Chapter 4: MILL TAILINGS IMPOUNDMENTS

As outlined in the introduction to this manual, a detailed site analysis should be conducted as a first step in tailings impoundment design. In addition, the design characteristics should take into account specific needs of the project as they relate to tailings disposal. Refer to the following publications for more detailed information on tailings impoundments:

1) Design and Construction of Tailings Dams, edited by David Wilson, July 1981, Colorado School of Mines Press, Golden, Colorado.

2) Design of Dams for Mill Tailings, C.D. Kealy and R.L. Soderberg, USBM Information Circular 8410, U.S. Department of Interior, Bureau of Mines.

The hydrologic characteristics of the site are an important consideration as surface and ground water will either have to be diverted around the impoundment, passed through the dam or stored behind it. The National Oceanic and Atmospheric Administration (NOAA) weather atlas or the snow load report generated by the University of Idaho are sources of hydrologic data. If the dam is built in an area where no discharge is allowed, the storage capacity of the structure must be a major consideration. The tailings impoundment must be designed to contain all process water and be able to hold additional precipitation from a probable maximum storm event.

The geology and structural stability of the foundation material, upon which the dam is to be built, also needs to be analyzed. Sound foundation material should help ensure that the dam is stable. Drilling and/or test pits dug with a backhoe could be used in foundation studies. A geologist or geotechnical engineer must be consulted for assistance with these studies.

Both the Idaho Department of Water Resources and the Idaho Department of Health and Welfare (Division of Environmental Quality) have rules and regulations that have to be followed in tailings impoundment design and construction. For specific authorities and requirements, see Appendix A.

Before dam construction begins, surface water should be diverted around the impoundment area. This will decrease the amount of water that must be stored behind the dam. Diversion dikes and interceptor trenches can be used to divert water. If the water contains sediments, it will have to be clarified before it can be discharged. A settling pond will need to be constructed to hold the sediment laden water. Refer to the following BMP's:

III.1	Diversion Dike/Ditch	V.6	Sediment Ponds
III.2	Interceptor Trench	V.8	Log and Brush Check Dams
III.8	Stream Alterations/Diversion		

Ground water seepage into the impoundment area can be controlled by lining the pond. It may be necessary to install a drain field under the liner so that seepage does not build up between the liner and saturated soil under the pond. A seepage build up could cause hydrostatic pressure to be exerted against the liner (if it is a synthetic liner) which could result in failures of seams and welds.

A liner will also prevent water contaminated with leachates and/or process chemicals from coming in contact with ground water. The pond can be lined with an impermeable clay or a synthetic material such as polyvinyl chloride (PVC) or high-density polyethylene (HDPE).

Tailings impoundments designed to hold cyanide solutions, sulfide tailings, or phosphate slimes must be water tight. Earth dam construction techniques are usually used in these instances. Earth dams are constructed from sand, gravels, and other "natural" pervious and impervious materials found at the site where the structure is to be built. This type of dam should be designed and constructed by a qualified specialist. Earth dam construction design must be approved by the Idaho Department of Water Resources if the structure will be over thirty (30) feet high. Refer to the following publications for additional information on dam construction: Earth and Earth Rock Dams, Engineering, Problems of Design and Construction by J.L. Sherard, et al.

There are several conventional methods of tailings dam construction; they are:

1. Dams built using mill tailings as the construction media; these include:
   a. The upstream construction method.
   b. The downstream construction method.

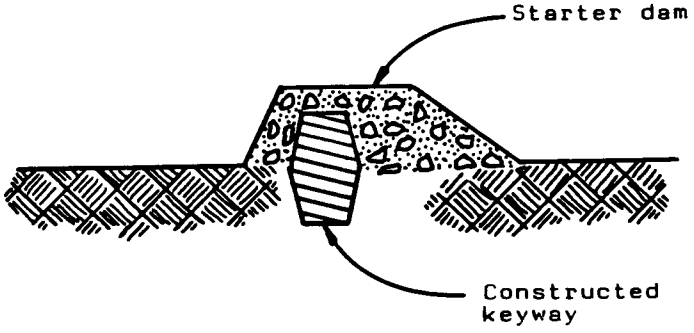
2. Dams built using borrow material as the construction media.

DESIGN CRITERIA:

1. Mill tailings impoundments should be designed by a qualified specialist (geotechnical engineer) in accordance with current engineering practices.

2. The foundation material should be tested to determine it's structural characteristics. Incompetent subsoil should be removed before construction begins. Build the starter dike on a firm base, free of organic material.

3. Excavate a "keyway" trench through the pervious foundation material into the impervious zone. The keyway trench should prevent water from seeping between the foundation and the starter dike. Backfill the trench with impervious material free of organic debris. Compact the material. Build the starter dike on the keyway trench. (See Figure 4-1)



Keyway

FIGURE 4-1

4. Do not construct the dam of homogeneous materials. Construction with heterogeneous materials will help control seepage and enhance structural stability. Starter dikes should be constructed of coarse rock, gravel mixed with sand, or other pervious materials. The dike should be erected in well compacted lifts.

5. The control of free water and seepage water is critical when designing tailings dams or waste disposal systems. When impounding tailings which are not very permeable, the disposal area should be large enough to hold the tailings while not increasing the surface level of the impounded material more than two (2) feet annually. As the impoundment area is built upstream of the dam, place materials of constantly decreasing permeability in this area. The pooled water should be kept as far away from the dam as possible.

6. When depositing tailings in the impoundment, place them in a relatively thin layer. Allow the tailings to partially dry out before placing the next layer. This will make the tailings material more stable and easier to reclaim.

7. When using the tailings impoundment, care should be taken to ensure that water is kept as far away from the face of the dam as possible. This can be done by decreasing the volume of water in the pond by reusing it for processing, by installing a decant system, or by pumping water out of the pond. Decant systems should be designed and installed by a qualified engineer. Improperly installed decant systems could cause piping which weakens the dam structure. If water is pumped out of the pond it must be relatively free of sediment and other contaminants. It should be pumped onto vegetated ground where it will not cause erosion or reach surface waters. The Idaho Department of Health and Welfare, Division of Environmental Quality, must approve plans for land application of wastewater. See Appendix A

DAMS BUILT FROM MILL TAILINGS

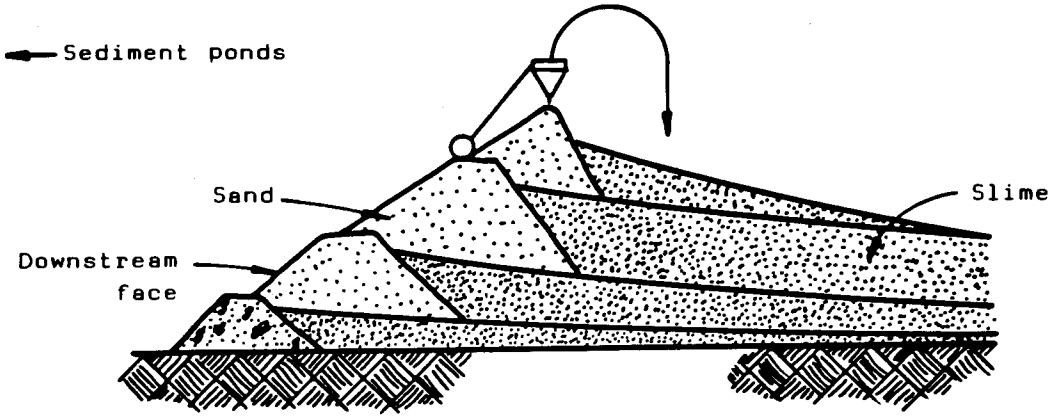
Upstream Deposition Method

Before construction commences on the starter dike, the site should be cleared of all topsoil and vegetation. The starter dike can then be built on a base free of organic material.

Build the starter dike on a firm, structurally sound foundation. Use coarse rock, gravel mixed with sand, or other permeable material for construction. The starter dike will act as the toe of the dam once build-up with mill tailings begins. (See Figure 4-2) The upstream side of the dike should grade into sand so tailings will not be piped through rock once deposition starts. (See Figure 4-3)

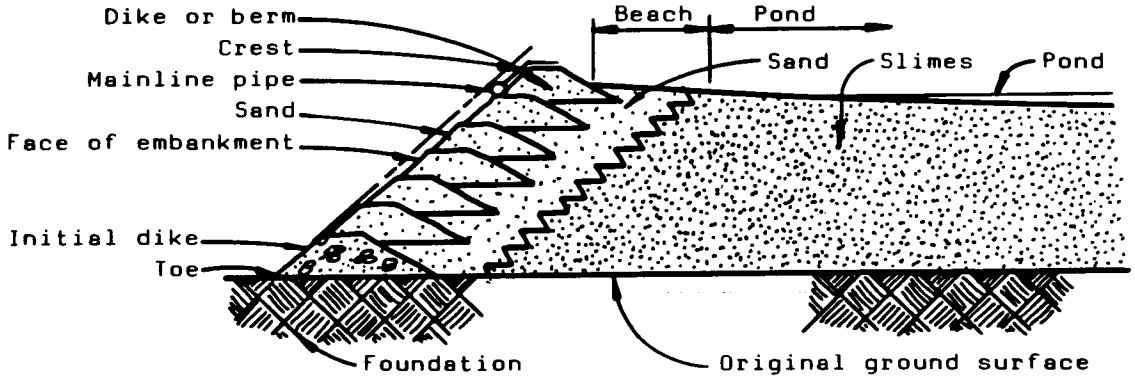
Drain fields may necessary beneath the starter dike (especially when the downstream construction method is used) to help reduce the water level at the face of the starter dike. Water from the drainfield may have to be directed behind a second dam or into a settling pond and then pumped back into the tailings impoundment if no discharge is allowed. Refer to the following BMP's:

III.7 Drain fields V.6 Sediment Ponds



UPSTREAM DEPOSITIONAL METHOD A

FIGURE 4-2



UPSTREAM DEPOSITIONAL METHOD B

FIGURE 4-3

After the starter dike has been completed, the main tailings disposal pipeline can be laid around the periphery of the dike. Bleeder lines, discharging into the pond, should be attached to the main line every ten (10) to fifty (50) feet depending upon the size of the dam. Cyclones can be used in conjunction with piping systems mentioned above, as cyclones help separate the coarser material from the slimes so they can be segregated into different parts of the pond.

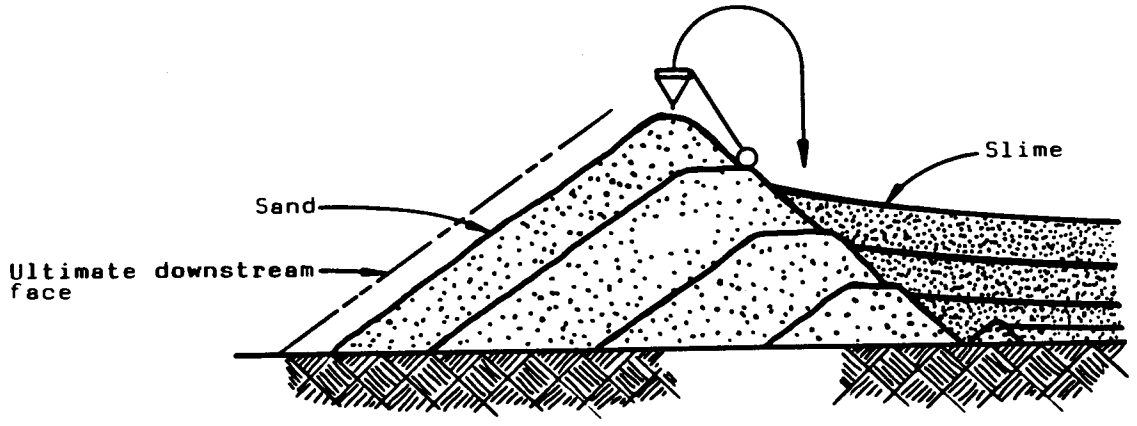
Dams built using the upstream deposition method have several advantages over other designs including : 1) lower construction costs, and 2) the speed with which the dam can be raised. (Using cyclones increases the speed of rise and also ensures a more uniform distribution of fines along the length of the starter dike.) Some disadvantages include: 1) the dam is built on previously deposited unconsolidated tailings, and 2) under static (motionless) loading conditions the dam height is limited because of the potential for sheer failure in a downstream direction. Dams built using the upstream deposition method are best suited for minor tailings impoundments that are not intended to be very high or hold large volumes of tailings and/or water.

Downstream Deposition Method

Build the starter dike as described in the upstream deposition method.

The downstream deposition method discharges coarse material around the outside of the starter dike while depositing the slimes on the inside. Cyclones uniformly spaced around the periphery of the dike are used to segregate coarse materials from the fines. This deposition method creates a rectangular dam (See Figure 4-4) which is both stable and safe. Considerable labor is required to move and maintain the cyclones.

Dams built using the downstream method have several advantages over the upstream method: 1) Larger, higher, and safer dams can be constructed using this method, 2) No part of the embankment is built on previously deposited material. This should make the dam more stable. One drawback to this method is the large volume of coarse material needed over time to increase the elevation of the dam. As the dam gets higher, larger volumes of coarse material will be required to retain the rectangular shape.



DOWNSTREAM DEPOSITIONAL METHOD

FIGURE 4-4

Dams Built of Borrow Material

This type of dam should only be used when tailings are not going to be deposited by peripheral discharge, or when uncontaminated slime is to be impounded, or when sand is deposited adjacent to the dike. Tailings sand should be dumped at the high side of the impoundment, adjacent to the dike (See Figure 4-5A).

Build the dike of a compacted mixture of clay, sand, and gravel. Build it in lifts. Compact each lift before the next lift is added.

The downstream material in the dike should be more permeable than the material deposited upstream. (See Figure 4-5B)

Sand or slime should be deposited adjacent to the dike, and water should be kept away from the dam surface.

DAM STABILITY CORRELATED WITH ZONING

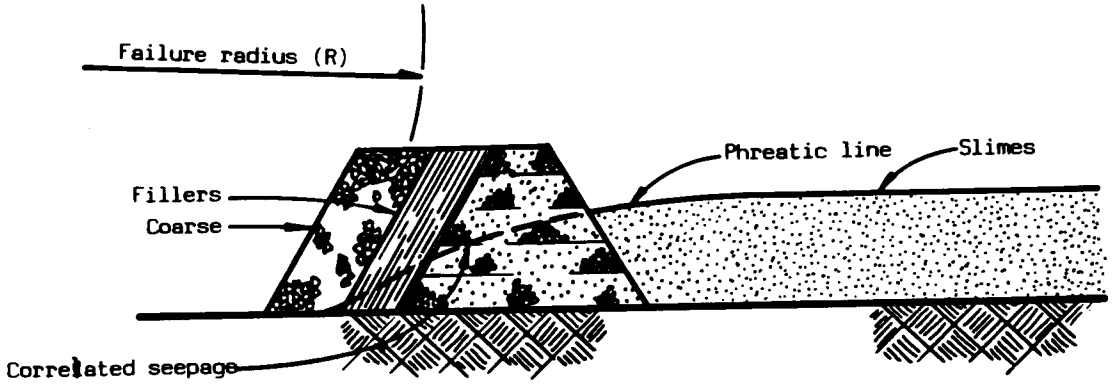


FIGURE 4-5A

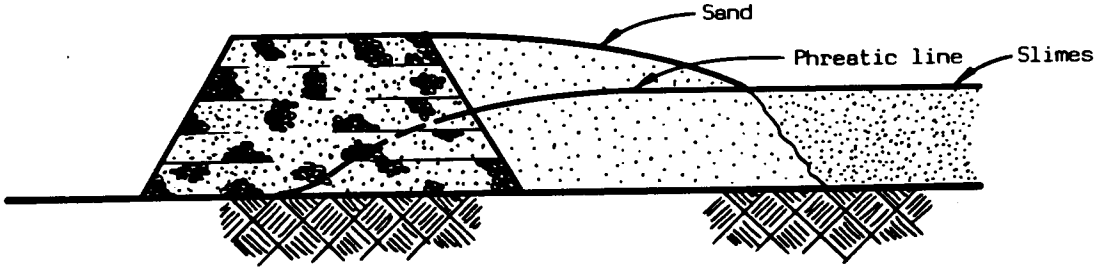


FIGURE 4-5B

RECLAMATION OF TAILINGS IMPOUNDMENTS

Upon completion of the mining project, both the tailings and dam need to be stabilized and reclaimed.

The tailings can be stabilized, in part, by dewatering. This occurs naturally by evaporation. Evaporation rates can be increased by trenching the tailings, which increases the exposed surface area. The tailings impoundment could also be dewatered by land applying non-toxic excess water.

If tailings cannot be adequately dewatered by evaporation, other methods will have to be used to stabilize the tailings. Coarse waste rock can be mixed with the tailings by pushing material from the edge of the pond toward the center of the impoundment. Heavy equipment with low surface pressures must be used for these operations. The tailings may also be covered with a layer of coarse waste rock, overburden, or an organic product such as straw or bark. This will help prevent wind and water erosion if vegetation cannot be established on the site.

Tailings that are difficult to dewater can be covered with a geotextile fabric or capped with clay. Capping tailings that have not been dewatered could cause future stability problems in the tailings impoundment. The potential exists for the build up of excess pore pressure in the tailings which could cause mobilization of the solid material. Capping may help prevent the infiltration of water into the tailings and reduce the potential for the formation of acid water in the tailings. The geotextile fabric must be well anchored at the edges of the pond and welded together where strips are laid adjacent to each other.

After the tailings have been dewatered and stabilized, they should be covered with topsoil and vegetated. If the tailings are acidic, lime may have to be applied before topsoil is spread, to adjust the pH. Refer to the following BMP's:

II.1	Topsoiling	II.2	Seedbed Preparation
II.3	General Planting	II.4	Broadcast Seeding
II.5	Drill Seeding	II.6	Vegetative Planting
II.8	Fertilizing	II.9	Maintenance of Revegetated Areas

During reclamation, diversion ditches should be cleaned out and maintained to divert water away from the site after it has been abandoned. Keeping surface water away from a reclaimed site can greatly reduce the potential for flooding, mass failure, and acid water generation which historically has been a major problem with abandoned tailings impoundments.

RECLAMATION OF THE DAM SURFACE

If feasible, the dam face should be sloped to 5:1 by adding fill material (overburden, non-toxic coarse tailings, waste rock) to the downslope side of the dam. (See Figure 4-6A) This will create a gentle slope that should help minimize erosion. Topsoil should then be placed on the dam face and the area seeded.

Another alternative is to place graded, coarse rock or riprap on the face of the dam to a depth of three (3) to six (6) feet. (See Figure 4-6B) This will help prevent water from running off the face of the dam and eroding it.

A third alternative for reclaiming the surface of the tailings dam is to cross ditch the face of the dam parallel to the contour. The grade of the ditches should not be less than 1% or greater than 5%. It might be necessary to line the ditch or seed it to decrease sediment production. This makes the ditches more stable, requiring less maintenance after the site has been abandoned.

METHODS OF TAILING DAM STABILIZATION USING A STABILIZING FILL AND USING A ROCK DRAIN

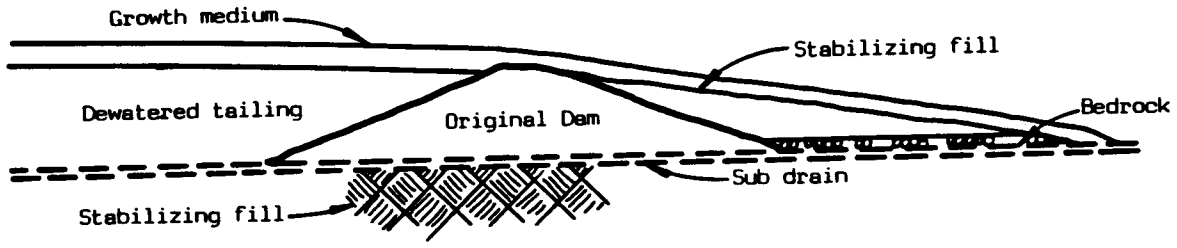


FIGURE 4-6A

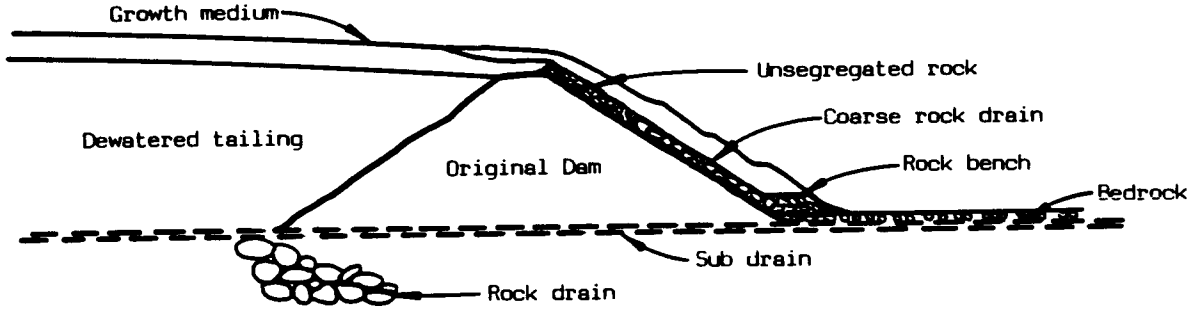


FIGURE 4-6B