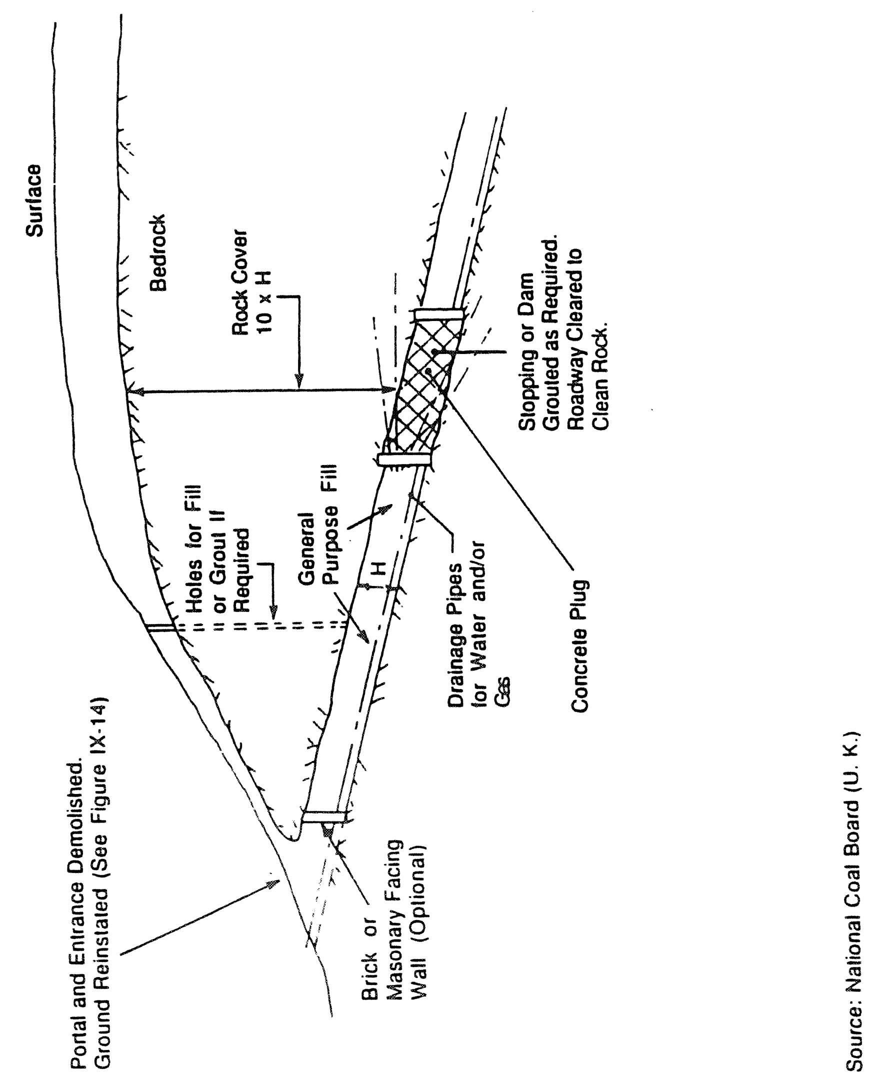
Source: Adapted From Drawing by A. Vance, BLM Utah

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 inby with a stopping at the shaft. Where access to the inby 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.

Figure IX-13
Permanent Slope Closure



Source: National Coal Board (U. K.)

X. REMOVAL AND RECLAMATION OF SURFACE IMPROVEMENTS

A. INTRODUCTION

In each exploration, mining or processing operation, some impacts on the land are caused by improvements such as buildings, storage sheds, plants, water tanks, etc. Complete reclamation of the site requires removal of these improvements unless an appropriate secondary use is anticipated in the reclamation plan, in the RMP or other land-use planning documents, or in consultation with the AO.

B. FACILITY REMOVAL

Provisions should be included in each reclamation plan to deal with removal of unnecessary facilities at end of mine life. Consider the following when addressing the reclamation of such improvements:

1. Identify facilities that will be removed or retained during period of interim shutdown and any facilities that may be retained upon permanent closure.

2. Identify facilities that have potential to create environmental liability or problems and ensure they meet state and Federal environmental protection requirements. These may include:

   - fuel tanks
   - surface storage tanks
   - chemical, drilling additive and explosive storage areas
   - shop and service areas (including areas where tires, lubricants, coolants, etc. may have been disposed)
   - openings to underground workings
   - unused machinery and equipment
   - septic systems
   - contaminated concrete pads and building foundations, and,
   - transformers (which may contain PCBs).

Coordinate with BLM Hazardous Materials coordinator to ensure proper removal, disposal, and necessary remediation.

3. Removal of underground storage tanks (USTs) must be in compliance with EPA and other applicable Federal, state, and local regulations at the earliest feasible time. Reclamation and remediation of the site should be completed in accordance with applicable EPA requirements and this handbook. Coordinate with BLM State Office or District Office engineering staff.

4. All foundations and paving associated with buildings and facilities to be removed should be broken up. Materials found to be in conformance with State and Federal requirements can be used for reclamation fill material, buried onsite, or removed. The location of the materials should be accurately documented. Any contaminated materials must be disposed of as necessary under applicable State and Federal requirements. The disturbed area should be reclaimed in accordance with all the applicable sections of this handbook.

C. POWERLINES AND COMMUNICATION LINES

Reclamation of powerlines and communication lines in some cases comes after other reclamation has been accomplished. To accomplish reclamation of powerlines, remove all towers, poles, cable, guy wires, and anchors. Reclaim access roads and revegetate in accordance with Chapter XII of this handbook. Where appropriate, a secondary use for some of the towers or poles would be for raptor nesting or roosting sites. This secondary use should be coordinated with the BLM biologist.

D. PIPELINES

Where pipelines are needed, ensure that they do not create unacceptable risks to environmental values. Where substantial environmental or human risk exists, periodic testing should be required, and malfunction alarms, and automatic block valve shutdowns should be installed.

Pipelines used in mineral operations vary greatly in size and material. Surface or buried pipelines create environmental impacts. For reclamation, surface pipelines should be removed. Any resulting berm or unvegetated areas should be revegetated in accordance with Chapter XII of this handbook.

Buried pipelines which did not transport hazardous materials should be left in place to minimize surface disturbance. Consideration should be given possible corrosion and long-term stability of all pipelines left in place. Failure or collapse of the pipeline could create subsidence and erosion problems. Access to the pipeline should be closed to eliminate hazards to birds and other small animals, and for large pipelines, to people and larger animals.

If a pipeline was used to transport hazardous materials, it must be cleaned and detoxified. The cleaning material must be disposed of properly and in accordance with existing regulations. An effort such as this should be conducted with the assistance of the appropriate BLM hazardous materials coordinator. The pipeline may then be removed, or if buried, left in place.

XI. LANDFORM RECLAMATION

A. INTRODUCTION

Shaping, grading, erosion control, and visual impact mitigation of an affected site are important considerations during review of the reclamation plan. The review process not only ensures that the topography of the reclaimed lands blend in as much as possible with the surrounding land forms, natural drainage patterns, and visual contrasts, but also enhances the success of revegetation. The principles and standards presented in this section of the handbook should be used in close conjunction with the sections on hydrology and revegetation.

B. SHAPING, GRADING, AND EROSION CONTROL

The final land form should:

- be mechanically stable
- promote successful revegetation
- prevent wind and water erosion
- be hydrologically compatible with the surrounding landforms, and
- be visually compatible with the surrounding landforms

The operator should not steepen slopes unnecessarily during the shaping process. Steep slopes are difficult to traverse with revegetation equipment and are highly susceptible to erosion, slumping, and landslides. Where practical, consider shaping the disturbance to a 3:1 slope (H:V) or flatter to enhance the success of revegetation. The angle and length of slopes can adversely affect the run-off velocity and increase erosion.

Final waste dump grading prepares the spoils for topsoil application and the grading work is usually accomplished using dozers, scrapers, or similar earth-moving equipment. Deep rip the shaped site prior to application of the topsoil or other suitable growth medium to eliminate compaction, to increase infiltration, and to provide for water retention reservoirs. Compaction of the wastes under the topsoil can cause problems even if the topsoil bed is loose. Plants that root in loose topsoil but can not penetrate the spoils under the topsoil, can be subject to soil-induced moisture or physical stress. Always rip on the contour to reduce the effects of surface run-off erosion.

Where large waste embankments are involved, see Chapter VIII on Mine Waste Management for more detail. Depressions which will accumulate surface water on the top surface of waste dumps or benches should be avoided unless they are planned as a part of meeting reclamation objectives. Accumulated water which is not planned for can supersaturate the wastes and cause slumping or dump failures and piping. The top surfaces of waste dumps, or other elevated flat portions of mined out areas should be graded inward from the outer rim toward drainage channels to limit overflow of the rim. See Figure XI-1.

Reapply topsoil, selected subsoil, or other suitable growth media to the shaped surface per the guidelines outlined under the Section on Topsoil Salvage and Reapplication and smooth or grade the growth medium to meet the reclamation requirements.

1. Shaping and Grading Checklist

The mine operator, and if possible, the equipment operator should be included in discussion on reshaping, which addresses:

a. Save topsoil or other suitable growth media to respread after shaping.

b. Determine what landform is most desirable to meet post-mining land use; evaluate angle of repose versus 3h:1v slopes, etc. Flatter is not always better; length of slope affects water velocity, erosion, and infiltration. Terracing and benching may be used to limit the length and angle of the slope and thus enhance the chances of revegetation success.

c. Reshape to a visually compatible contour.

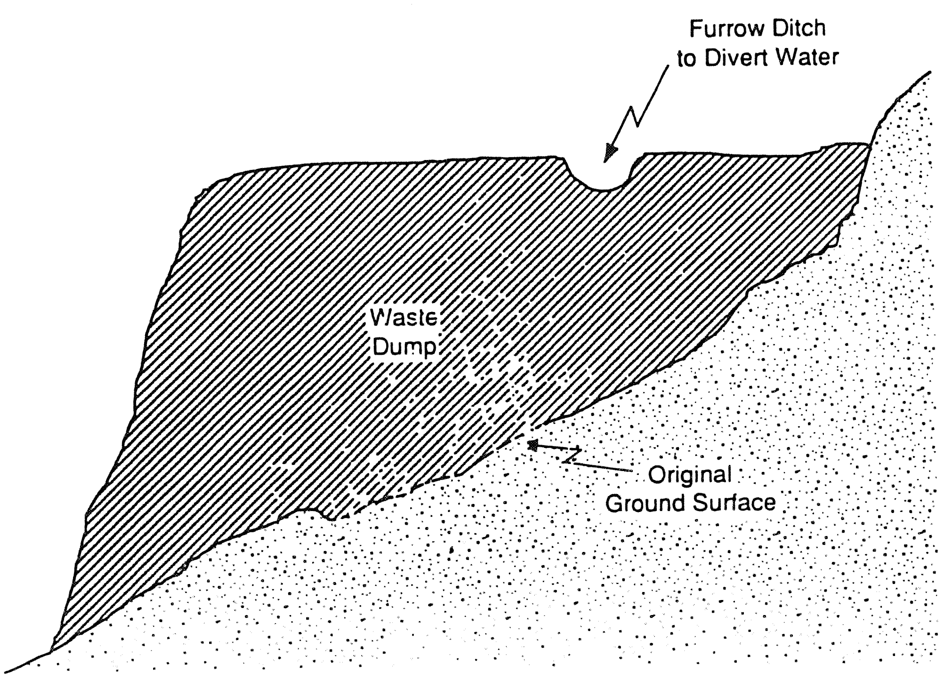
d. Do not steepen slopes in shaping. This may cause slope failure.

e. Do not create ponds or depressions that will accumulate surface water unless they are planned and engineered for a specific purpose which is compatible with ultimate reclamation goals.

f. Leave graded surfaces somewhat roughened to trap seed, slow runoff, and provide favorable micro-climates for revegetation.

Figure XI-1

Figure XI-1
Top of Waste Dump Configuration



g. Provide for internal and external drainage of treated areas.

h. Consider long-term mass stability and safety requirements. Where large tailings sites or waste embankments are involved, get review and input from a geotechnical engineer. Characteristics of material and types of equipment need to be considered.

i. Be aware that large dozers can push fill material uphill on a 40-percent slope; beyond 40 percent their efficiency is very limited. See Figure XI-2.

C. PIT BACKFILLING

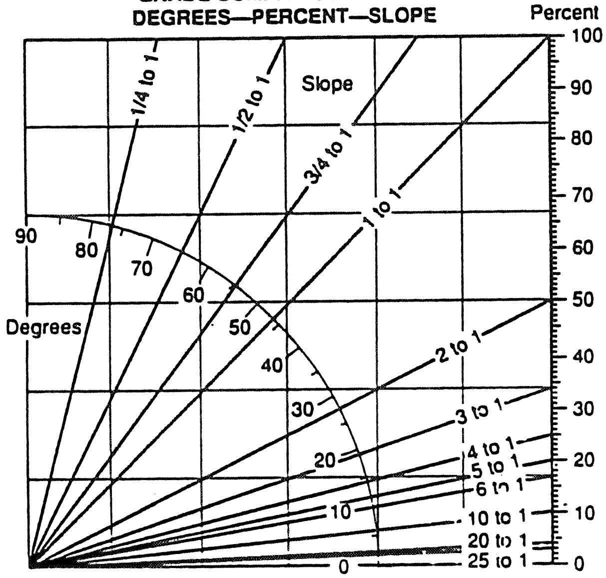
Pit backfilling provides an effective means for reclamation of the disturbed lands to a productive post-mining land use. However, development of some commodities and deposit types may not be compatible with pit backfilling. Additionally, some waste material is not suitable for use as backfilling material.

The reclamation plan should describe in detail the proposed backfilling procedures. Pit backfilling, where technologically and economically feasible, should be planned for the purposes of establishment of the contour of the land consistent with the proposed post-mining land uses and reduction of visual impacts. While pit backfilling may satisfy the post-mining land use and long-term visual impacts, backfilling to original contour may be impossible or undesireable. Visual and land use concerns may be satisfied by shaping of the backfilled material. The reclamation plan should address the mitigation of unique impacts such as re-establishing big game migration routes and the development of features which enhance wildlife habitat.

Reclamation of pits can occur either concurrently with mining or upon completion of the mining phase of the operation. Pit reclamation can result in complete pit backfilling, partial pit backfilling (including scree slope backfilling), highwall slope reduction, or a combination of these. The method chosen for pit reclamation is based upon the long-term land use planning goals for the area, the mitigation of long-term environmental impacts, and the associated need to reduce offsite impacts associated with waste and tailings disposal.

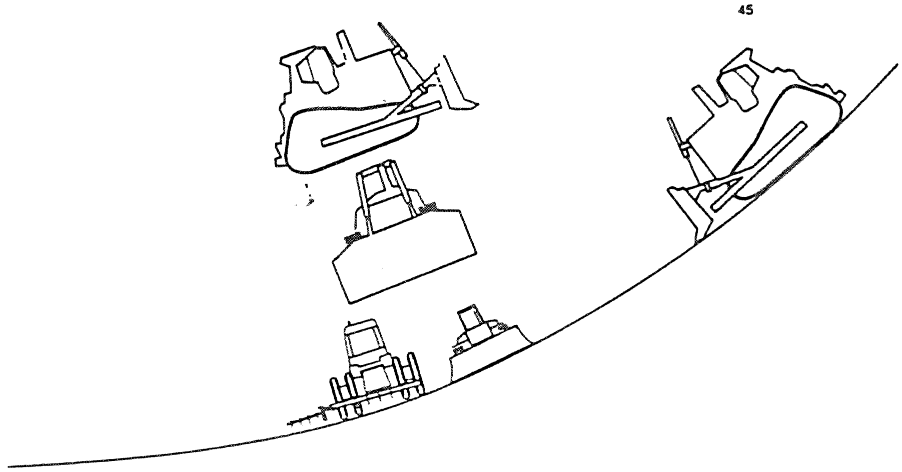
Figure XI-2
Equipment Slope Workability Graph

GRADE COMPARISON CHART
DEGREES—PERCENT—SLOPE



Grade In Degrees and Percents

Degrees	Percent
1	1.8
2	3.5
3	5.2
4	7.0
5	8.8
6	10.5
7	12.3
8	14.0
9	15.8
10	17.6
11	19.4
12	21.3
13	23.1
14	24.9
15	26.8
16	28.7
17	30.6
18	32.5
19	34.4
20	36.4
21	38.4
22	40.4
23	42.4
24	44.5
25	46.6
26	48.8
27	51.0
28	53.2
29	55.4
30	57.7
31	60.0
32	62.5
33	64.9
34	67.4
35	70.0
36	72.7
37	75.4
38	78.1
39	81.0
40	83.9
41	86.9
42	90.0
43	93.3
44	95.6
45	100.0



The reclamation plan should describe in detail the proposed backfilling procedures. Concurrent pit backfilling can be considered as a means to accommodate backfilling to pits during the operational life of a mine. The purpose of this mitigation measure is to backfill as much material as possible in conjunction with project activities, reduce the size of overburden piles, and reconstruct some wildlife habitat in the area of the mine pits. This method for backfilling is generally employed at sites which have multiple pits.

A method of partial pit backfilling developed in an effort to accommodate some pit backfilling without covering the potential future ore resources is scree slope backfilling. The primary objective in this approach is to conceal mining excavations (principally the upper portions of pit walls) from visibility.

1. Special Considerations for Open Pit Mining

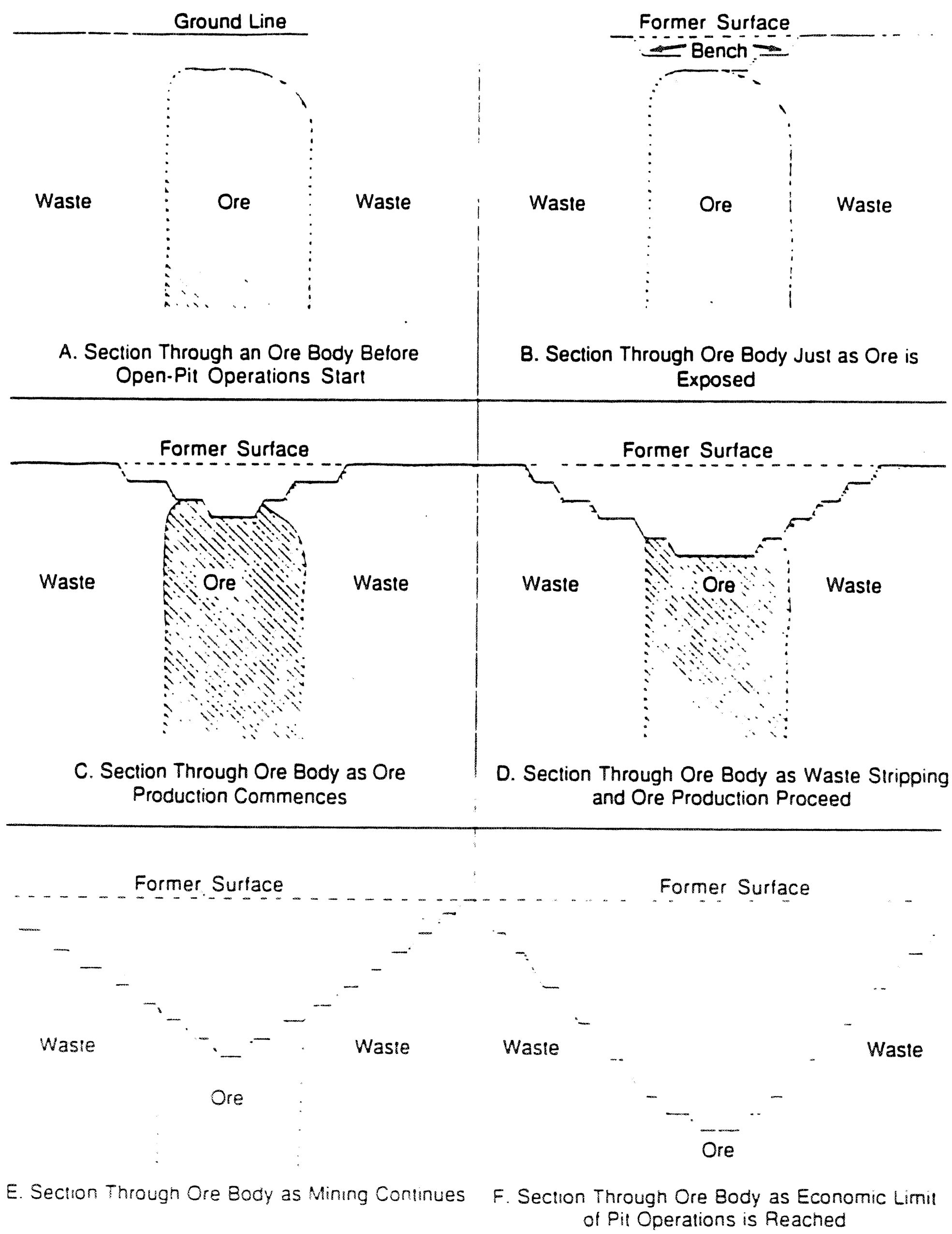
Open pit mine optimization is achieved by extending the pit to the point where the cost of removing overlying volumes of unmineralized "waste" rock just equal the revenues (including profit) from the ore being mined in the walls and bottom of the pit. Because there is usually mineralization remaining, favorable changes in an economic factor (such as an increase in the price of the commodity or new technology resulting in a reduced operating cost) can result in a condition where mining can be expanded, or resumed at a future time. This economically determined pit configuration is typical of the open pit metal mining industry and is of critical importance in efforts to maximize the recovery of the mineral resource.

Figure XI-3 illustrates the "conical" configuration typically used in open pit mining. To recover all the known ore reserves the entire pit must remain exposed through progressively deeper cuts. Backfilling can not begin until the ore reserves within the specific pit are depleted at the conclusion of mining.

Surface strip mining can often accommodate backfilling because the reserves usually occur in the form of a flat-lying bed, at shallow depth over a large spatial area. See Figure XI-4. Accordingly there is no need to stockpile and rehandle the excavated material, except during the first cuts. Under certain circumstances, where multiple pits are being sequentially excavated, it is feasible to backfill one mined-out pit concurrently with mining of a subsequent pit.

Figure XI-3

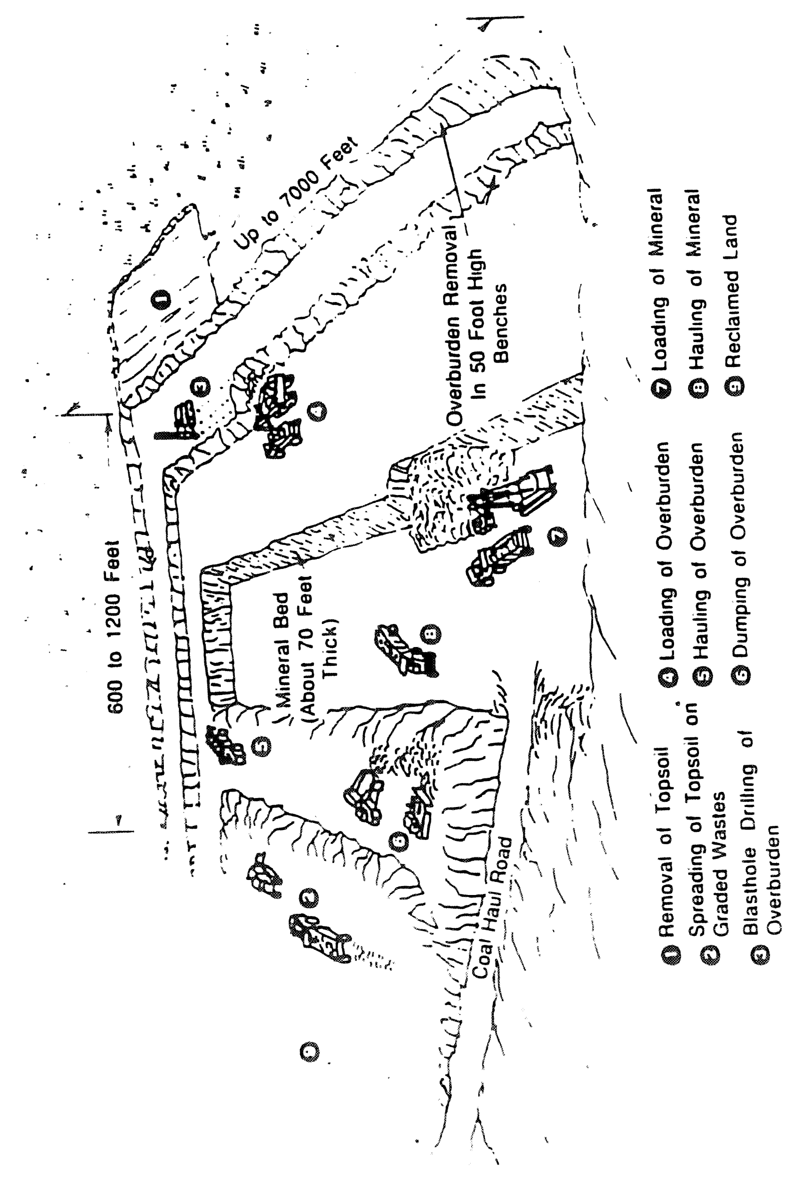
Figure XI-3
Typical Open Pit Mine



Chapter 11

Figure XI-4

Figure XI-4
Surface Strip Mine Backfilling



2. Technical and Operational Aspects of Pit Backfilling

Once an open pit has been mined, it is generally not possible to replace all the material excavated from the pit, or to restore the land surface to its former condition, due to physical constraints. Broken rock occupies a much greater volume than solid rock. As a result of this expansion or "swell factor", all of the rock that has been broken and removed from a pit during mining will not fit back into the pit. As explained by the National Research Council in its report on surface mining of non-coal minerals:

- "...waste and tailings resulting from mining and processing expand an average of about 30 to 40 percent, and very few mines take out enough ore to leave space in the mine workings to backfill all waste and tailings. Thus, even if the huge cost of backfilling were incurred, waste and tailings would still remain on the surface at many mines..."(NRC, 1979)

3. Environmental Effects of Pit Backfilling

Since backfilling procedures involve activities associated with mining (loading, hauling, and dumping of materials), the types of impacts from this are similar to those which occur during mining. Proper backfilling materials handling and placement is dependent upon chemical and physical material characteristics and site-specific considerations. Depending upon the size of the open pit, backfilling can extend the duration of operations from a few months to several years. The potential unavoidable impacts of pit backfilling are summarized as follows.

4. Effects of Complete Pit Backfilling

The primary change from a mining operation that does not include backfilling to one which includes complete backfilling is the extended duration of this project's effects. The benefit of complete pit backfilling is that the final landform will most closely approximate the pre-disturbance conditions.

5. Effects of Scree Slope Backfilling

The primary objective of this alternative is to conceal mining excavations that would otherwise be visible from lower view points. See Figure XI-5. In areas where the topography surrounding the pits is steep, scree slope backfilling requires additional ground disturbance. Therefore, wildlife habitat is impacted because of the need to construct haul roads to the top of the pit high walls.

6. Effects of Concurrent Pit Backfilling

This method is suggested as means to accommodate backfilling of multiple mine pits concurrently during the operational life of the project. This alternative can reduce the size of the overburden piles and reconstruct some wildlife habitat in the area of the mine pits. In most cases this alternative results in no significant increase or decrease in environmental impacts when compared to the alternative of not backfilling the pits.

Concurrent pit backfilling generally can not be used if material from different pits must be simultaneously mined and blended to meet mill feed head requirements. Also, the second pit must be developed for production far enough in advance so that ore from the initial pit can sustain the operation until the second pit is capable of supplying all the ore needed for the process plant.

D. HIGHWALLS

Final highwall configuration, including consideration of overall slope angle, bench width, bench height, etc., should be determined during the review of the plan. The maximum height of the highwall should be determined using site-specific parameters such as rock type and morphology. In most cases, the maximum height is regulated by various State agencies.

1. Reclamation

The normal procedures are to either leave the exposed highwall or to backfill and bury the highwall either totally or partially. It is important that the backfill requirements be determined during the plan review process and included in the approved plan. Some overall guidance for highwall reclamation follows.

Figure XI-5

Figure XI-5
Scree Slope Backfilling

Slope=2 (Horizontal): 1 (Vertical)

a. Shape partially exposed highwalls (above the backfill) when practical. See Figure XI-6.

b. Blasting down the exposed highwall is a practice not generally recommended. Under certain conditions blasting could result in an unacceptable increase in the surface disturbance. Therefore, the impacts of blasting down highwalls should be carefully scrutinized.

c. Where the exposed highwall exhibits a low profile, can be safely worked, and consists of soil materials capable of supporting plant life, it may be possible to hydromulch the exposed highwall using a slurry of water, seed, fertilizer, biodegradable fibers, and a tackifier to keep the mulching in place.

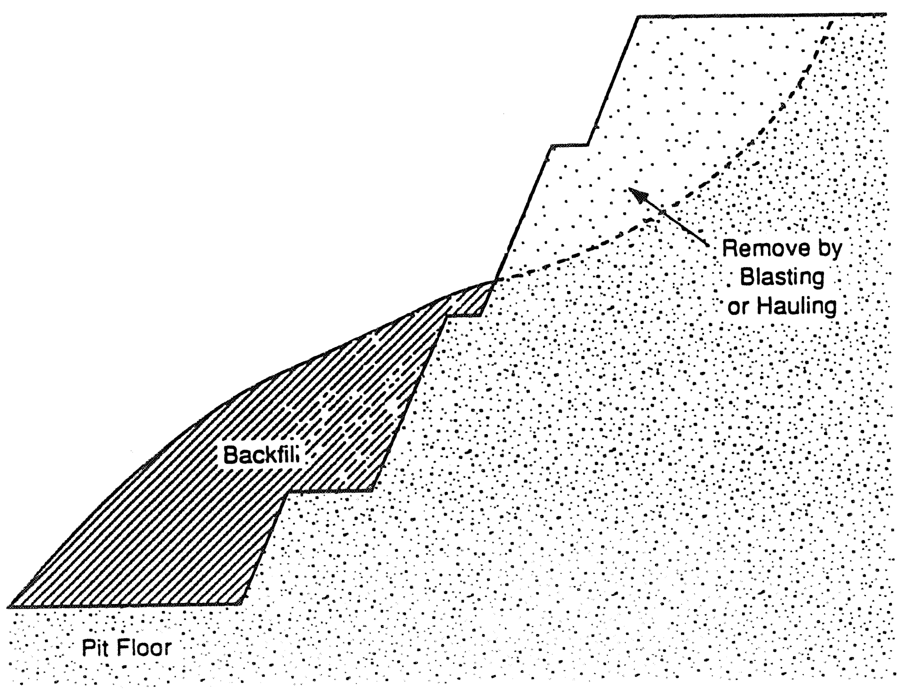
d. Steep highwalls (exceeding 3:1 (H:V)) should be benched to provide a stable slope. This has the additional benefit of creating a niche for vegetation and provides nesting areas for birds.

e. Benching near the top and rounding the edge back will provide a safety feature by reducing the distance of and the chance of falling.

f. Appropriate fencing or berming at the top of the highwall is necessary to abate some of the hazards to people and animals.

Figure XI-6

Figure XI-6
Highwall Reclamation



XII. REVEGETATION

A. INTRODUCTION

A primary goal of a revegetation program is to stabilize the surface against the long term effects of erosion. Another major objective is the return of the site to a productive post-operational use. The revegetation process begins after the disturbed area has been shaped, graded, and treated, and the topsoil or other suitable growth medium is spread and smoothed. The revegetation of the affected lands shall be accomplished in a timely manner and consistent with the reclamation plan. Lands which did not support vegetation prior to mining because of soil conditions may require no revegetation.

B. SOILS MANAGEMENT

The use of topsoil or other selected replacement material as a growth medium to be spread over lands disturbed by mineral activities during reclamation must be considered during reclamation planning. The amount and quality of replacement soils used will have a effect on the future productivity of the reclaimed lands. Proper soils management is critical to reclamation success. Some factors to consider early in the reclamation planning process include:

1. Amount and quality of the topsoil to be saved.
2. Alternatives to spreading topsoil.
3. Storage location and duration of storage of salvaged soils.
4. Protection of stored and salvaged soils.
5. Feasibility of direct replacement of the salvaged soils.
6. Required thickness of replacement soil.
7. The volume of available replacement soil.
8. Availability of additional growth media to supplement topsoil replacement.

A site-specific soil survey should be conducted as a part of the baseline studies. The soil survey should be conducted in accordance with the standards of the National Cooperative Soil Survey (See SCS USDA Handbooks 430 and 436). The purpose of the soil survey is to identify suitable soils for use as growth media or for other special purposes. Soil resources within the zones of proposed disturbance should be inventoried for volume and suitability prior to the disturbance. See Table XII-1. Soils high in clay content may not be suitable to support plant growth but may be suitable for use as an impermeable barrier in waste management. The acceptability of soils is also dependent upon moisture, organic matter, soluble salts, selenium and boron content, bulk density and other factors.

Table XII-1. Soil Suitability for Reclamation Purposes (courtesy of the USFS Intermountain Forest and Range Experimental Station-Logan, Utah)

SOIL PROPERTY	SOIL QUALITY			
	GOOD	FAIR	POOR	UNSUITABLE
Texture	sandy loam loam silt loam	sandy clay loam silty clay loam clay loam	sandy clay loamy sand silty clay	clay >60%
Rock & Gravel (% by volume)	0-10	10-20	20-40	>40
pH	6-8	5-6 8-8.5*	4.5-5 8.5-9*	<4.5 >9
Na absorption ratio, (SAR)	4	4-8	8-16	>16
Electrical Conductivity (millimhos/cm)	3	3-7	7-15	>15

*Check for heavy concentrations of Boron or Lime.

All replacement soils and material suitable for reclamation should be salvaged wherever feasible and stored for later use in reclamation or if conditions permit, applied directly to recontoured areas ready for reclamation.

Corrects Format in Chapter 12

Salvaged materials should be properly stored and revegetated if necessary to protect the stockpiled soils from erosion. Concurrent topsoil replacement is preferable to long-term topsoil storage. Studies have indicated that long-term storage of topsoil may result in the loss of vital organisms in the soil. Stockpile sites should be located in areas which will not be affected by future operations and are easily accessible for removal at the time the soils are needed.

The appropriate replacement thickness of growth media is usually based on the amount of available topsoil or growth media and past experience with application depths. In general, the poorer the chemical and physical properties of the spoil or waste materials, the greater the required depth of the replacement soils. When the availability of good soil materials is limited, consider the qualities of the soils available. Generally, a thin layer of topsoil over unproductive subsoil will result in greater plant productivity than a thin layer of topsoil alone.

In those cases where the waste materials are finely textured and exhibit no phytotoxic properties (i.e. highly acid or saline), about 6-12 inches of replacement topsoil or other suitable growth medium, if available, should be sufficient. Coarse textured (rocky) waste or waste exhibiting phytotoxic properties may require greater thicknesses and additional treatment. Disturbed areas containing highly phytotoxic materials may require some form of mechanical treatment, such as sealing the dump with clays, prior to application of the topsoil. Where the volume of replacement soils is limited, variances to the above recommendations or uneven placement may be justified.

Certain fine grained substrata which exhibit favorable reclamation properties, may be used to advantage as a soil medium or as a mantle to cover rocky waste.

Reapplied topsoil or selected subsoils should be tested for nutrients, pH, and toxicity factors prior to planting.

C. SEED BED PREPARATION

The first revegetation step is to prepare the newly spread soil material for seeding and planting. The soil material must be permeable enough to absorb precipitation and to allow for root penetration. In arid zones, seedling establishment is difficult and highly variable; therefore, proper seedbed preparation is extremely critical.

Seedbed conditioning provides important benefits for plant germination, establishment, and long term vitality by loosening the compacted soil material, providing catchments to increase water available to plants, and creating microsites that shelter seeds and seedlings. The seedbed should be conditioned to collect, hold, and absorb as much moisture as possible.

Equipment for seedbed conditioning ranges from rippers and discs or chisel plows to spring tooth harrows and rakes.

After the topsoil is applied and graded, consider scarifying, shallow ripping, or disking the site to eliminate compaction and provide for increased infiltration rates. Ripping or disking will retain water in the seed bed which is essential to the success of the revegetation. Rip, disk or harrow on the contour of the slope to reduce the effects of surface erosion.

Some important considerations in seedbed preparation are:

1. Final shape or landform should be compatible with the surrounding landforms where practicable. If possible, natural drainage should not be altered, except where necessary to protect unstable soils or tailings or toxic materials areas. The seedbed should be tested for growth potential prior to seeding. Capillary breaks may be necessary to isolate toxic subsoil materials.

2. Soils and subsoils that have been highly compacted should be ripped. Subsoils should be ripped prior to the placement of the topsoil or other growth media.

    a. Rip the mantle when it is relatively dry to permit shattering beneath the surface. Moisture content should not exceed field capacity.

b. Ripping should generally be 2 to 3 feet deep on 2- to 3-foot centers. A "rule of thumb" is the distance between rippers should be equal to the depth ripped. Ripping depth may be limited by the characteristics of subsoil materials. For example, in arid regions, ripping may bring calcium-rich materials to the surface, which may inhibit germination.

D. FERTILIZATION

Many disturbed areas and waste embankments may be nutrient deficient at the time the reclamation is performed and may require fertilization to ensure the seedlings establish themselves. Fertilization is the addition of a natural or man-made substance to the soil to supply plant nutrients. Its use can be justified when operations disrupt the soil balances that affect nutrient availability. Fertilization can be done before, during, or after seeding, however it is usually more advantageous to fertilize prior to seeding. After the initial fertilization and subsequent establishment of plants, the natural process of nutrient cycling is expected to maintain the plant community. Consider the following when fertilizing reclamation projects:

- Soil materials should be tested for nutrient levels prior to fertilization. Only available nutrients are important. Macronutrient (e.g. nitrogen, phosphorus, potassium, calcium, magnesium, iron and sulfur) and micronutrient (e.g. zinc, boron, selenium) deficiencies will be determined by the soil sampling.

- The nutrient content of bagged and bulk fertilizers is expressed as a percent of the content by weight. Example: A 100-pound bag marked 10-10-10 means 10% nitrogen, 10% phosphorus (P_2O_5), and 10% potash (K_2O_5).

- Equipment to apply chemical fertilizers (common agricultural fertilizers) range from broadcast spreaders and drill seeders for dry or granular fertilizer, subsoil injectors for liquid fertilizer, and hydro-seeders for applying a slurry of fertilizer and water. The application of biologic fertilizers (manure, compost, etc.) will require special equipment.

- For best results, fertilize before planting, and harrow or drill the fertilizer into the soil material to increase the effectiveness of the fertilizer. If it can be demonstrated that the seedlings can be established without fertilizer, consider the application of the fertilizer after the seedlings are established.

- Usually fertilizer applied with a hydro-seeder will be done in conjunction with seeding. Not only are fertilizer slurries sometimes incompatible with organic mulches, but can be toxic to the seed, and should be applied in separate operations.

- Nitrogen fertilizers should be those that will release at the time of germination. Losses of available nitrogen over the winter season may reach 30%, therefore, adjust application rates to account for these potential losses.

- Adult plants which exhibit a yellowish-green color and drying of the lower parts of the plant usually are deficient in nitrogen or iron. Phosphorus deficiencies in plants often cause a purplish color in the leaves and the plants display poor root development, stooling, and spreading.

- Application of low nitrogen levels reduces weed growth. Higher levels of phosphorus improves root development with no appreciable increase in the growth of weedy species.

E. SOIL AMENDMENTS

The use of soil amendments is often an important part of preparing disturbed areas for revegetation. Most disturbed sites exhibit soils that have received impacts to their chemical and/or physical characteristics (e.g. compaction). These impacts affect the ability of the soil to function effectively as a growth medium for vegetation and generally increase the likelihood of soil surface instability. Soil amendments are natural or man-made materials incorporated into the soil to improve the soil-water or soil-air relationships in the soil profile by altering the chemical and/or physical properties of the disturbed soils. Soil amendments help provide a suitable environment for vegetation establishment. Soil amendments include, but are not limited to: wood chips, calcium chloride, various organic mulches, gypsum, and lime. When incorporated into the soil, these materials help mitigate compaction problems, improve water infiltration, neutralize acidic or alkaline conditions, modify soil structure, and enhance water holding capacity while improving drainage.

F. SEED SELECTION AND HANDLING

The following are some general guidelines for seeding:

- Select species from a similar climatic zone and soil type. Minimum moisture requirements should determine selection.

- Seed a mixture of species. Consider species for both warm and cool season growth. Use a good balance of types which provide for the planned post-reclamation use, such as grazing or wildlife habitat.

- Do not over-seed. Too many seedlings will compete for available moisture and nutrients.

- Protect seeded areas from use until the vegetative cover is established and self-sustaining. In areas where it is impractical to limit access, use species which are quickly established.

1. <u>Species Selection</u>

Selection of adaptable plant species is essential for successful reclamation. In severe environments such as deserts, alpine zones, or windy ridgetop exposures, the number of adaptable species will be less than for sites in moderate climates. The proper selection of adaptable plant species will depend on the prevailing climatic and soil conditions in the project area (see appropriate seed selection handbook for your area). The seed selection should be consistent with the Resource Management Plan post-mining objectives, (i.e. wildlife habitat and/or grazing).

Criteria for determining plant species adaptable for the project site should include:

- Ability to quickly establish and stabilize the specified surface
- Ability to withstand the extremes of climate at the site
- Ability to survive with little or no maintenance
- Ability to establish itself on the soil material
- Availability of seed from commercial seed suppliers
- Form and growth characteristics
- Forage preference and palatability to grazing herbivores

The selection of plant species (seed mixes) should be diverse, and when practical include grasses, forbs, and shrubs. Trees and shrubs should be re-established where the post-mining land use includes wildlife habitat. Species to be planted as permanent cover shall be self-renewing (perennial) to maintain the plant community. Introduced, naturalized or non-indigenous plant species, may be included in the approved seed mixture if they support the approved post-operational land uses and do not conflict with long-term vegetation management goals. See Appendix 2 for some suggested species for reclamation use.

Seed mixes should include certain species which provide for quick cover, embankment stabilization (i.e. deep rooted legumes), litter production, nitrogen fixing capabilities, etc. Observe native plant species growing in the project area on both the undisturbed lands and disturbed lands.

The purpose for seeding is to establish ground cover and protect the soil from erosion and to prevent invasion of undesirable species. Grass species are best suited to this because they have a fibrous root system. Sod forming species are best at reducing erosion.

Consult with BLM specialists, county agents, or other experts, and appropriate research reports regarding reclamation research and proper seed selection.

Some general considerations for species selection follow:

- Recommendations for species selection can be obtained from the BLM, the Soil Conservation Service (SCS), or the Forest Service.
- Elevation and slope aspect are also important factors that should be considered when selecting plant species.
- The Soil Conservation Service (SCS) Plant Material Centers has information about seed and seed dealers. The Centers are an excellent source of information. Also consider botanical gardens and native plant organizations as possible sources.
- All seed purchased should have species name, percent germination, percent pure live seed, percent weed seed and other contaminates, collection location (especially important for native species) and testing date specified on bag. States require that seed planted within the State contain no injurious or noxious weeds.

2. <u>Seed Acquisition</u>

Seed of adaptable plant species may be purchased or collected from native plants in the vicinity of the project site. Some guidelines to seed acquisition include:

- Purchase seed from dealers with experience in the geographic area. All purchased seed should be packed for the growing season in which it will be used.

- If collection of native seeds is viable, locate appropriate stands of adaptable seed species before the seed matures and collect the seed only after it matures. Collect seed in cloth or paper containers but never seal in plastic bags as this practice may retain moisture and cause molding of the seed. Clean and separate the seed from the undesirable debris as soon as the material is dry.

- Store the cleaned seed in a cool dry location in cloth bags. Be sure the germination percent, collection location, pure live seed, and percent weed contaminates are specified on the bag label. BLM may inspect the labels prior to the application of the seed.

- Legume seed and certain other types of seed (e.g. bitterbrush seed) should be inoculated for best results.

G. SEEDING AND PLANTING

Seeding and planting should be done as soon as the seedbed preparation is completed, and if possible schedule the seeding just prior to the longest precipitation period or when available moisture is most favorable for seedling establishment. In many locations, seeding prior to snowfall enhances germination success in the spring. By beginning the revegetation immediately after the seedbed preparation is completed, competitive less desirable species will not be given an advantage and the seedbed will not degrade physically or biologically. Quick establishment of vegetative cover protects the soil from erosion. Seeding and planting patterns should be designed to best provide the desired post-mining use.

Seeding rates must be based on pure live seed (PLS) percentages and seeds per square foot or pounds of pure live seed per acre. Seeding rates which are too low may result in sparse stands which may fail to stabilize the site, while excessive rates waste seed and may result in stagnant, overly dense stands with reduced plant vigor. The seed mixtures and application rates should be described in the plan and approved by the AO.

Two basic seeding techniques are drill seeding and broadcast seeding. The type of seeding to be used is dependent upon the terrain and species to be used, and both methods may be employed at the same site. Broadcast seeding can be divided into ground seeding, aerial seeding, and hydroseeding. Drill seeding is considered an effective method of seeding for most grass species, while other species must be broadcast. If the seedbed is smooth and free of large rocks, consider seeding the site with a cultipacker-type seeder to assure the seeds are evenly distributed and to control seeding depth. However, if the site is rough and rocky, a rangeland type drill may be more effective. Where broadcast seeding is the only alternative, do the seeding immediately after the site has been prepared and cover the seed by raking to provide for a good seed-soil contact.

Seeding depth is important for successful germination. Generally, small seed should be seeded closer to the soil surface than large seed. Most seeds should be planted from 1/8 inch to 1/2 inch deep, depending upon seed size and type. Seeding too deeply delays emergence and reduces total emergence, while seeding too shallowly increases desiccation and causes faulty root systems. Covering most seed is important. Some seeds will not germinate when uncovered, birds and rodents will feed on the exposed seed, and seed may wash or blow away before it germinates.

Steep slopes and rocky soils may prohibit the use of most mechanical seeding equipment. Where equipment can be used, seed drills will usually ensure good seeding success. Special note should be given to the depth of planting. The appropriate depth of planting for the selected species should be used.

Broadcast seeding is often required on portions of the disturbed area. Some types of seed should always be covered with soil. Some suggested methods are a weighted chain link fence, light chain, culti-peater, or harrow. Broadcast seeding works best when done just after completion of the final earthwork, when the surface is soft and friable.

H. SHRUBS AND TREES AND OTHER TRANSPLANTED SPECIES

Planting techniques range from hand planting to sprigging to transplanting. Planting must be done so competition from other species on the site is minimized. It is preferable to establish shrubs and trees on critical revegetation sites through transplanting techniques using containerized or bare root stock. Where possible leave undisturbed buffers of trees between roads and pits to serve as a natural seed source.

Transplanting requires consideration of the following factors:

- Available sources of adaptable stock (e.g., Federal nurseries)
- Care and hardening of the plants prior to planting.
- Determination of the correct time to plant.
- Methods of planting, including considerations of spacing, watering, etc.
- Care and assessment following planting.

Shrubs and trees may often be planted in crucial big game areas to mitigate habitat loss. Well-placed shrubs and trees within the reclaimed area may provide a seed source for future establishment. Shrubs can be established from containerized stock or by selected excavations of shrubs just off site of the project area. The following should be considered when planting shrubs or trees:

- Adapted species should be selected for use with parent material from a similar climate zone.

- Care and hardening of the plants should be considered prior to planting. This can be done by the supplier.

- Adjust time of planting to local conditions.

- Site conditions and preparation at the time of planting.

- Methods of planting, spacing, fertilizing, watering, and post-planting care.

I. MULCHING

Mulches can be used in reclamation to stabilize soils until permanent plant cover becomes established. Mulches not only reduce or prevent wind and water erosion, a good mulch cover will protect the seeded area from the severe effects of heat, cold, and drought. Mulching materials can be organic or inorganic, natural or man-made, soil enriching or inert. When organic mulches are decomposing they can create a serious carbon/nitrogen imbalance in the soil and may require additional nitrogen fertilizer to compensate for the nitrogen tied up in decomposing the mulch. Annual or non-competitive perennial cover crops may also be used as mulch. Commonly used mulches include, straw, hay, jute, wood chips and other woody material, and synthetic biodegradable fibers.

Hay and straw mulches should be applied at the rate of 2000 to 3000 pounds per acre. Fiber mulches are best applied as a hydromulch (in a slurry of water and tackifiers) at a rate of at least 2000 pounds per acre. If seed and fertilizer are added to the hydro-mulch, caution should be taken to ensure the addition of fertilizer to the slurry does not make the slurry toxic to the seed. Apply the hydromulch to a rough surface, such as an exposed road cut, using suitable tackifiers to keep the mulch in place. The use of hydro-mulching on cut-banks is effective for distances up to 150 feet.

Light colored mulches will reduce summer soil temperatures while dark colored mulches raise the soil temperatures (effective for raising spring soil temperatures).

The following are suggestions for using mulches:

- Commonly used mulches include; straw, crushed rock, hay, synthetic mulches, biodegradable fibers and blankets, wood chips and wood fiber, and jute. Care should be taken to ensure that hay mulch does not include noxious weed seeds.

- Dark-colored mulch will raise spring soil surface temperatures.

- Light-colored mulches will reduce summer soil surface temperatures.

- Mulching will reduce frost heaving of new seedlings.

- Mulch reduces rain splash, surface wind, particle movement and other erosional effects.

- Mulch should be applied to a roughened surface. Do not grade smooth. Apply asphalt or other suitable tackifiers or crimp mulch into the surface to keep it in place.

- Hay and straw mulches for seeding cover and erosion control should be applied at the rate of 1,000 to 3,000 pounds per acre. This amount will provide a 1- to 3-inch deep ground cover.

- Mulch can be applied by hand on 3:1 or less sloping sites up to 1 or 2 acres in size. Larger, steeper sites will require a power blower or mulcher. These power mulchers have a range of approximately 150 feet from an access road.

- Fiber mulches can be applied effectively in a slurry of water, seed, and fertilizer with a hydromulcher. In low-precipitation areas, seed should be applied prior to hydromulching.

- Mulching that is crimped into the soil on dry sites may wick moisture out of the soil in some conditions.

- The use of seeded blankets may be a viable alternative to separate seeding and mulching, especially on steep slopes.

J. REVEGETATION OF ACIDIC MINING WASTES

Revegetation of acidic mine wastes can pose particularly difficult long-term reclamation problems. Acidic mine wastes are toxic to most vegetation. Virtually all mines which recover ore from sulfide minerals have some potential for acid mine waste, either as tailings piles, waste rock dumps, or low-grade ore stockpiles. Acidic wastes must either be amended chemically or isolated from the weathering environment in order for ultimate reclamation to be successful. The exact measures necessary to ensure reclamation success will depend on a variety of site-specific factors. Often, acidic mine wastes will require some form of engineered cover system to isolate wastes from plant rooting zones. Capillary breaks are effective means of isolating the waste materials. For a detailed discussion of this topic, refer to Volumes I and II, Draft Acid Rock Drainage Technical Guide, prepared for the British Columbia Acid Mine Drainage Task Force. The Bureau of Mines may be able to provide additional assistance.

1. Lime Amendment

Inclusion of a lime amendment into the cover system may help prevent acidification and improve the potential for revegetation success. Lime amendments may also have other applications. A lime amendment is particularly effective when the cover system includes a capillary break from the acidic materials below. Inclusion of lime into a cover system is not likely to be effective in reducing acid mine drainage caused by water infiltration through the cover system. The waste material can usually release sufficient acid to overcome the effect of the amendment.

Where the net neutralization potential (NNP) of waste rock or one of the cover layers is negative (i.e. the material is acidic), it may be beneficial to incorporate lime into the cover system as a neutralizing agent. When considering lime application it is important to determine if it will be necessary to add lime above the amount indicated by the NNP. The NNP is a minimum number and it is often necessary to substantially increase the amount of lime added to account for other natural processes, such as precipitation of iron on the lime, which limit the availability of the lime for acid neutralization. The rate of lime incorporation is usually expressed in tons of $CaCO_3$ necessary to effectively neutralize 1000 tons of waste material.

Lime can be added in several different forms. Slaked lime (CaO) and hydrated lime (CaOH) are the most effective neutralization agents. However, the relative abundance and correspondingly lower cost of limestone ($CaCO_3$) make it more common for this use. Lime amendments are usually disked or harrowed into the surface to prevent coating and subsequent reduction of moisture infiltration. Application of more than 30 tons of lime per acre may prove to be impractical. It is also possible to mix lime into waste material in batches to assure even distribution. It is best to have a range of sizes present in the lime amendment to ensure consistent reaction and acid consumption. Normally, an agricultural grind meets this requirement.

2. <u>Bactericides</u>

The oxidation of sulfide minerals is catalyzed by the bacteria *Thiobacillus ferrooxidans*. This bacteria can speed the reaction by several orders of magnitude. The activity of the bacteria can be limited by the application of bactericides to pyritic waste materials and cover systems. Bactericides should be considered short-term remedies, which may be particularly applicable in aiding the establishment of vegetation. Once a vegetative cover is established, oxidation may be sufficiently inhibited to allow for reclamation success.

K. TEST PLOTS

It is often appropriate for an operator to install test plots prior to revegetation of a large disturbed area. This process will enable the proper seed mixture, fertilization type and rate, and other soil amendment requirements identified in the reclamation plan to be evaluated on a site-specific basis. In addition, it allows for the use of new and innovative techniques which have not been widely proven. A major advantage in using test plots is that failures are much less costly to the operator and the environment than "real-life" failures. Requirements for test plots should be developed in conjunction with BLM renewable resource specialists, such as range conservationists, wildlife biologists, soil scientists, and surface protection specialists.

XIII. POST-MINING MULTIPLE USE MANAGEMENT

A. INTRODUCTION

The approved post-mining land use planned for in the RMP or other land-use planning document determines to great degree the specific requirements of the reclamation plan with regard to revegetation, land form reclamation, and many other aspects of reclamation. The specific post-mining use or uses may also have an impact during the operation which is directly related to the reclamation goals and activities necessary for a particular site. Specific considerations should be given to wetland and riparian area management, wildlife and fisheries management, range management, recreation management, forestry management, and visual resource management.

B. WETLANDS AND RIPARIAN AREA MANAGEMENT

Wetlands include areas adjacent to and influenced by streams (whether waters are surface, subsurface, or intermittent), springs, lake shores, marshes, potholes, swamps, muskegs, lake bogs, wet meadows, and esturine areas. Riparian areas are a form of wetland transitional between permanently saturated wetlands and upland areas. They include the vegetative zones along the banks of rivers and streams and around springs, bogs, wet meadows, lakes, and ponds. See Figure XIII-1. Of particular management concern are riparian areas in arid and semi-arid ecosystems.

Riparian-wetland areas are among the most productive and important ecosystems, comprising nearly 1 percent of the public lands. Characteristically, these areas display a greater diversity of plant and animal life and vegetation structure than adjoining ecosystems. Healthy riparian-wetland systems filter and purify water as it moves through the riparian zone, reduce sediment loads and enhance soil stability, provide micro-climate moderation when contrasted to extremes in adjacent areas, and contribute to groundwater recharge and base flow.

Departmental and BLM policy on riparian area management requires that action be taken to avoid adverse impacts associated with the use and modification of wetlands. Overall management of wetland areas must be based on site-specific characteristics and settings. The goal of reclamation of riparian/wetland sites is to minimize disturbance and to restore and preserve the natural beneficial functions of those wetlands. Such functions include:

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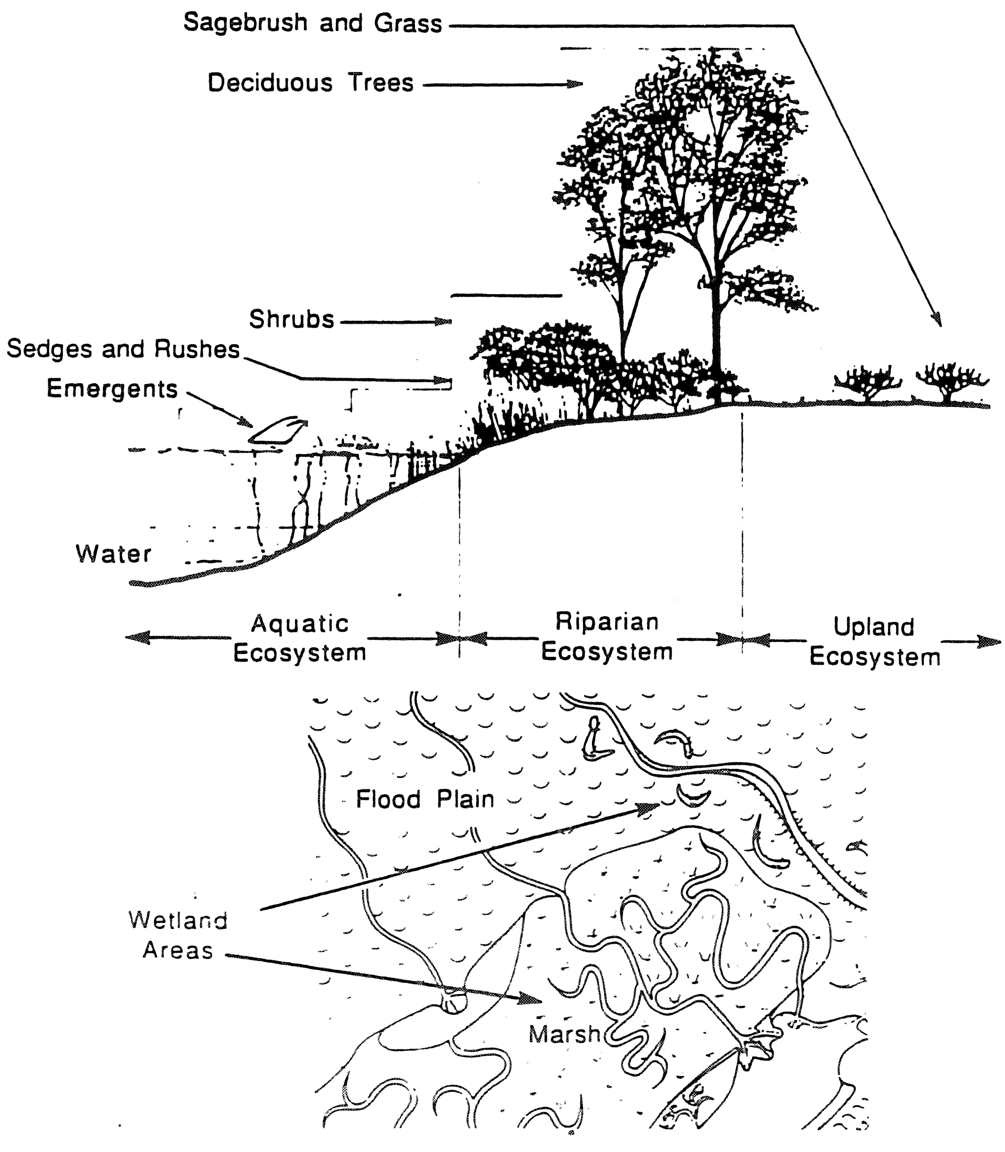
Figure XIII-1

Figure XIII-1
Examples of Riparian and Wetland Areas



- Dissipating stream energies associated with high flows, thus reducing erosion.

- Filtering of sediment and pollutants carried with overland flow and aiding alluvial valley floor and floodplain deposition.

- Improvement of headwater storage potential, which can result in making water available for release throughout the year.

- Development of root masses that stabilize stream banks against cutting action.

- Providing vegetative cover adequate to shade the water and maintain water temperatures suitable for the survival of fisheries and other aquatic life.

- Maintenance of water oxygenation during the colder winter months suitable for survival of aquatic life.

- Production and maintenance of food chains which include fish.

- Maintenance of habitat to host the food chain base.

- Production and maintenance of a food supply and habitat for non-aquatic animals.

- Critical water sources for wildlife in many arid areas.

Specific reclamation actions should restore the natural functions of streams, including flood energy dissipation, bank building, sediment filtering, water storage, and aquifer recharge. Where riparian and other wetland areas are in poor condition, efforts to improve or enhance the riparian resources should be made as a part of complete watershed management.

Wetland management must be conducted within the framework of Federal government policy, a policy of "no net loss of wetlands". Reclamation activities must be conducted so as to provide this mitigation for any wetlands disturbed by the mining operation. In addition, the construction of wetlands as a part of reclamation may provide mitigation for off-site losses of productive wetland areas.

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C. WILDLIFE AND FISHERIES MANAGEMENT

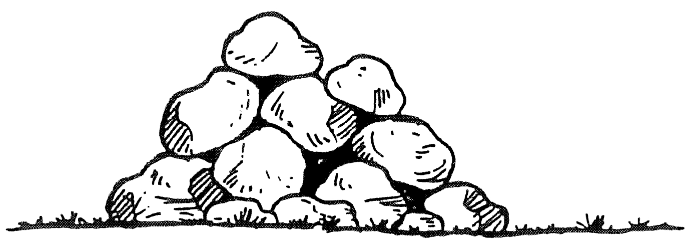
Minimizing impacts to the wildlife and fisheries resources is an important consideration in reclamation. Protection of the threatened and endangered species and their habitat is provided for under the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.). Where wildlife and fisheries habitat will be part of the post-operational uses, all wildlife and fisheries habitat reclamation and mitigation procedures should be described in the approved plan. Baseline data of the wildlife and fisheries use will provide a valuable reference for development of the reclamation plan. The reclamation plans should include the following.

For reclamation to provide wildlife habitat, emphasis should be placed upon habitat features that promote maximum vegetative species diversity and value following operations. Reclamation designed to produce a desirable mix of shrubs, grasses, and forbs will benefit wildlife. Leave buffer zones of native vegetation wherever possible to perpetuate the re-establishment of native species. Integrate the vegetative components and those landform features required to perpetuate diverse and habitat-sufficient plant communities. To accomplish this, incorporate diverse slopes, surface undulations, minor depressions, swales, convoluted drainages and rock or brush piles. The reclamation plan should include a statement of the wildlife and/or fisheries reclamation objectives.

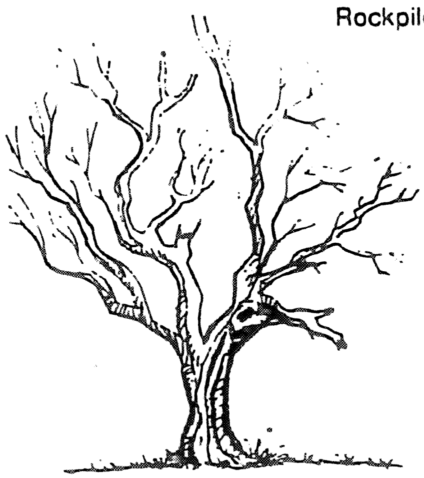
Suggested reclamation practices to enhance wildlife habitat include restoration of diverse land forms, direct topsoil replacement to the disturbed or shaped areas, shrub and tree transplants and construction of rock and brush piles and water developments. See Figure XIII-2. Suggested reclamation practices to enhance fisheries habitat include water source development, where necessary, stream rehabilitation which emphasizes diversity of habitat through stream morphology (ie. gradient,sinuosity) which includes a variety of fish habitat structures like pools, riffles, lakes etc. as the objective. See Figure XIII-3. Riparian zones and wet meadows should be protected, or the long term impacts mitigated. Specific impacts, such as the interruption of migration routes, loss of critical species habitat and loss of wildlife production areas should be mitigated. Additional information which may be useful is found in Chapter VII, Sections F, I, and J.

Figure XIII-2
Examples of Wildlife Enhancement

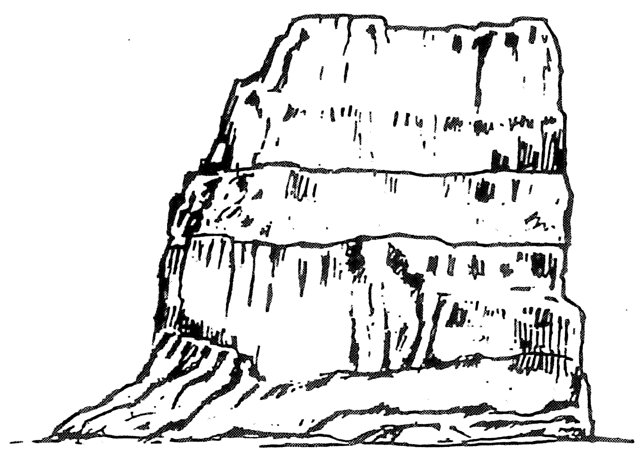
Wildlife Habitat Enhancement—
Slash Pile for Small Mammals + Birds



Rockpile for Small Mammals + Birds

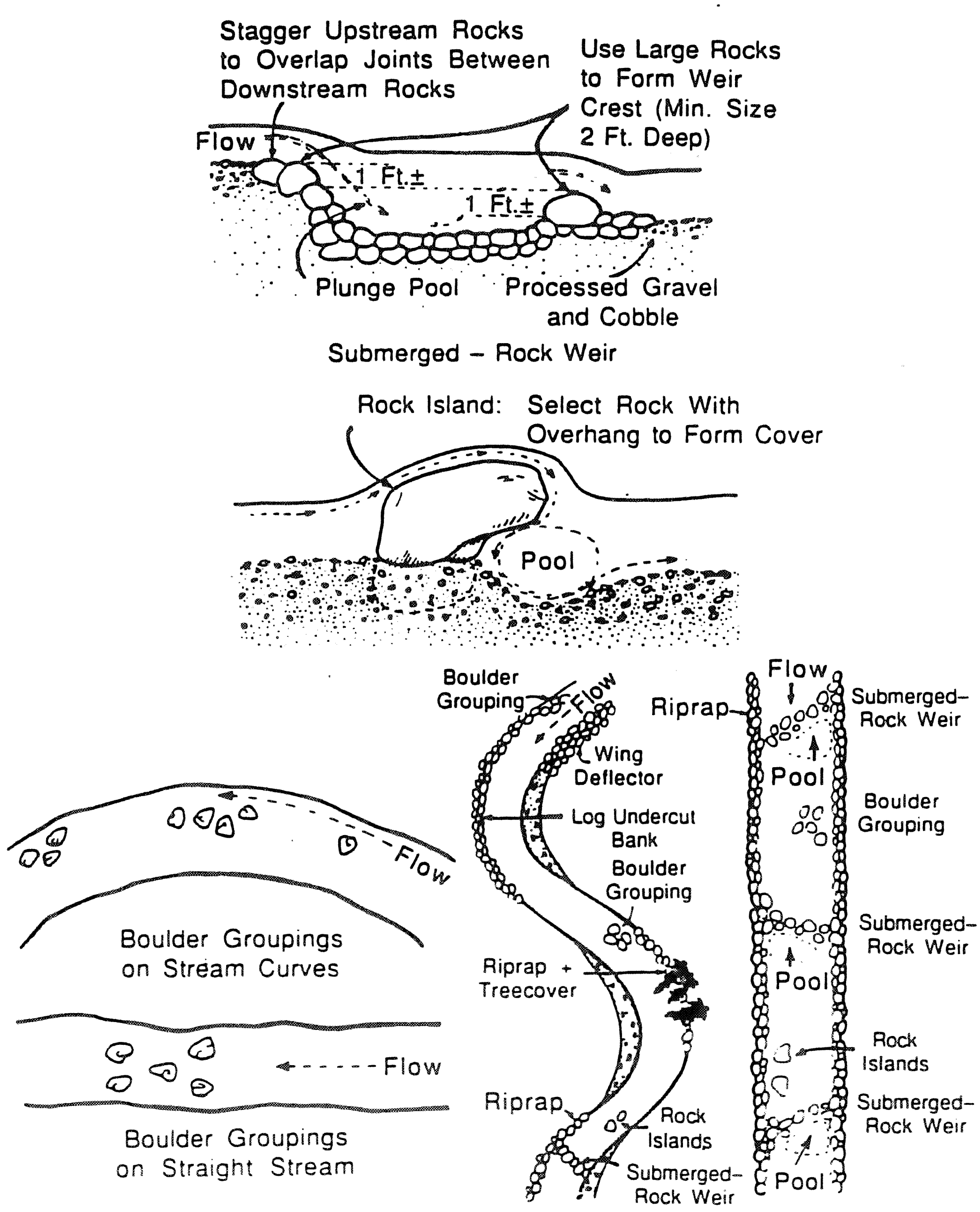


Tree Snag Left for Nesting
and Roosting



Highwall With Niches
for Raptors.

Figure XIII-3
Examples of Fisheries Enhancements



Source: *Placer Mining in Alaska*, BLM Alaska State Office, 1989.

D. RANGE MANAGEMENT

Rangeland postmining land use is a major land use on reclaimed areas in the West. Rangeland can be defined as a vegetation system established to provide for food or browse for domestic livestock and/or indigenous wildlife without the need for constant maintenance. Rangeland can thus be quite variable in the type of dominant vegetation: grasses; legumes; forbs; shrubs; or trees. Grassland, steppe, desert, or forest can be rangeland.

The vegetation established on reclaimed areas for rangeland use should be compatible with surrounding range. Rangeland restoration is basically no different from restoration of any other land use. A reestablished rangeland does not necessarily have to match premining conditions species for species or density for density, but should meet the requirements set forth in the reclamation plan.

E. RECREATION MANAGEMENT

Recreational land can be any land use or combination of land uses which provides for a planned or anticipated use by the general public. Examples of recreational use include hunting, hiking, camping, picnicking, and nature study. The combinations of revegetation systems and specific landform reclamation procedures useful for establishing recreational uses are limitless. In many cases of postmining recreational land use, it is desirable to establish a water resource. In addition, a diverse mixture of plant types is usually desirable for any recreational use. The typical recreational uses often occur on areas reclaimed for other postmining uses.

Planned uses for reclaimed areas can be tailored to recreation. These could include railroad beds converted into bike paths or off-road vehicle trails, revegetated mine roads to be used as hiking and nature study trails, and drill pads reclaimed for use as campsites. Many other recreational uses for reclaimed lands could be included as a part of the reclamation plan. These recreational uses should be planned taking into account the resource values present at a particular site, such as scenery, water resources, etc.

F. FORESTRY MANAGEMENT

Forestry uses of reclaimed land can be established for commercial timber tree production, long-term watershed protection, wildlife habitat, recreation, firewood production, or any combination of these or other purposes. A forestry use will usually remain as such for long periods of time without requiring intensive maintenance. Maintenance can be applied, and in some cases is very desirable for maintaining the quality and vigor of the established stand.

Whether the intended forest is comprised of a limited number of species (as for tree farming) or a wide diversity of species, there is little difference in the feasibility of the reclamation, provided the proper techniques and methods are applied in conformance with any existing timber management plan.

G. VISUAL RESOURCE MANAGEMENT

The BLM has a basic stewardship responsibility to identify and protect visual values on public lands under the authority of FLPMA and NEPA. Actual reclamation of the site is conducted in accordance with the Resource Management Plan and the approved reclamation plan. To the extent practicable the reclaimed landscape should have characteristics approximating or compatible with the visual quality of the adjacent area with regard to location,scale, shape, color, and orientation of major landscape features and meet the needs of the planned post disturbance land use.

The visual management class of a particular area provides guidance for the design, development, and reclamation of a project in that area. Visual design considerations should be incorporated into all surface disturbing activities. BLM Manual Section 8431 provides the process for rating the visual contrasts for an area and may be useful in evaluating the impacts of an operation and the success of reclamation.

The visual resource management (VRM) aspects of the reclamation plan should be monitored in cooperation with the VRM Coordinator in the appropriate field office. Further information on the VRM program can be found in BLM Manual Sections 8400 (Visual Resource Management), 8410 (Visual Resource Inventory), 8430 (Application of Visual Resource Management Principles to Project Planning and Design), 8431 (Visual Resource Contrast Rating), and 8440 (Environmental Assessment), and in BLM Handbooks H-8410-1 (Visual Resource Inventory) and H-8431-1 (Visual Resource Contrast Rating).

H. WILDERNESS MANAGEMENT

In some cases, mining will be conducted in wilderness study areas (WSAs). Operations in WSAs must be reclaimed to be substantially unnoticeable in the area as a whole in order to meet the nonimpairment criteria unless grandfathered or valid existing rights exist. Reclamation of these operations must ensure prevention of unnecessary or undue degradation of the environment and provide for reasonable measures to preserve the wilderness character of the area. If mining operations are proposed in Wilderness Areas, the requirements for operational constraints and reclamation are likely to be specific to a particular Wilderness because of the enabling legislation, valid existing or grandfathered rights. For additional guidance refer to Manual Sections 8550 and 3802.

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Glossary of Terms

-A-

<u>acid mine drainage</u>: water with a pH less than 6.0 discharged from an active, inactive, or abandoned mining operation.

<u>acidic</u>: a solution containing a high hydrogen ion concentration (pH < 7).

<u>akaline</u>: having the qualities of a base (pH > 7).

<u>alluvial valley floor</u>: the unconsolidated stream-laid deposits holding streams with water availability sufficient for subirrigation or flood irrigation agricultural activities.

<u>authorized officer</u>: any employee of the Bureau of Land Management delegated the authority to perform the duty described in the section in which the term is used.

-B-

<u>backfilling</u>: the filling in of a place from which rock or ore has been removed.

<u>baseline data</u>: environmental or other data used to characterize an area prior to the start of any mining or reclamation activity.

<u>basin relief ratio</u>: the ratio of basin relief to basin length, i.e. the ratio of the difference in elevation of the highest and lowest points in a stream drainage basin to the horizontal distance of the straight line from the mouth of the drainage to the farthest point on the drainage divide of the basin, parallel to the principle drainage direction.

<u>bedload potential</u>: the expected capacity of a stream to carry materials, such as the larger and heavy materials (e.g. boulders, pebbles, gravel), immediately above the stream bed by traction or saltation.

<u>bendway radius of curvature</u>: the radius of the inside curve of a bend in a stream or waterway.

<u>bendway shear stress</u>: the shear stress created at the outer curve of a bend created by the change of direction of the current of a stream or waterway.

<u>benthic organisms</u>: organisms living on, in, or at the bottom of a body of water.

<u>berm</u>: an artificial ridge of earth.

Corrects Format in Glossary

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Glossary of Terms

bioremediation techniques: the use of introduced or native organisms to minimize or correct pollution occurrences.

bladed areas: any area where the original surface is disturbed by mechanical equipment such as graders, bulldozers, or front-end loaders.

brush barriers: sediment control structures made from vegetation such as tree limbs, branches, etc.

-C-

casual use: activities ordinarily resulting in only negligible disturbance of the Federal lands and resources. See 43 CFR 3809.0-5(b).

closure: the act of closing any phase of a mining operation where further operations is not intended.

concurrent reclamation: reclamation activities carried out as an integral part of ongoing mineral exploration, development, or extraction operations.

conductivity: the relative ability of a material to carry an electrical current.

convection: transfer of heat by means of the upward motion of the particles of a liquid or gas that is heated from below.

Corps of Engineers' Section 404 Permit: a permit obtained from the U.S. Army Corps of Engineers, as required by Section 404 of the Clean Water Act, necessary to conduct activities which impact wetlands or riparian areas.

cover systems: designed structures or systems which minimize or prevent the infiltration of surface or meteoric waters.

crimping: the act of mechanically pushing mulch into the soil to keep it in place.

cross valley dump: a waste disposal system designed to traverse a valley perpendicular to the longitudinal direction of the valley.

curved-arc failures: failure of a slope or highwall in excavated material characterized by a curved escarpment.

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cut slope angle: angle from horizontal of the slope of an excavation.

cutoff trenches: excavations designed to reduce the flow of surface water across otherwise smooth surfaces.

-D-

debris slide: a small, rapid movement of largely unconsolidated material that slides downward to produce an irregular topography.

deoxygenation: the process of removing free oxygen from water.

desalination: the process of making potable water from saline waters.

design storm event: the maximum probable precipitation event for which structures are designed to contain and manage the associated surface and subsurface flows (e.g. the 24-hour storm event with a likelihood of reoccurance at 10-year intervals, i.e. the 10-year, 24-hour storm event).

diffusion: the permeation of one substance through another.

drainage density: the ratio of the total stream lengths of all stream orders with a drainage basin to the area of that basin projected to the horizontal plane.

drawdown wells: wells that when pumped lower the water table or piezometric surface of an aquifer.

drill seeding: a seeding technique where individual holes are drilled for each seed or seed group.

drill hole site: surface locations where a drill hole is drilled. This may or may not require excavation or pad construction.

drop structure: a hydrologic structure designed to reduced the sediment load of a stream by allowing for controlled sedimentation.

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Glossary of Terms

-E-

earth flow: a rapidly moving flow of mixed soil, rock, and water.

erosion: the group of physical and chemical processes by which earth or rock material is loosened or dissolved and removed from any part of the earth's surface.

eutrophic: applied to a body of water which is rich in dissolved nutrients but has a seasonal oxygen deficiency in the stagnant bottom waters.

exploration: the removal of overburden, drilling, trenching, construction of roads, or any other disturbance of the surface for the purpose of determining the location, quantity, or quality of a mineral deposit.

-F-

factor of safety: the ratio of the available shear strength to the developed shear stress on a potential surface of sliding determined by accepted engineering practice. Also called safety factor.

flocculation: the gathering of suspended particles into aggregations.

French drains: a covered ditch containing a layer of fitted or loose stone or other pervious material.

-G-

gabion: a bottomless wicker cylinder or basket filled with stones and used in engineering to prevent erosion or to trap sediment. Gabions are usually constructed of open weave metal, such as chain link fencing.

geotextile: any of a number of plastic, rubber or other synthetic compounds which are used either as a cushion or drain layer in liner systems.

ground water: water at or below the water table, used in a broad sense to include all water beneath the surface of the earth.

Corrects Format in Glossary

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Glossary of Terms

growth medium: soil or other material capable of supporting plant growth.

-H-

hazardous waste: a waste material which presents some toxicological or mutagenic hazard to humans or animals.

head of valley dump: a waste disposal system constructed at the narrowest end of a valley.

headgate: a watergate or floodgate of any race or sluice.

heavy metal pollution: contamination of surface or ground water, soil, or other material by cations or compounds of metals such as lead, arsenic, mercury, etc.

highwall: the unexcavated face of exposed overburden or ore in an opencut of a surface or for entry to an underground mine.

hydraulic scouring: the erosion of the bed or bank of a waterway by the action of flowing water.

-I-

incendive temperature potential: the temperature of the spark generated by a particular material when struck. The higher the temperature, the more likely that the spark will create an ignition of flammable material.

infiltration: the act or process of passing into or through a substance.

interim reclamation: reclamation conducted during temporary periods of operational cessation or shutdown. In general, interim reclamation is not adequate for permanent closure of an operation.

interim shutdown: a temporary closure of an operation or cessation of activity for a short (less than 1 year) period.

-L-

leach pads: mineralized material stacked so as to permit wanted minerals to be effectively and selectively dissolved by application of a suitable solute.

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Glossary of Terms

__leachate__: liquid that has percolated through the soil or other medium. A solution obtained by leaching.

__leaching__: extracting a soluble compound from an ore by selectively dissolving it in a suitable solvent.

__liner__: a layer of impervious material placed in a ditch or pond to prevent leakage.

-M-

__microclimate__: the climatic conditions of a small, generally restricted, area.

__mill effluent__: a liquid, solid, or gaseous product, frequently waste, discharged from a mineral processing facility.

__mining__: the science, technique, and business of mineral discovery and exploitation.

__moisture barrier__: an impermeable material or structure designed to prevent the inflow of water or aqueous solutions.

__moisture retention zone__: a material or structure designed to capture and store water or aqueous solutions.

__mulch__: a covering, as of straw, leaves, manure, etc., spread or left on the ground around plants to prevent excessive evaporation or erosion, enrich the soil, etc.

-N-

__National Pollutant Discharge Elimination Standards (NPDES) Permit__: a permit obtained from EPA or an implementing State agency governing point source discharges of water or aqueous solutions into the waters of the United States under Clean Water Act authorities.

__neutralization__: process by which acid is added to an alkaline solution or an alkali to an acid solution until they become neutral.

__neutralization potential__: a measure of the relative ease by which a solution may be neutralized.

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Glossary of Terms

-O-

open pit: a form of mining operation designed to extract minerals that lie near the surface. Waste or overburden is first removed and the mineral is broken and loaded.

operations: activities conducted for the purpose of prospecting, exploration, extraction, or other exploitation of a mineral or minerals. Operations also include reclamation and closure activities.

order 1 and 2 streams: order 1 streams are the smallest, unbranched streams in a drainage basin. Order 2 streams are formed by the confluence of two Order 1 streams.

overburden: material of any nature, consolidated or unconsolidated that overlies a mineral deposit.

-P-

permanent stream channels: natural drainages containing persistent streams.

permeability: a measureme[illegible] [illegible]ree to which water or other fluid will p[illegible] [illegible]tance.

pH: the sym[illegible] [illegible] reciprocal of hydrogen ion co[illegible] [illegible]ter. A measure of the relativ[illegible] [illegible]lution, with lower numbers [illegible] [illegible]mbers (>7) being alkaline [illegible]

phytotoxic: [illegible]

pit: an exca[illegible] [illegible]e earth.

precipitation: [illegible] [illegible]on in the atmosphere, [illegible]

prospecting: an [illegible] [illegible]cted towards locating a mineral depo[illegible]

pure live seed: a [illegible] of the percentage of seeds of the desired species [illegible]h will germinate out of the total seeds in a mixture.

Corrects Format in Glossary

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Glossary of Terms

-R-

__reagent__: a substance that, because of the reactions it causes, is used in analysis and synthesis.

__reclamation__: those actions taken to restore mined land to a post-mining use approved by the authorized officer.

__reclamation bond__: a financial guarantee of cash or an approved surety held by the BLM or other regulatory or surface management agency to ensure proper reclamation is completed.

__reclamation plan__: a document containing the specific procedures and techniques to be used to reclaim a site, which is approved by or submitted to BLM and/or any other surface management agency. A reclamation plan is an integral part of a mine plan, exploration plan, plan of operations, notice, or permit, but can be prepared as a separate document.

__regrading/grading__: shaping of the surface of an area disturbed by mining to prepare the area for reclamation.

__revegetation__: reestablishment of vegetative cover on a disturbed area.

__rill__: a small erosive feature caused by the channeling of water on slopes

__riparian area__: a form of wetland, transitional between permanently saturated wetlands and upland areas. They include the vegetative zones along the banks of rivers and streams and around springs, bogs, wet meadows, lakes and ponds.

__ripping__: the act of mechanically breaking compacted soils or rock to facilitate excavation.

__rock filters__: sediment trapping structures constructed of various sized rocks.

__rock stilling basins__: a particular type of sediment trap constructed of rock.

Corrects Format in Glossary

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Glossary of Terms

-S-

scarified: loosened with a cultivator or other mechanical device.

sediment ponds: any natural or artificial structure or depression used to remove solids from water and store sediment or other debris.

sediment barrier: any natural or artificial structure used to remove solids from streams or drainages.

sediment trap: any natural or artificial depression used to remove solids from streams or drainages.

seedbed: topsoil or other suitable growth medium which has been prepared for seeding by working and by addition of necessary amendments.

side-cast material: the material which is removed from an excavated area by pushing, blasting, or using other methods, and is disposed of adjacent to the excavated area.

sidehill dump: a waste disposal method in which the waste material is placed on the outslope of a natural hill.

silt retention ponds: a sediment pond designed to store small -sized (silt) sediments.

siltation: small sized sedimentary particles carried by surface runoff and redeposited.

slime ponds: a reservoir of any kind into which slimes are conducted in order that they may have time to settle or in which they may be reserved for subsequent treatment.

slope: average inclination of a surface, measured from the horizontal.

soil: the unconsolidated natural surface material present above bedrock; it is either residual in origin (formed by the in-place weathering of bedrock) or it has been transported by wind, water or gravity.

spoil: overburden or other waste material removed during mining.

Corrects Format in Glossary

spoil piles: the area where mine waste or spoil materials are disposed of or stored.

sprigging: a method of planting trees or shrubs using only small branches, or sprigs, of the plant.

stooling: a growth pattern of some plants, especially grasses, where new shoots are produced directly from the roots in a cluster.

subsoil drainage system: a natural or artificial drainage established under the ground. Such systems are often necessary to establish the proper moisture level in the surface growing medium and to prevent erosion from excessive surface runoff. Such systems are also necessary to allow proper aquifer recharge.

surface water runoff control plan (also called a storm water management plan): a plan, or portion of a larger plan, which addresses the issue of surface runoff of meteorological waters. This plan is often a part of the required plans for an NPDES permit.

surface mining: mining at or near the surface. Also called strip mining, placer mining, opencast or opencut mining, and open-pit mining.

suspended solids: solid material that can be separated from a liquid by filtration.

-T-

tackifier: a material added to a hydroseeding or hydromulching mix to make the mix sticky and thus improve the chances of adherence of the mix to the soil or other growth media.

tailings: the inferior leavings or residue of any mine product after most of the valuable ore has been extracted. Generally refers to mill effluent.

toxic substances: refers to any substance that has a poisonous effect on a form of animal or plant life.

turbidity: the state or condition of having the transparency or translucence disturbed, as when sediment in water is stirred up.

-V-

valley leach: a leach pad which is constructed so as to fill or partially fill a valley.

visual resource management: BLM system to classify the landscape into visual resource classes, each of which has a specific management prescription.

-W-

waste embankments: Slopes composed of discarded overburden or other waste material as a part of some dump or pond structure.

water bars: combination of ditches and barriers to direct flowing water off of a disturbed area.

wetland area: area adjacent to and influenced by streams, springs, lake shores, marshes, potholes, swamps, muskegs, lake bogs, wet meadows and esturine areas.

Corrects Format in Glossary

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