Technical and Economic Feasibility Analysis for the Selection of Tailing Deposits

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Subject: mining economy and mining evaluation.

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Summary

The mine 2016-I project requires to have 80 (ktp) of fine mining waste for 20 years. Therefore requires sites with a storage capacity of 500 (Mton) Equivalent to approximately 400 (Mm3), to a dry density of 1.3 (ton/m3). The analysis of the feasible alternatives and the selection of the optimal technical-economic alternative consider two fundamental aspects: The site or place of deposit (storage) and the method of deposit.

In principle the location of the storage site should be close to the Concentrator Plant, Which in turn must be close to the deposits that will be exploited, in order to minimize the costs of transporting the tailings between the two points. In addition, the deposition site must comply with certain geomorphological and geotechnical conditions that make it suitable for storage purposes, also at a minimum cost. The Mina 2016-1 project consists of three fields to be exploited in series. According to the topography supplied by CIA MINERA 2016-1. Therefore, the objective of the present study is to look for appropriate sites. In this wide area of work, some alternatives of location for the deposit have been proposed, which have been analyzed with an integrated methodology for the analysis of the alternatives of sites, which considers In order to finally obtain the selection of one or more suitable sites to propose to CIA MINERA 2016-1.

INTRODUCTION

Humanity is currently facing a series of environmental problems caused by global warming, ozone depletion, acid precipitation, global pollution of the planet and a deteriorating epidemiological environment.

All these factors contribute to a habitability crisis, since it threatens the planet's ability to maintain a large-scale civilization. In the last twenty-five years, and especially in recent years, there has been a series of national and international pressures to combat environmental degradation.

As a result, environmental issues are increasingly addressed in the overall context of development process and policies. All metallurgical process in the concentration of minerals is obtained apart from the concentrates and the tailings, which are results of different processes of benefit of minerals. So tailings are defined as particles of crushed rocks that are produced or deposited in the form of pulp (Paste with water). This definition reaches the vast majority of wastes from mineral processing, after recovery of mineral values.En la minería y en la metalurgia extractiva especialmente, el principal énfasis está en la extracción de los valores minerales; considerando que los relaves son simplemente un producto de desecho con características físicas y químicas propias. On the other hand the disposal of tailings is commonly identified as the most important of the environmental impacts in many mining projects. In this sense, the present study will affect the economic and technical criteria in the selection of a tailings deposit.

PRESENTATION OF THE PROBLEM

An open-pit mining company with a daily waste production of 80 Kton and with an operating time of 20 requires a deposit to store 500Mton of waste with an average density of 1.3 ton / m3.
The analysis of the feasible alternatives and the selection of the alternative consider two fundamental aspects: the site or place of deposition and the method of deposition. Both aspects should be considered together for the selection of the alternative.
The tailings deposit studied belongs to a mining company that has scheduled an annual production and defined operating time, reason why the necessary conditions for an expansion or regrowth of the deposit and tailings are not considered. This study was performed to meet the current needs of the mining company.
The study carried out in this case does not have detailed information of the land or detailed information of the costs of the construction of a deposit of these dimensions reason why will be a study based on information of old projects already realized.
The current role played by the miner with respect to economic and social prospects allows me to study the

construction of a tailings deposit from a technical, economic, ecological and social point of view.

OBJECTIVES

Main:

- Develop a methodology for the selection of a tailings tank.

Secondary:

- The use of a decision matrix in the selection of tailings deposit with technical and economic criteria.
- Show the most important parameters to be taken into account in a tailings deposit.

METHODOLOGY

RELAY TANKS

It is a work that is constructed to safely contain the tailings coming from a plant of benefit of minerals, mainly by flotation. Tailings are composed of ground material and water with reagents. A tailings dam consists of a retaining wall, normally constructed with the coarse fraction of the tailings, and a cuvette. In the cell the fine solids sediment and on the surface a lagoon of clear waters forms.

1. Tailing tanks

1.1 Construction of the Wall Water Top Method: consists of a starter dam constructed with compacted loan material on which the deposit of the tailings begins, using classifiers called "Hydrocyclones"; The coarser fraction or sand is discharged through the underflow of the hydrocyclone (Underflow) and deposited next to the initial wall, while the finer fraction or sludge, which exits through the upper flow of the hydrochloride (Overflow) is deposited towards the center Of the block at a point farther from the wall, so that a kind of beach is formed by sedimenting the heavier particles of sludge and much of the water flows, forming the sedimentation well or sedimentation lagoon. Once the deposit is close to being filled, the wall is lifted, displacing the hydrocyclones to a higher elevation in the direction upstream and beginning a new stage of discharge of sands, and heaving of the wall; The construction is successively continued as indicated.

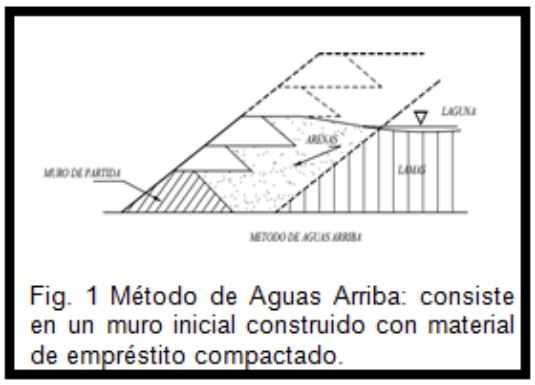


Fig. 1 Método de Aguas Arriba: consiste en un muro inicial construido con material de empréstito compactado.

1.2 Construction of the Wall Water Down Method: Construction also starts with a wall of compacted borrowing material from which the sand is emptied to the side of the slope downstream of this wall and the sludge is deposited towards the water slope above. When the wall has been raised sufficiently, usually 2 to 4 m., The lifting of the wall is carried out, displacing the hydrocyclones to a higher elevation in the direction downstream and beginning a new stage of discharge of sand and heaving of the wall.

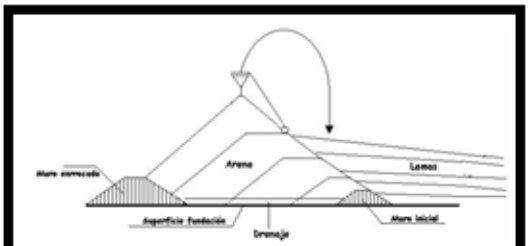


Fig.2 Método de aguas Abajo (Capas de arena inclinadas)

1.3. Construction of the Wall Method Central or Mixed Axis: it starts, like the previous methods, with a wall of compacted borrowing material, on which the cyclone sands are deposited towards the downstream side and the slats towards the water side above. After the drainage of sands and slats corresponding to the initial wall has been completed, the sand and sludge feed line is elevated along the same initial vertical plane of the crowning edge of the starting wall. This makes it possible to achieve a wall of sands whose axis is maintained in the same vertical plane, whose upstream slope is more or less vertical, and whose slope of downstream can have the inclination that the design considers adequate. This method requires an intermediate volume of sand between the 2 previous methods, and allows to achieve sufficiently stable walls

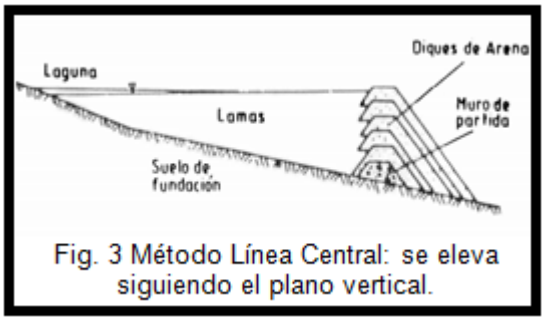


Fig. 3 Método Línea Central: se eleva siguiendo el plano vertical.

2. Tailings Reservoirs: This type of tailings deposit consists of constructing a resistant wall made entirely of borrowing material, compacted and waterproofing the inner slope of the wall and also part or all of its crowning; The tailings are deposited complete in the bucket without need of classification, but also must have, a system of evacuation of the clear waters of the lagoon that is formed. The fundamental difference between a reservoir intended for the accumulation of water and one destined for tailings is that while the water reservoir is built at once with its final capacity, the tailings dam can be executed in stages as the Deposit of the tailings, so as not to anticipate investments and reduce their present value to a minimum.

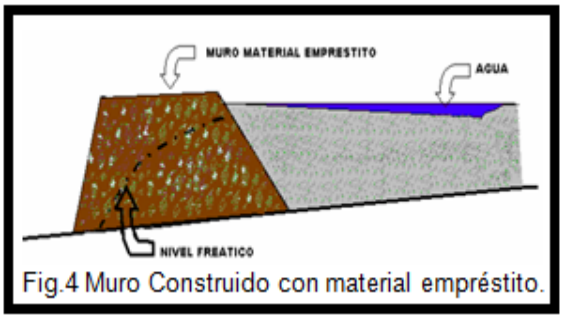


Fig.4 Muro Construido con material empréstito.

3. Thickened Tailings Reservoir: The procedure is based on the higher viscosity reached by tailings pulp when increasing solids concentration, this type of tank does not require the construction of a dam to limit the area involved, it is recommended the construction of A small embankment slightly away from the outer edge of the reservoir, which serves to contain a volume for the deposit of the water dislodged by the tail, which is collected by a landfill or other device to be pumped and recirculated. This small embankment serves both to collect rainwater and to lead it to natural channels. Another basic principle of this type of deposit is derived from the difference in material segregation between a diluted pulp and a concentrated pulp.


Fig.5 Disposición de Relaves Espesados (Método Robinsky)

4. Filtered tailings deposit: This type of tailings deposit is very similar to that of thickened tailings, except that the material contains less water due to the filtering process using equipment similar to those used to filter concentrates, such as Are the press or vacuum filters.


Fig.6 Disposición de Relaves Filtrados

5. Storage of Tailings in Paste: The tailings in paste correspond to a mixture of water with solid, containing abundant fine particles and a low water content, so that this mixture has a thick consistency, similar to a high density pulp . A good tailings paste requires at least 15% weight concentration of particles smaller than 20 microns.
    - In pulp tailings deposits, the following are significantly reduced:
        - The need to design and build large deposits.
        - The volume of materials involved in the construction of deposits.
        - The risks of geomechanical failure associated with conventional locks.
        - The risks of generation of acid waters and leaching of metals.
        - The management of clear water volume.
        - Loss of water by infiltration and evaporation.
        - The soil surface to dispose the tailings, optimizing the use of the soil.
        - The emission of particulate material.

    - In the tailings deposits in pulp the following significantly increases:
    - Recovery of water from tailings
    - The environmental acceptance of the community.
    - The possibility of co-depositing with other mining waste (sterile or ballast)
    - Operational flexibility.

- Vegetation or remediation activities can be developed in parallel to the operation.
- Allows the encapsulation of contaminants in the tank.

Fig. 7 Depósito de Relave en Pasta.

MAIN COMPONENTS OF A RELAY DEPOT

a) Bucket.- Corresponds to the physical volume available where the sludge (fines) and much of the water from the tailings are deposited in such a way that the clear water lagoon is formed in it due to the sedimentation of the fine particles. The bucket is the most important component in relation to the life of the tank.

b) Wall or Perimeter Prism or Resistant Prism.- This wall delimits the bucket and allows to contain the residues that are discharged in it. Therefore, the perimeter wall is generally the most important component in relation to the stability or degree of security of the deposit.

c) System of Discharge and / or Classification and Selection of Tailings.- The system of discharge of mining waste allows to deposit these in the bucket, reason why a failure of this system is translated in the stop of the efficient operation of the deposit. In addition, often this system is also used to classify and select the residues, so as to use part of them as material for the construction of the perimeter wall (use of cyclones)

d) Area of discharge of the Waste or Zone of Beach .- The area where the waste is discharged to the bucket is called the beach area because it is usually dry on the surface and resembles a beach of fine sand. It is the part of the tailings deposit located in the vicinity of the emptying line, this beach of form next to the resistant prism.

e) Poza de Aguas Claras or Decantation Lagoon.- Corresponds to the lagoon of clarified waters that forms in the bucket due to the sedimentation or decantation of the solid particles. This pool allows the recovery of water and at the same time the evacuation of these from the bucket.

f) Drainage system.- It is the system (for example draining fingers or beds) used to depress the water table inside the wall, usually protected by filters to prevent the flow of water from entraining the fine particles and To cause clogging of the system.

g) Waterproofing System of the Bucket.- If the tailings in the bucket contain toxic substances, water infiltration to the subsoil must be avoided, as these could cause contamination of the groundwater resources and / or surface area of the area. Location of the deposit.

h) Detour Channels.- These are built ditches or tunnels built on the slopes to capture and divert surface runoff, preventing them from entering the tailgate or tailings pond.

i) Crowning berm.- It is the horizontal strip of greater dimension of the external slope of the resistant prism or retaining wall.

j) Emergency landfills.- They are variable threshold landfills intended to evacuate the excess water accumulated in the bucket of a latch as the sedimentation pond grows by heavy rains.

DECISION MATRIX

Based on the main and secondary objectives to select the appropriate place to deposit the tailings was obtained:

OBJECTIVE WEIGHTING FACTORS	
Objetive	Weighting Factor(%)
Maximize tank stability.	22%
Minimize negative public perception.	22%
Minimize tailings transport costs.	18%
Minimize the cost in fills of wall.	15%
Management of basin and location of water dam.	15%
Minimize water seepage.	5%

STABILITY OF DAMS

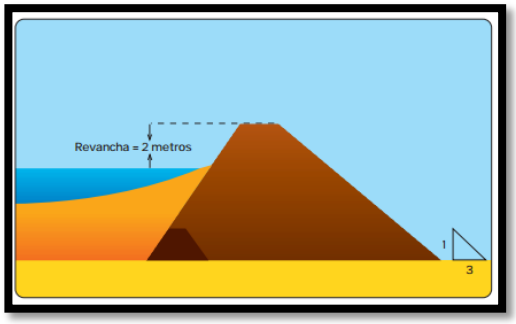
The tailings dam project considers the following analyzes:

- **Stability against liquefaction**

The liquefaction is a phenomenon that originates the resistance of the soil, to the point of producing a flow failure. The susceptibility of a soil to liquefaction depends heavily on the density and initial stress conditions on saturated soils; When the level of the groundwater is a few meters from the surface. In this case the soil could deform and move as the tailings accumulate, with the risk of causing a collapse of the dam

- **Stability against overflow**

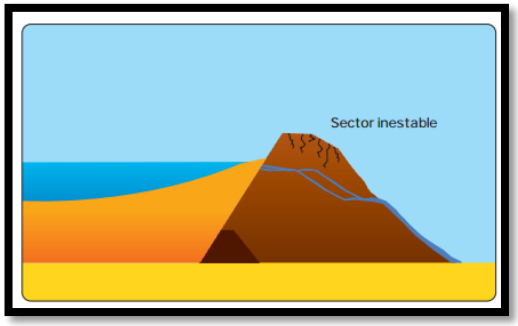
Poor control of surface water flow can lead to crown overflow and consequently tailings dam collapse. The height of the dam must consider a minimum free edge to contain the discharge of the tailings flow, as well as the precipitation water falling into the reservoir and the runoff water entering the drainage basin



- **Stability against internal erosion**

➢ Cracking: It is related to the existence of tensions that can be related to the rheological properties of the constituent materials, the type of soil, the resistance and the deformability in soil traction breakage, the height of the dam, the magnitude of the effects Seismic and the occurrence of intense and prolonged rains.

➢ Tubing or internal erosion: This phenomenon can occur due to the presence of a hydraulic fissure, unsealed pipes, compaction defects, rupture of the waterproofing filter, inadequate filters or drains, etc.



ENVIRONMENTAL IMPACT

Tailings operations are complex and specific to the site, and involve environmental aspects and particular physical characteristics; their effective administration depends on the application of both administrative and technical knowledge and experience.

The most relevant environmental impacts to consider are in function of the magnitude of the possible damage that can cause and the frequency of occurrence of these events in other mining operations around the world.

- **Tailings dam failure**

Around the world at least 63 large-scale tailings dam failures were reported and caused considerable environmental damage during the years 1960 and 2014. Damage from tailings dam failure is:

➢ Contamination of water, causing the rupture of the water supply to the surrounding communities.
➢ Massive death of fish in nearby marine habitats.
➢ Damage to agricultural land, etc

- **Surface water control**

Although the water inside the tailings dam can be treated or reused in the concentrator plant, it can generate an environmental impact by:

- Be evaporated by the climatic conditions of the place where it is operated. It is therefore important to review the climate records and evaluate existing methods to avoid air pollution with elements that are foreign to the natural composition of the air.
- Rainfall is present when combined with the liquid substances of the tailings, to overflow the dam and to contaminate by direct contact the soil and the surrounding area. It is therefore important to carry out a review of the rainfall records in the area in question.

- **Infiltration control**

  The liquid part of the tailings is able to infiltrate and bequeath to contaminate the water table. If this happens the soils through which these fluids travel would be the main affected. Then the surrounding communities and biodiversity directly or indirectly dependent on groundwater.

  It is therefore fundamental to make a study of the stratigraphic column of the land in which the tailings dam will be established, waterproofing it if necessary with geo-membranes or an alternative method that is equally efficient or better. Not stopping to control by the relevant methods once it is in operation.

TRANSPORT OF RELAYS

The tailings are transported by means of centrifugal pumps which drive the pulp of tailings delivered by the thickener, passing or by a stage of cycloneado, through tanks and discharging these in the field or tailings dam.
Therefore, when calculating the costs of tailings transportation, the most important parameters are:

- **Amount of waste to be transported:** this defines the capacity of the pump (s) needed to meet the need. At the same time it establishes the capacity and power of the electric motors to use.
- **Distance from the plant to the dam:** determining factor in the cost of transportation and total cost of operation of the tailings dam. The further away, the greater the energy required to move the required flow rate, hence the higher energy cost.

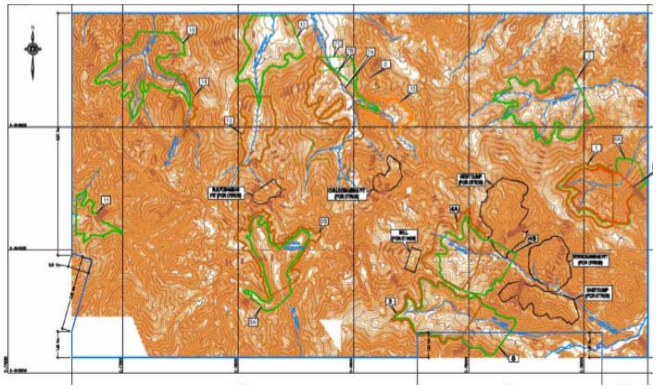
Keep in mind that usually the place chosen to store the tailings are below the level of the plant of treatment of minerals, because it is managed to take advantage of that difference of heights in the transport, making gravity a help.

RESULTS

DESCRIPTION OF THE PROBLEM

- Project Name: UNI 2016
- Surface mining operation
- Daily tailings production: 80000 tons.
- Life of mine (LOM): 20 years
- Total tailings production: 400 Mm3

POSSIBLE ALTERNATIVES



PRE-SELECTED PLACES

SITE	VOLUME OF DAM (Mm3)	DAM HEIGHT (m)	LENGTH OF DAM (m)
2	440	15	2200
3	407	200	1670
4	445	220	1245
6	416	130	953
8	402	120	2225
9b	424	210	1174

SUMMARY EVALUATION FOR RELAY DEPOSITS

Based on the main and secondary objectives to select the appropriate place to depopulate the tailings was obtained:

- Deposit stability 22% (A).
- Minimize negative perception 22% (B).
- Minimize transportation cost 18% (C).
- Minimize wall volume 18% (D).
- Minimize water management cost 15% (E).
- Minimize infiltration 5% (F).

SITIO	A	B	C	D	E	F	PONDERADO	RANKING
2	3	2	3	3	3	3	2.78	4°
3	3	2	4	3	3	3	2.96	2°
4	3	4	5	3	3	4	3.63	1°
6	2	4	3	1	4	3	2.79	3°
8	2	3	1	4	3	2	2.55	6°
9b	2	4	1	5	2	3	2.85	5°

CONCLUSIONS

1. The purpose of the report was to generate a model that will serve as a basis for the selection of tailing, for which the most relevant parameters previously detailed and justified in the report were taken.

2. One of the most sensitive parameters in the selection of the tailing is the stability of the tailings that, due to failures, generate human, economic and ecological losses, causes:
   - Level of the water wall rises (generates instability or overflow)
   - Control the quantity and quality of sands to keep the slope stable
   - Possible excessive deformations, leaks in the wall, presence of cracks
   - Seismic events (generates liquefaction)
   - Failure plans for precipitation or wind erosion.

3. By using the "MATRIX OF DECISION" applied to the selection of tailing, it is allowed: To make a coherent decision in the election and to justify the decision of the tailings deposit. This matrix is supported by a technical - economic - ecological criterion.

4. The matrix allows me to know that the best option to build a tailings deposit is option 4..

5. By analyzing tailings disposal methods a substantial advantage of the filtering method was reached by:

   - Investment reverses (recovers additives for reuse in the concentrator plant).
   - Water is recovered as a resource (after treatment).
   - Savings in tailings storage spaces, due to better compaction of waste.
   - Increase in the life of the tailing
   - Reduction of environmental problems and greater confidence on the part of the population

RECOMMENDATIONS

- Conduct seismic response studies in the tailings deposits in operation to evaluate and guarantee their stability

- Design an adequate drainage system, to reduce the saturated area and the possibility of liquefaction

- Control the compactness and the content of fines of the thick tailings of the dam of the deposit to guarantee an appropriate behavior.

- It is recommended to identify value elements in the tailings and evaluate their recovery as commercial products (as is known the schemes to produce copper considers the recovery of minerals as gold and silver, but all other elements remain in the tailings).

- By way of example, it can be mentioned that the value given to tailings by the content of elements such as Gallium, Germanium, Silver, Titanium, Copper, Selenium and Potassium in the form of Potassium Chloride at current market prices, Amounted to 56.5 million dollars for one million tons of tailings

- It is advisable to carefully consider the weights in the decision matrix because they are considered according to the analyst's criteria. (In this case the group)

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