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THICKENED TAILING DISPOSAL IN ANY TOPOGRAPHY

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It is shown that the Thickened Tailing Disposal System results in less environmental impact than most other systems used in the mining industry today. The initial and operating costs are generally lower and the system can be adapted to any given topography. The most damaging aspect of tailing disposal is usually seepage into the surrounding environment. Such seepage cannot be prevented entirely, but the thickened tailing disposal system creates less contamination than conventional methods. It maximizes evaporation, optimizes runoff and eliminates dusting. The construction of high and costly confining dikes and dams is eliminated. Finally, it is shown that the tailing disposal area can be readily rehabilitated. One case study is given to show how topographical features can be used to advantage to dispose of tailing safely and economically, using the thickened tailing disposal system.

Introduction

The Thickened Tailing Disposal System has only recently (1) been introduced into the mining and mineral processing industry. This paper describes the system and indicates its principal merits. The environmental impact is discussed and the use of natural topographical features is illustrated by one case study.

Principles of the System

The system consists of thickening the tailing and discharging the slurry through permanently-established spigots overlooking the disposal area. The tailing, being of a relatively thick consistency, will come to rest beneath the discharge spigots at its natural angle of repose forming a conical side-slope against the valley wall or discharge ramp. By judicious positioning of the spigots it is possible to regulate the configuration and elevation of the tailing deposit, while at the same time eliminating a major environmental hazard -- the need for confining perimeter dikes. If the area already contains dikes, the use of the thickened discharge system will make it possible to dispose of considerably more tailing without increasing the height of the dikes.

The system also eliminates the large flat 'slimes' pond -- a normal feature of conventional disposal operations. A tailing which has been thickened to slurry consistency will not segregate during deposition. The fine-grained fraction (slimes) of the tailing remains disseminated evenly throughout the deposit. This is contrary to the behavior of unthickened conventionally discharged tailing where the coarse-grained fraction settles out close to the spigots and the fines are carried out to the 'slimes' pond.

Although there are no fixed limits regarding the tailing slope that can be chosen, a six percent slope (3.4°) has been commonly recommended as a maximum. Reclamation and climatic conditions generally govern this decision.

The tailing deposit is accompanied by a small tailing water pond located generally within the limits of the disposal area. Sometimes, however, the pond may be established outside the limits in order to provide more room for tailing. By design this pond receives both tailing and natural runoff from the tailing deposit and surrounding watershed, together with a small fraction of tailing fines transported by the runoff. All runoff water eventually reaches the tailing water pond naturally, without constructing special drainage systems. Natural terrain contours are used to advantage for this purpose, together with designed positioning of the discharge spigots.

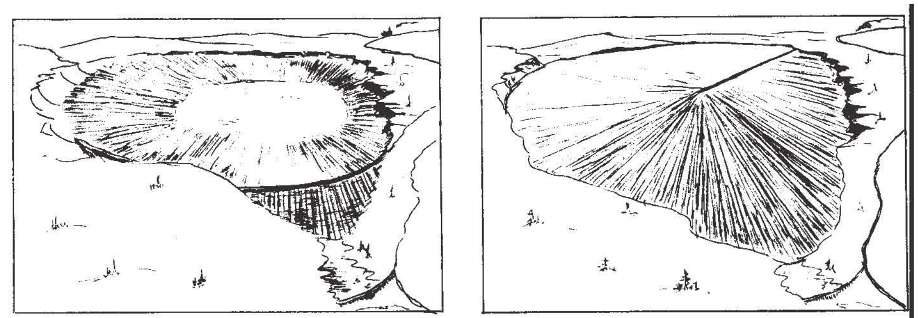

Figure 1 Comparison of the conventional and thickened tailing disposal systems

Depositional Behavior of Thickened Tailing

Generally, it would be anticipated that even with thickened tailing, the coarser fraction should settle out closer to the point of discharge in accordance with the laws of sedimentation. This segregation by size, however, does not occur. The heavy slurry flows downhill from the spigots without effective sorting. When the slurry reaches an underlying slope less than the natural depositional slope of the thickened tailing, the viscosity of the material overcomes the gravitational and dynamic forces acting on the flowing slurry, and the flow slows to a stop. Thus, layer by layer the deposit accumulates. Because any liquid flow will always seek the steepest slope and spread out on flat surfaces, the deposit will build up in thin layers of very uniform thickness, generally less than 2 inches (50mm). Because there is no segregation of materials, the viscosity remains constant whether the tailing is near the discharge spigot or several thousand feet away. Therefore the slope attained anywhere along the deposit is identical and uniform.

There are several factors which determine the steepness of the slope of the deposited tailing.

a. Percent solids of the tailing at discharge. As a tailing is thickened it progressively changes from a mixture of solid particles and liquid to a non-segregating slurry. The state at which the latter occurs is the minimum percent solids to which any tailing must be thickened. Typically, a slurry of this consistency will stand at slopes of 1 to 2 percent. Additional thickening will result in steepening of the deposited slope at an ever-increasing rate. Figure 2 illustrates typical laboratory tailing deposition test results.

b. Grain-size distribution of the tailing. The finer the tailing, the less percent solids is required to achieve the same depositional slope. The coarser the tailing, the more thickening is necessary. Figure 3 shows the results of tests made on many different tailing samples. For every mine a different relation is obtained between the slope of the deposited tailing and its percent solids.

c. The pH of the tailing. The pH of the tailing can have a very significant effect on the depositional slope. This appears to apply only to tailings having a pH on the basic side, but not necessarily to all tailing types.

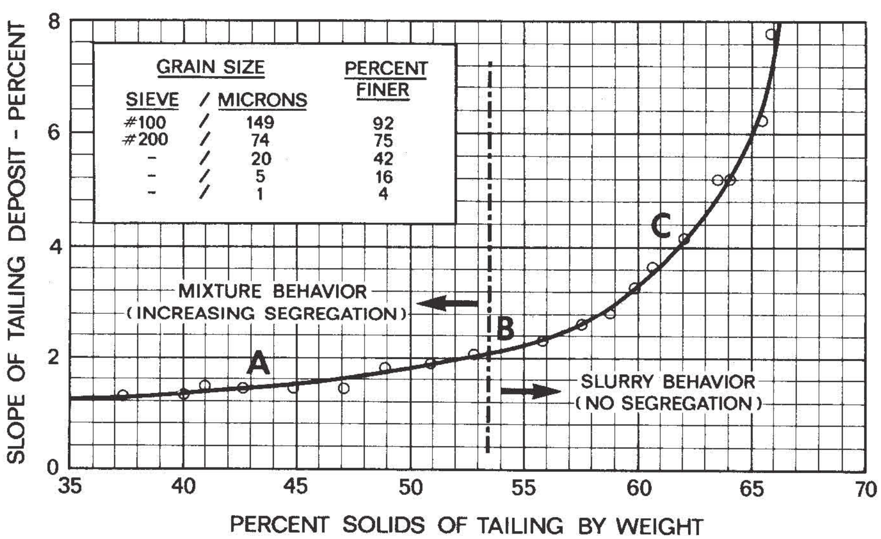

Figure 2 Typical laboratory tailing deposition test results

d. Rate of discharge per spigot. Another important factor which affects the slope of the deposition is the volume of flow from the discharge point. It has been found that if the same volume of material is discharged from several points instead of one discharge point, the resultant slope is steepened by as much as 0.75 to 1.0 percent. In order to benefit from this phenomenon and thereby reduce the degree of thickening to a minimum, it is advantageous to install a series of spigots for simultaneous discharge.

The depositional behavior of the tailing and the desired final tailing slope will dictate the tailing disposal program. Initially, the percent solids could be at the point of commencement of 'slurry behavior' (see point B in Figure 2). If tailing is being discharged into a valley, the initial percent solids is maintained until the toe of the resulting slope reaches the property line or tailing area boundary. At this time the percent solids of the tailing being produced is increased (say, to point C in Figure 2). This produces a steeper slope with no change in the position of the toe. If discharge is from a built-up ramp within the disposal area, the discharge spigots and ramp will also have to be raised at this time. The requirement of progressive thickening may permit the gradual acquisition of thickening equipment. Thus a minimum number of thickening units may be required at the start, followed by additional units being installed in subsequent years, as dictated by the tailing disposal schedule.

As the tailing deposit increases in thickness the underlying tailing consolidates to an ever-increasing density. Even small increases in percent solids create substantial increases in the strength of the deposit, as represented by the rapidly increasing slope of the deposition curve, Figure 2.

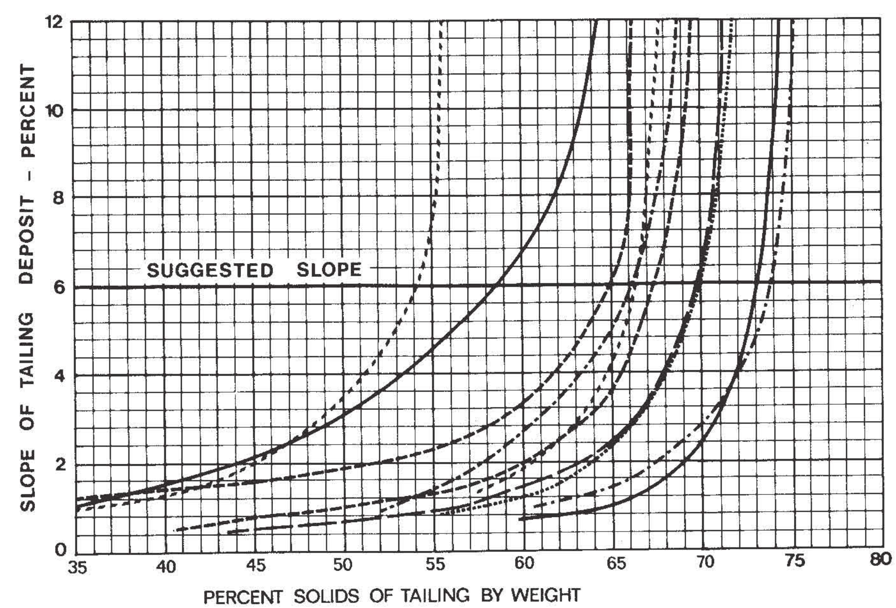

Figure 3 Laboratory test results showing tailing deposition curves. Tailing samples were obtained from different mines

Environmental Concerns

Dusting

Dusting develops along the dry perimeter surfaces and beaches of conventionally discharged tailing. At low percent solids in conventional disposal operations the tailing segregates into sand, silt and clay fractions as it flows from a discharge spigot. It is the fine sand and silt-size fraction, left on the dry perimeter beach, that is susceptible to being picked up and transported by wind. Conventional tailing disposal operations require periodic repositioning of the discharge lines and spigots. After the spigots are moved, the area dries out and dusting can result. With thickened tailing disposal dusting is prevented for the following reasons.

a. The discharge spigots remain essentially at the same location until termination of operations. This ensures that the tailing surfaces are continually rewetted.

b. Because there is no segregation of tailing particles after discharge, the capillary rise in the tailing is determined everywhere by the finest fraction -- the clay size. Such material has very high capillary rise. Thus there is a continuous rise of pore fluid to the surface of the tailing which tends to keep it moist.

c. It is envisaged that after completion of the mining operations, the surface of the tailing will become desiccated to produce a dense dust-free surface. This occurs because of the even dispersal of fine clay-size particles which act as a bonding agent throughout the tailing. Such behavior has been observed in the laboratory with many different tailing samples.

Resistance to Erosion by Runoff

During operations some erosion of the tailing by runoff from precipitation is anticipated and provision must be made to accommodate the eroded tailing. One way is to provide space in the runoff pond for 2 or 3 percent of the total volume of tailing. Alternatively, a better approach is to maintain the toe of the developing deposit somewhat short of the tailing disposal area boundary. The runoff material will settle in this area and eventually will be covered by tailing discharged during the last year or two of operations.

Runoff velocity is the primary cause of surface erosion. Velocity is dependent on the slope and on the thickness of the flowing sheet of water. Climatic conditions and the length of the tailing surface will determine these factors.

Three mechanisms are identified that act simultaneously either to decrease or increase erosion potential. Because of the complexity of the problem the interaction of these mechanisms is difficult to predict.

a. One of the favorable features is the retention of the fine particles (slimes) in the tailing slurry due to the process of thickening prior to discharge. The fine particles act as a binder for the coarse fraction due to inter-particle friction and cohesion. Figure 4 illustrates the critical water velocities (scour velocity) for quartz sediment -- a material not unlike a mine tailing. The curves show that particle sizes in the range of 0.1 to 0.5 mm will scour at the lowest velocity. By discharging unsegregated tailing whose mean particle size is considerably smaller at 0.01 to 0.05 mm, a higher velocity for scour is necessary. On a tailing slope of say 4 percent a moderate amount of runoff will flow at a velocity of approximately 0.7 ft/sec. (200 mm/sec). It thus appears that many deposits would undergo only minor erosion, the developed velocity being too low to scour the surface.

b. An unfavorable mechanism that is expected to increase erosion is the impact of rain drops on the dry (or wet) surface of the tailing. Each drop will tend to pluck out some tailing particles. It is expected, however, that this plucking will take place only over a limited period of time at the start of any rain. Progressively, as a sheet of runoff water develops on the tailing surface, it will absorb the impact of the rain drops and thus reduce the amount of plucking.

c. The third mechanism in the erosion process is a beneficial one. The flowing sheet of water may wash out some of the fine and intermediate particles from between the coarser particles and storage capabity for these eroded fines must be provided as stated earlier. However, as the upper finer particles are removed, the remaining coarser particles may create a protective blanket against further erosion.

It is concluded that erosion of the tailing surface by precipitation and runoff is not serious for typical design slopes of 4 to 6 percent.

Stability under Earthquake Loading

Earthquake effects are considered to be minimized on a deposit of tailing at a 4 to 6 percent slope, discharged by the thickened tailing disposal method. Thickened tailing, when discharged, is in a completely liquified state. This state is similar to that produced by liquefaction of a sand or silt deposit during an earthquake. It is under this liquefied condition (steady state condition) that the tailing will flow until it reaches equilibrium with the underlying slope. After deposition the material consolidates (excess water is squeezed out), and its shearing strength increases very rapidly. The rate at which strength is gained can be measured by the slope obtained in laboratory deposition tests (see Figure 2). As the tailing consolidates and increases in strength it acquires a capability of standing in a liquefied condition at a much steeper slope than that at which it was deposited. The factor of safety against flow gradually continues to rise.

In the upper few feet of the deposit, where consolidation is still progressing rapidly, it is possible that some mass movement due to inertia during an earthquake could occur. At a depth of 3 to 4 feet, where the tailing is more consolidated, movement is restricted. Furthermore, no movement is expected to occur after the termination of the earthquake, because the material in a homogeneous artificially liquefied state (created by the earthquake) does not contain sufficient liquid to convert the material back to a flowable condition. A large amount of liquid is required to cause the tailing to flow again on the slope at which it was deposited, a slope of 4 to 6 percent.

Seepage

Disposal by the thickened tailing discharge system has certain advantages over the conventional approach with regard to reducing the amount of seepage into the underlying soil formations.

The sloped tailing deposit is not contained by dikes, or has much smaller dikes and therefore seepage through such structures is either eliminated or at least greatly reduced.

By the elimination of the slimes pond the free hydrostatic head which is found on conventional disposal areas is also eliminated. Without a free head of liquid above the tailing surface, any downward seepage movement will be immediately arrested by the development of a substantial capillary rise potential (suction). This will occur because the fines in the tailing are disseminated throughout the mass and it is the fine fraction which contributes most to the capillary forces. Capillary rise in the typical fine fraction of mine tailing can theoretically attain 150 or more feet.

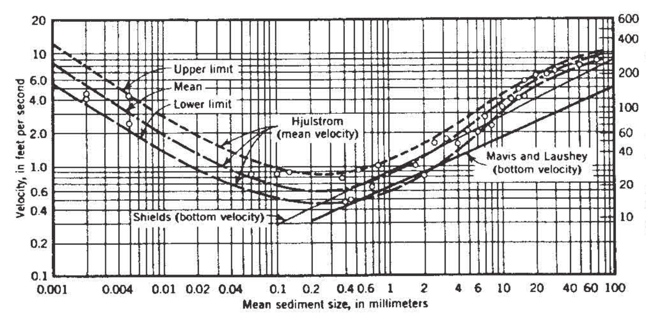

Figure 4 Critical (scour) water velocities for quartz sediment as function of mean grain size (2)

Reclamation

One of the common requirements for successful reclamation of a tailing pond is to ensure that the final soil surface is not too wet nor too dry for plant growth. Such a condition is provided automatically by the thickened tailing disposal system. No regrading of surfaces is necessary. The gentle planned slope of 4 to 6 percent provides good drainage which also enhances surface evaporation. There is no slimes pond nor a buried decant pipeline as in conventional tailing ponds. The system contains only a simple overflow structure at the lowest topographical point in the disposal area. No major operation is involved in abandoning this structure.

With regard to surface treatment and re-vegetation of a tailing disposal area, the system provides a substantial advantage over conventional disposal areas. It is suggested that the surface can be treated and seeded immediately after termination of tailing deposition, without the aid of any earthmoving or farming equipment.

Some weeks or months prior to the termination of mining operations, appropriate neutralizer, fertilizer, seed and possibly topsoil should be added to the tailing immediately prior to discharge. Because the tailing is in slurry form segregation of the added ingredients would not occur. Furthermore, the build-up of the material would occur in a layer of uniform thickness. The longer the discharge is maintained at one location, the thicker will be the deposited treated tailing. It would therefore be possible to place a uniformly treated layer of preplanned thickness and to cover the entire tailing surface. The process would be automatic. Furthermore, in most topographical settings, proper planning of the positions and elevations of the tailing discharge spigots will allow progressive reclamation procedures to take place. That is, it should be possible to progressively fill a tailing disposal area to its ultimate tailing height, and then to follow immediately with progressive reclamation.

Finally, if there is any question regarding the ability of the tailing to sustain vegetation, in spite of the application of neutralizer, an alternative solution is proposed. It also relies on the use of the thickened tailing disposal concept. Towards the end of mining operations natural rock and/or soil from the vicinity of the mine or from the upper benches of an open pit mine could be used as a soil cover. Alternatively, 'clean' waste rock could be stockpiled for this future use. The material must be free of sulphides and other potentially toxic ingredients. It is to be mined, crushed, milled and thickened to form a slurry which can then be released through the existing tailing line onto any new or old tailing surface. By control of the slurry consistency it will be possible to match the slope of the soil cover to that of the underlying tailing, thereby assuring a uniform and consistent cover. It would no doubt be advantageous to add some fertilizer to the soil before discharge. Possibly shredded roots of local fast-growing plants and/or seeds could be added as well. It is expected, of course, that only the crushing and milling circuits would be in operation; the floatation circuit, etc. would be closed down. Thickeners would still be required.

As an example, a 9000 ton per day concentrator would produce enough material to cover a 200 acre tailing pond with 8 inches of non-toxic soil at 75 percent solids in a period of only 28 days.

Case Study

A case study is described hereunder to illustrate the advantages of the thickened tailing disposal system and at the same time to indicate how conversion to such a system can be achieved. The study described is in the preliminary stages of design at the moment.

Alcan Smelters and Chemicals Ltd. are planning to convert their conventional disposal system at Arvida, Quebec to a thickened tailing disposal operation.

The key to successful conversion lies with the ability to thicken the extremely fine bauxite tailing to a slurry consistency which will permit a sloping deposit to be formed. Over the past few years Alcan has developed proprietary deep thickener technology which achieves the necessary percent solids to attain 2.5 percent tailing slopes.

Figure 5 shows the present layout of one disposal system slated for conversion.

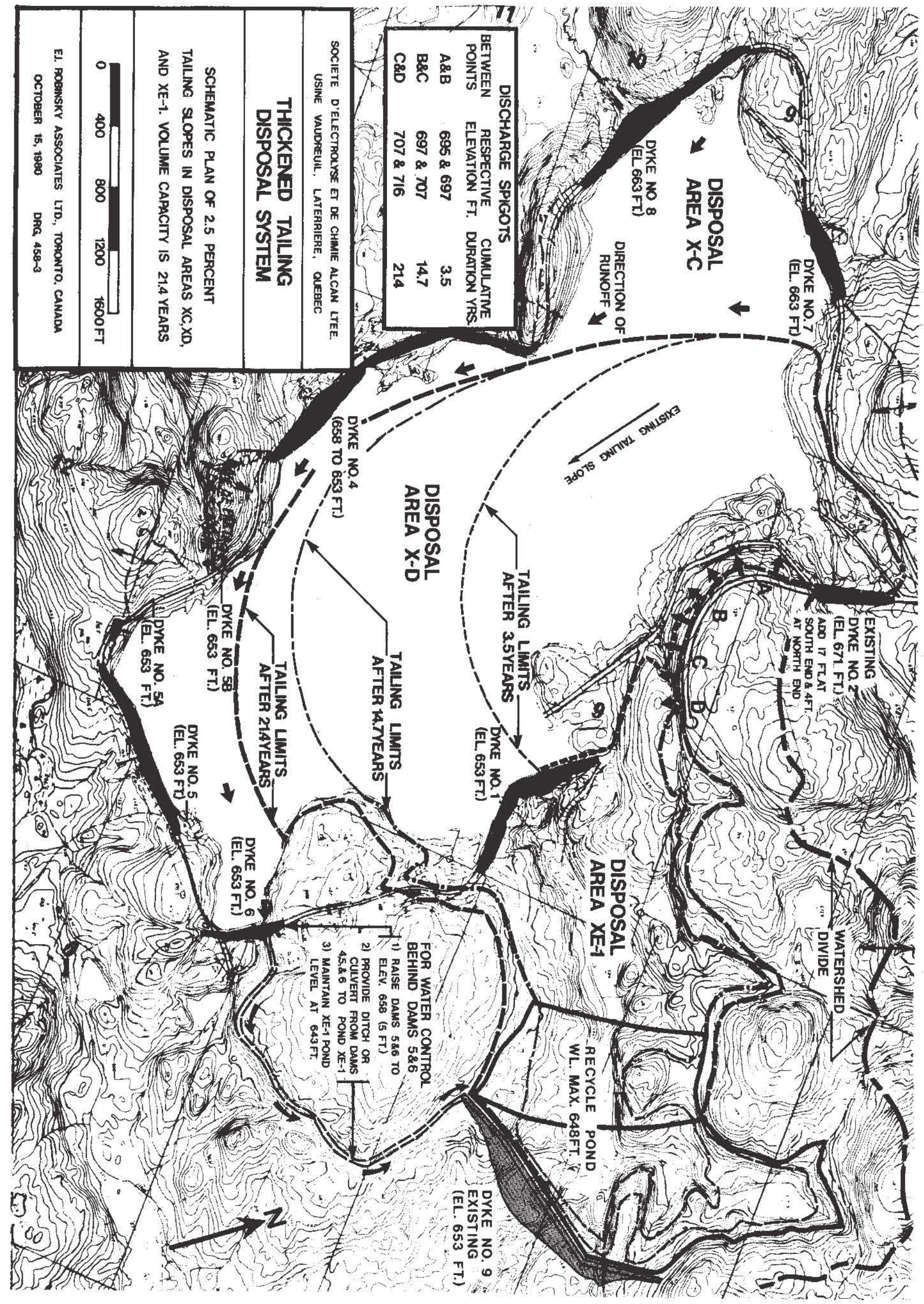

Figure 5 Plan of tailing disposal areas Alcan Smelters and Chemicals Ltd., Quebec

Active Areas X-C and X-D can provide disposal capacity for three more years. Area XE-1, still unused, can accommodate another 7 years of production. In other words, these two areas will have sufficient storage capacity for the next 10 years of operation. By conversion to the thickened tailing disposal system, the total disposal area will accommodate 21.4 years of tailing storage using 2.5 percent tailing slopes (illustrated). An additional 20 years can be accommodated by moving the discharge ramp higher uphill and by additional thickening of the tailing to attain 4.5 percent slopes (not shown on Figure 5). Thus 41 years of storage can be accommodated without constructing new dikes or raising any of the existing ones.

Discharge is to be effected simultaneously from a series of spigots established between points A and B. Progressively, discharge will be advanced towards point D.

Two alternative schemes are being considered.

1. Discharge for 21.4 years to 2.5 percent slopes as shown in Figure 5, then cover the entire deposit with 4.5 percent slopes for a total of 41.4 years. Reclamation would follow thereafter. The advantage of this scheme is that less thickening (less cost) is required in the immediate future.

2. Discharge at slopes greater than 2.5 percent starting above point A and moving the spigots progressively eastward past point D. Progressive reclamation would follow. The advantage of this scheme is that the impoundment and runoff surface areas are reduced as the spigots are moved eastwards and the reclamation program can follow immediately.

To be noted in Figure 5 is the position and elevation of the spigots, together with scheduling of the duration of discharge. Proper planning will permit full control of the shape and extent of the tailing deposit. Thus it is possible to plan adequate toe distances to existing dikes to accommodate surface runoff, drainage and any necessary overflow or recycling structures.

Conclusions

In conclusion, the thickened tailing disposal system provides the following advantages over the conventional system.

Any chosen disposal area can accommodate considerably more tailing than could be accommodated by conventional storage systems.

Overall cost of tailing disposal is reduced substantially through the elimination of confining dikes, the reduction in size of tailing and return water pipelines, and the elimination of pipe abrasion by pumping at low velocity. Finally, reclamation procedures are simple and automatic.

The environmental impact is small. Dusting is inhibited and seepage potential greatly reduced by the elimination of the slimes pond and the provision of a self-draining sloped surface. Safety is enhanced through the elimination or reduction in size of the perimeter confining dikes.

Acknowledgement

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