Esperanza Project — Drivers for Using Thickened Tailings Disposal

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Abstract

In 2006/2007, SRK undertook the feasibility and detail design of the Esperanza thickened tailings disposal facility for Antofagasta Minerals PLC. The Esperanza project in Chile's northern Region (Region II) is located in the extremely arid Atacama Desert with 10 mm or less of annual precipitation. The Esperanza project at a nominal production tonnage of 95,000 tons per day will consume approximately 80 million m^3 of water per year. These volumes of water are not available except from the sea ~180 km away and 2000 m lower. This places a significant premium on the cost of water and therefore every cubic metre that can be saved and re-used is economically beneficial to the project.

The Esperanza tailings site is formed by a natural flattish and wide quebrada or dry river valley. The height of the toe containment dam is at the mouth of valley, and therefore its cost to the project is governed by the ultimate beach angle of the deposited tailings. Beach slopes achieved and their prediction has been the subject of some significant discussion at previous thickened and paste tailings seminars (Jewell, et al., 2002), as well as at existing operations around the world. SRK adopted a measured approach to this issue, where pilot scale testing was undertaken, solutions implemented at other operations were reviewed, and ultimately a risk-based development strategy was proposed.

The SRK design also attempts to address operational issues that were identified at existing thickened tailings operations, such as the management of low density tailings and run-off water management. The design used the latest engineering deposition modelling software to create a picture of the tailings disposal over time that could also be used to facilitate the permitting of the facility. This paper presents the engineering and environmental drivers for choosing thickened tailings disposal, addresses emerging design and operational results, and shows how pilot plant data was incorporated into the ultimate design.

1 Introduction

In 2006/2007 SRK undertook the feasibility and detail design (SRK Consulting, 2007) of the Esperanza thickened tailing disposal facility for Antofagasta Minerals PLC. The Esperanza project in Chile's northern Region (Region II) is located in the extremely arid Atacama Desert with 5 mm or less of annual precipitation. The Esperanza project at a nominal production tonnage of 95,000 tons per day (tpd) will consume approximately 80 Mm^3 of water per year. As these volumes of water are not available from traditional sources such as groundwater or surface water, the only viable source is from the sea located approximately 180 km to the west and at an elevation difference of 2000 m. This places a significant premium on the cost of water and therefore every cubic meter that can be saved and re-used is economically beneficial to the project.

The tailings project also marks a significant ramp-up in proposed production tonnages from any existing thickened tailings operation around the world and the risks associated with using this technology could be financially significant. It will also likely be the first project of its kind in Chile, i.e. with minimal containment. Given the uncertainties and the need to generate useful data for the feasibility engineering, it was felt that a pilot plant campaign should be undertaken.

2 Esperanza mine site

The Esperanza site is located in northern Chile in the Atacama Desert at an elevation of approximately 2000 m above sea level. The production rate for the project will be approximately 95,000 tpd and consists of two main ore type, namely porphyry and andesite. The precipitation for the site is in the order of 10 mm per annum while the evaporation ranges from approximately 5 mm per day in winter to more than 8 mm per day in summer. The site climatic conditions are characterised by hot days and cool to cold nights, and extremely windy afternoons caused by heating of the desert.

The geomorphology of the site is characterised by soft rounded hills heavily eroded by wind and historic flood events. In particular, the basin chosen for the Esperanza tailings facility corresponds to an old flat alluvium deposit surrounded by gravely terraces. The layout of the facility is shown in Figure 1.

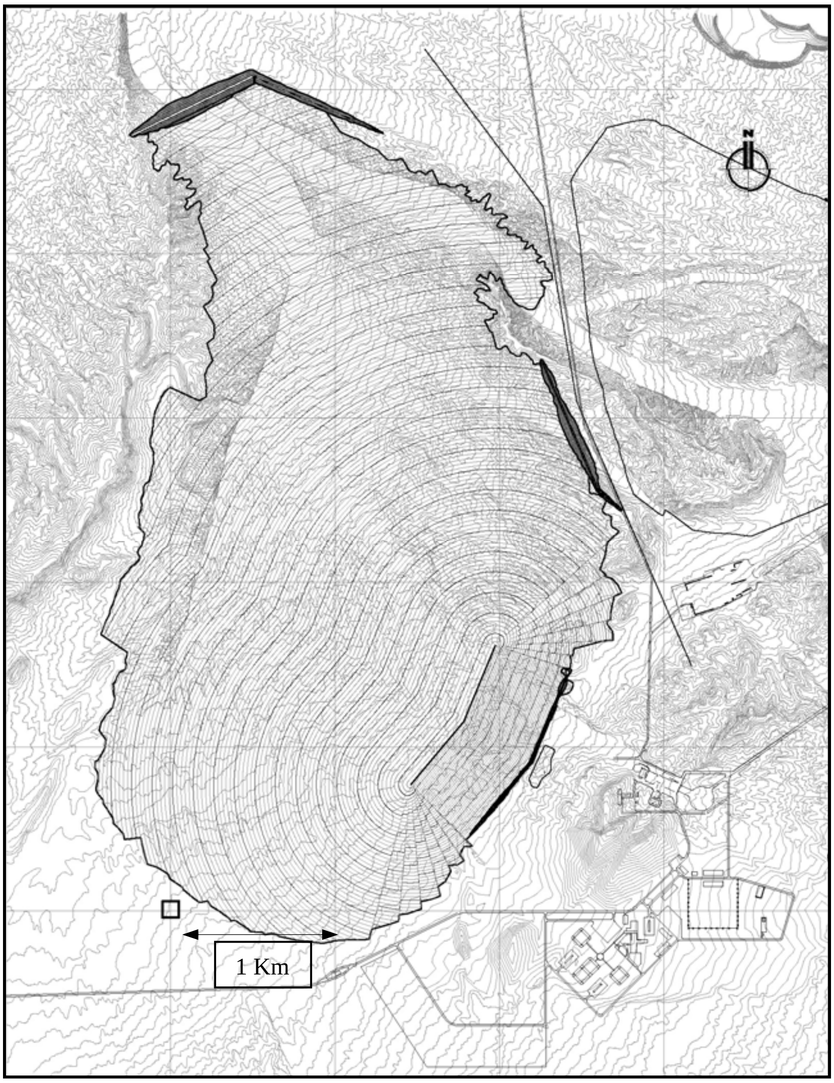

Figure 1 Layout of the proposed Esperanza tailings facility

In addition, given the elevation of the site from the coast and the distance, the cost of make-up water, i.e. sea water, was estimated to be upwards of US\$1.80/m^3. This makes that any effort to recover water from the thickeners and re-cycled to the process vital for the project economics.

3 Operational risk strategy

SRK evaluated various thickened/paste tailings operations around the world and the major issues they encountered at commissioning and during subsequent operations. Note – these issues were with specific reference to thickened tailings and do not discount the normal issues that occur during regular commissioning of tailings facilities. The main issues identified included the following:

- Non-performance of the thickeners, i.e. the tailings densities are lower (or higher) than designed.
- Variations in the thickener performance with ore type.
- Surface water management, i.e. significant run-off volumes from the deposited tailings.
- Lower than designed beach slopes.
- Seepage containment and associated costs for containment or interception measures such as liners.
- Fugitive dust.

To address these issues, Antofagasta Minerals and SRK implemented a number of steps, which included a pilot plant phase, detailed modelling and design, and additional visits to thickened tailings operations.

4 Pilot plant

The pilot plant campaign was run in two stages, the first one in Santiago city comprising milling, process, concentration and tailings thickening processes; and the second was run in the Esperanza area with just a thickening plant using tailings that was produced in Santiago, transported to site and re-pulped.

The pilot plant campaign was designed such that it was a scaled version, i.e. the discharge pipe and areas were scaled to the tonnage in the similar ratio to those of the proposed operational situation. The thickening plant, operating at a rate of 1 tonne per hour, was able to produce a broad range of solids concentrations. The main objective of the trials was to evaluate the potential beach angles that would likely be achieved for given tailings products and solids concentrations. Additional objectives of the trials were to obtain the necessary information to dimension the thickeners, set the target solids content, and perform rheological and geotechnical tests to use as inputs for the tailings disposal design. Further data from the trials was an indication of the likely amounts of run-off water from the deposited tailings.

Both stages included tailings deposition simulating a central discharge cone. Undisturbed and disturbed samples were tested to determine design parameters and the geometry of the disposal shape/cone was surveyed.

Beach trials in Santiago indicated beach slopes ranging from 3 to 6 %, while the on-site trial produced beach slopes ranging from 4 to 9 % (Table 1). The slope ranges observed were dependant on the various tailings types and also whether it was an upstream or downstream slope. On the basis of the pilot plant beach slopes a design beach slope of 4% was selected for the downstream or main beach slope of the tailings facility.

The pilot plant testing showed that the cyclically deposited tailings will reach a moisture content of approximately 15% after 30 days (see Figure 2) and a corresponding dry density of approximately 1.6 t/m^3 (see Figure 3).

Table 1 Pilot plant — tailings beach angles measured on site

Material	Beach Angle %	
	Upstream slope	Downstream slope
Andesite	10.3–11.7	7.0–9.7
Porphyry	12.2–8.9	8.4–7.0
Andesite	7.9–7.0	4.6
Andesite		7.4
Range	7.0–12.2	4.6–9.7

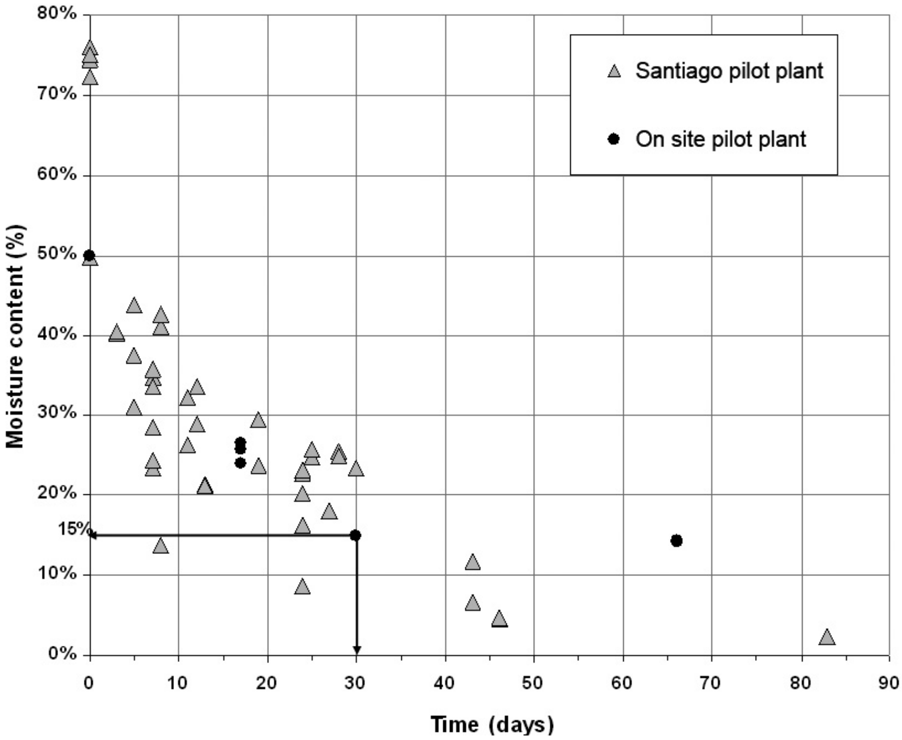

Figure 2 Change in moisture content with time

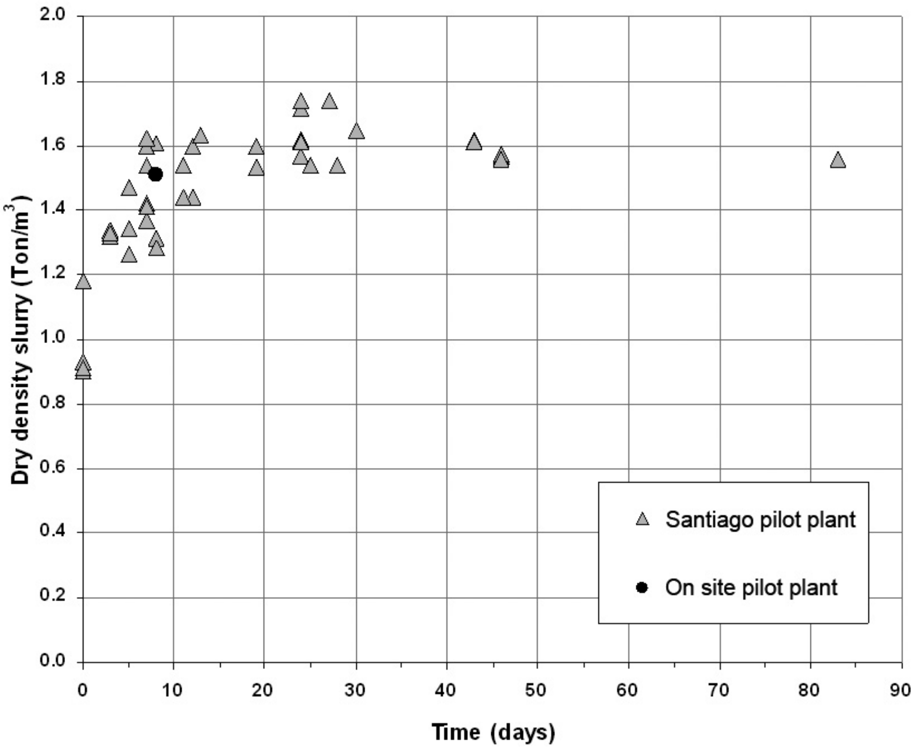

Figure 3 Change in dry density

5 Detailed design

5.1 Low density tailings

Thickener underflow densities and tailings ore types fluctuate and these along with issues at mill and thickener start-up could result in low density tailings being discharged from time to time. To cope with this, the tailings disposal system was designed such that low density tailings would not erode the beach. This system includes a “dump mechanism” whereby low density tailings at start-up or times of thickener underperformance could be disposed of without eroding the beach.

The tailings disposal pipeline has also been designed as a multiple spigot system over a length of approximately 2500 m. Experience at thickened tailings operations in Australia (McPhail, et al., 2007) has shown that beach angles can be significantly improved by using multiple spigots and reducing energy at the individual spigot locations.

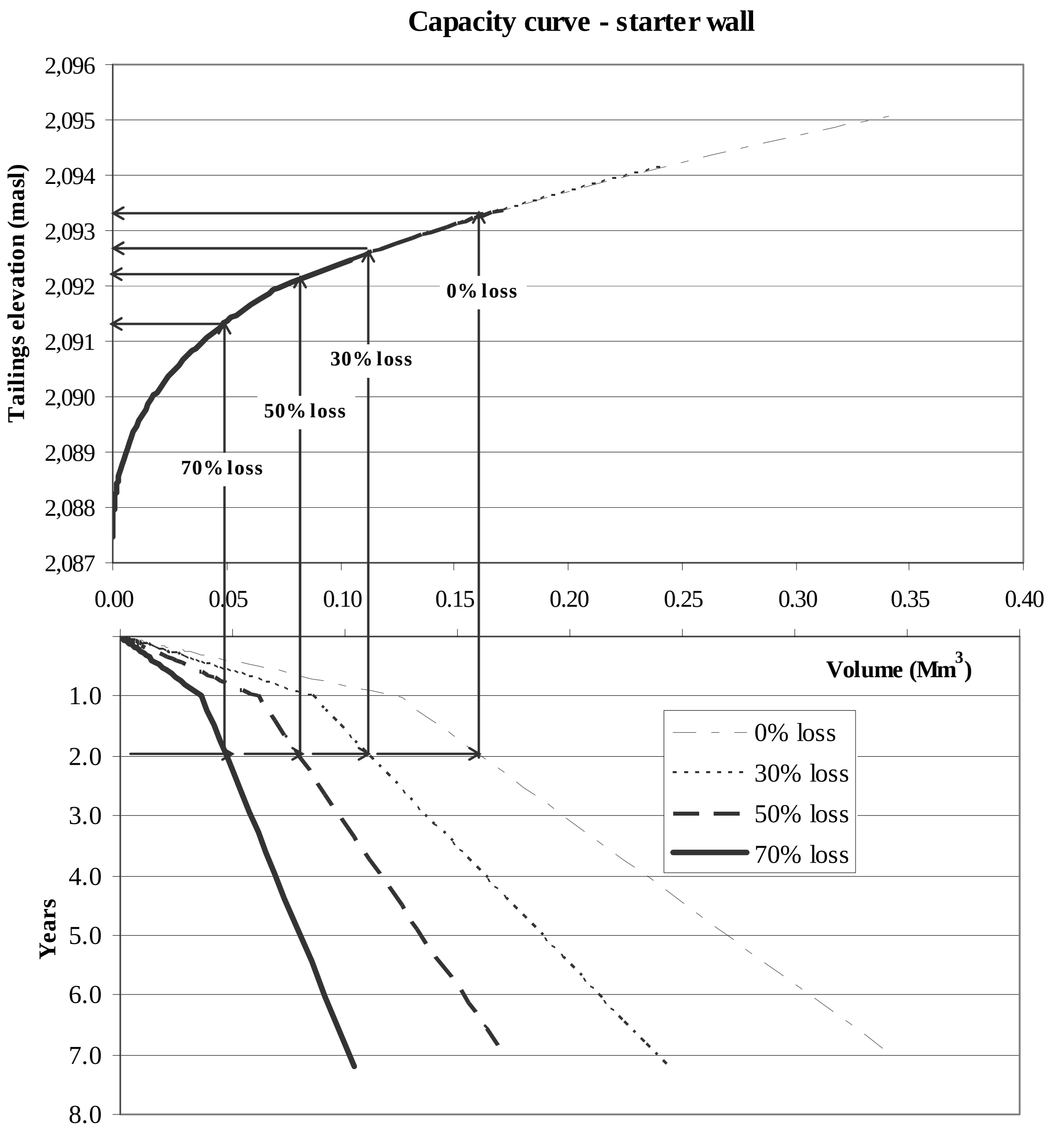

Figure 4 Elevation of sloppy tailings against starter wall

In order to prevent low density tailings run-off out of the basin, a starter wall was designed to close the natural drainage path. The main issue was to quantify the amount of sloppy tailings and estimate the percentage of tailings that will settle out while it runs off towards the wall. Figure 4 shows the capacity curve of the basin and the lower portion defines four different rates at which low density tailings could reach the wall. A conservative approach could be to consider a low density tailings with a low to zero moisture loss resulting in 100% of the tailings reaching the wall. However, this would require an unacceptably high starter and final wall. SRK analysed the operational thickener underflow data from an existing paste operation in Chile as well as published data. Based on this data, SRK assumed that there would be ten events in the first year of operation and three events in subsequent years, where each event results in low density tailings for a period of 4 hours.

Due to the high evaporation rate at the Esperanza site, it has been estimated that high moisture losses from the tailings along the flow path may be expected, in the order of 70–50%.

Thus, the management of the plan for low density tailings is either to divert the tailings stream into a designated area that could be cleaned periodically or if this area eventually is exhausted, to open additional spigots at the main tailings line such that the total sloppy flow is spread over a larger area, thus reducing the energy of the tailings and therefore the propensity to erode the beach.

5.2 Beach slopes

The pilot plant was scaled such that the deposition rate reflected the expected rate of rise of the main facility. SRK believes from experience that the current issues of beach slopes not meeting design criteria at other operations is related to excessive rates of rise and energy of the tailings at the spigot point. Existing paste or thickened tailings operations that have been converted to multiple discharge points, such that rates of rise at individual spigots are reduced and the energy spread, are now performing at or better than their designed beach angles. Thus, the designed tailings disposal system includes multiple discharge points which were introduced to reduce the flow energy. Tailings will be deposited into a given "sector" for a minimum of seven days and then cycled to the next one, with deposition returning to that "sector" in thirty days.

Given the length of time for the Esperanza tailings to reach the starter wall of approximately eight years, excluding low density tailings release episodes, the tailings beach can be managed to achieve the designed slope. Should the beach angle be too low, as measured and monitored via annual tailings facility audits, corrective measure can be implemented. It is envisaged that these measures could include changes to the deposition such as increasing the number of spigots used, training tailings staff in the use of the spigots to manage the beach slopes, and potentially additional raises to the main containment wall. Periodic survey of the beach is important in order to assess the performance and implement corrective measures timeously.

5.3 Surface water management

While the site is a desert, with almost no rain for many consecutive years, rainfall events do occur. Given the dry and unsaturated nature of the ground, i.e. relatively low permeability, and the lack of vegetation, runoffs can be significant. Experience at other thickened tailings operations has shown that significant flows of water will be shed from the large and relatively impervious surface of the tailings. Thus, water management on the facility is important to prevent runoff accumulations at low points in the basin such as against the starter wall, which may cause unwanted water seeping out of the boundaries of the tailings deposit. In order to intercept seepage, drains were laid out at the inner toe of the starter wall. These will be capable of capturing most of the runoff water and conveying it beneath the wall through a pipe to a lined evaporation pond.

External catchment areas are managed by a diversion channel that surrounds most of the eastern and southern boundary. This runoff will be diverted to a sub-basin that joins the main basin downstream of the starter wall.

5.4 Water management

Water balance evaluation showed that what was not recovered in the thickener was "lost" from the system at the design tailings solids content of 67%. Figure 5 shows that for the first two years the tailings surface will yield some "free water", i.e. the difference between excess water in the tailings from the thickener versus losses to evaporation and infiltration.

Once the excess water segregates from the main tailings mass, it runs off rapidly, thus escaping onto the dry tailings or soil ahead of the advancing tailings flow. Excess water thus infiltrates and does not reach the starter wall (see Figure 6). In addition, by using cyclic deposition, the infiltration depth can be controlled with evaporation occurring from the tailing surface when tailings deposition is rotated away from that particular area. The tailing deposition system, i.e. available pipe and spigots, and disposal management plan has been designed such that each cyclic deposition will deposit a layer of approximately 200 mm of tailings over a period of approximately one week.

Thus, even if some excess water is produced at the disposal points, recovery of it might not be practically possible.

Transient events of sloppy tailings could yield more water than thickened tailings, and as the terrain slope is in the order of 4 to 5%, it would run towards the starter wall, as described earlier. This water will be managed downstream and therefore it was not included in the water balance.

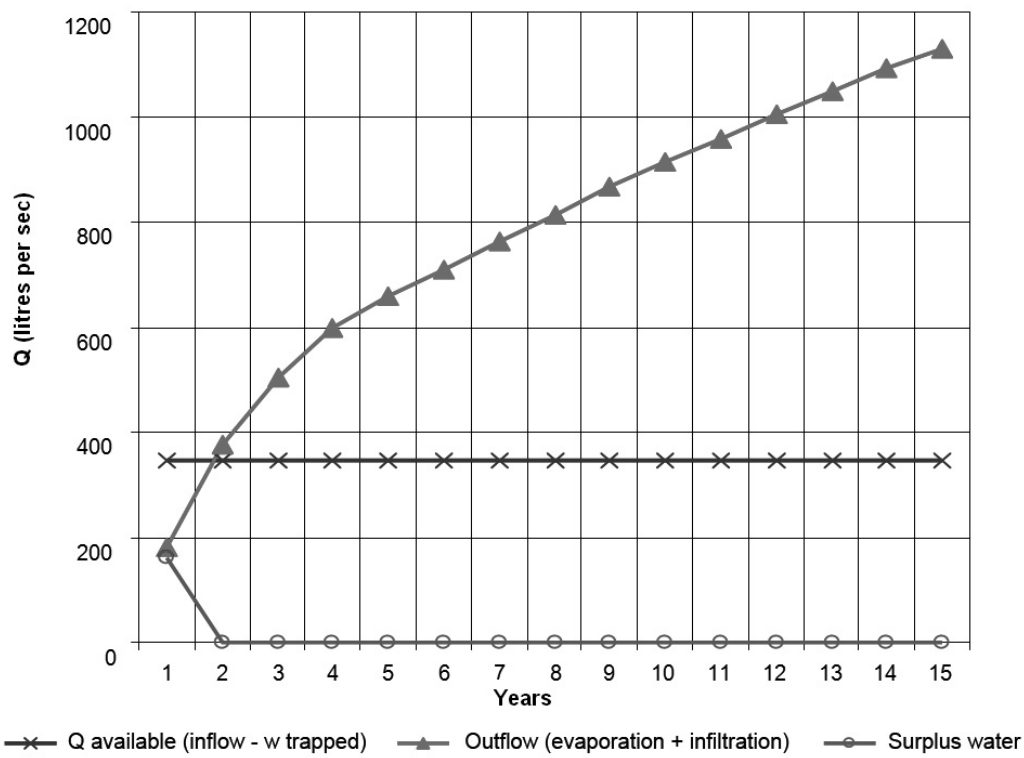

Figure 5 Potential discharge exiting the system – thickened tailings cp= 67%

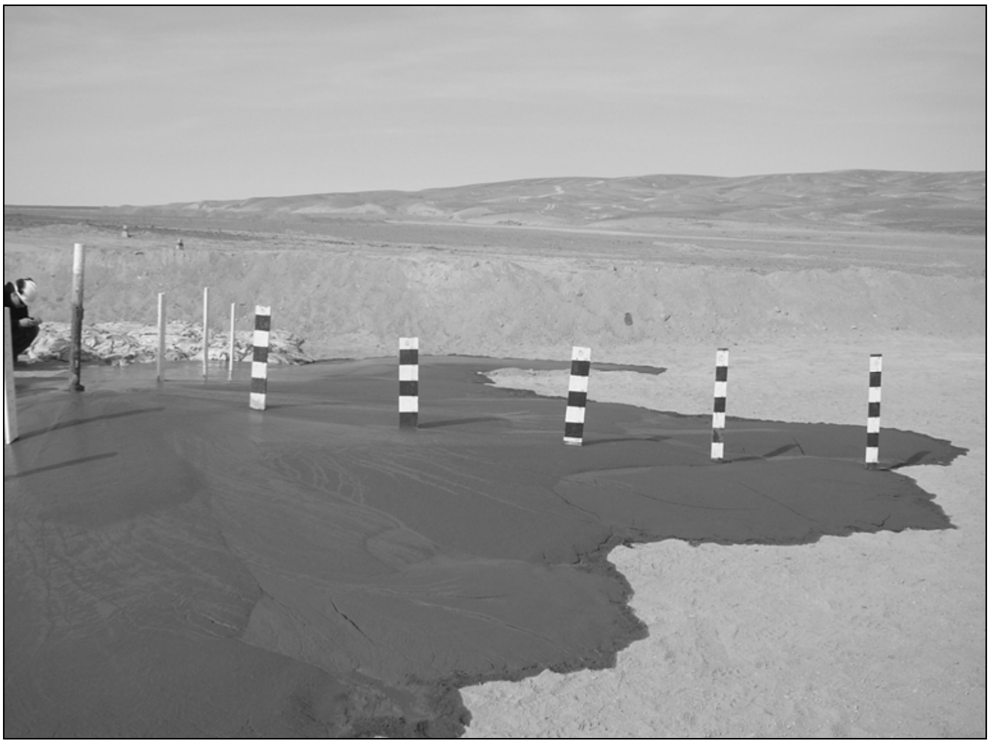

Figure 6 Fresh tailings with segregating excess water

5.5 Seepage

The Esperanza site, in particular the designated tailings area, is located on top of a very thick alluvium cover, consisting of superficial recent sands and gravels overlying an old 300–600 m deep gravel deposit. According to the hydrogeological study, the alluvium is dry, with moisture contents as low as 1%.

These characteristics constrained the design of unlined conventional deposits due to the high risk of losing excessive water to bottom seepage. Basin treatment or containment design could lead to excessive costs. On the other hand, not implementing such measures could lead to poor water recovery from the pond and downstream environmental impacts.

Thickened tailings were thus found to be a feasible strategy to overcome excessive infiltration from the tailings mass. However, it remained unclear how much seepage would be produced without providing additional containment to the basin.

In order to clarify this, the pilot plant scope included an investigation programme and detailed seepage modelling to validate the results of the pilot plant. The results of the pilot plant and modelling indicated that the use of the thickened tailings technology eliminated the need for costly liner systems. In addition, the facility design included a decant system that removes any tailings supernatant or precipitation run-off from the tailings facility to a synthetically lined pond. The tailings facility and the tailings have little or no excess water, and combined with the low permeability of the unsegregated tailings, eliminate the seepage water source, and hence all seepage.

5.6 Dust

Given the large surface area of exposed tailings, the lack of water associated with the tailings and experience at existing conventional tailings operations in the Atacama, fugitive dust was a major concern for the project. However, the pilot plant testing and the evaluation of similar operations using saline water indicates that the salt forms a crystalline structure within the tailings matrix that resists dust generation. Figure 7 shows a dry crust formed at the cone produced at the pilot plant in Esperanza.

Figure 7 Dry saline crust formed after a few days of air-drying at the Esperanza site

6 Conclusions

Given the measured approach and due diligence that has been undertaken, it is expected that the use of thickened tailings for the Esperanza project will be successful. The use of thickened tailings and water recovered will allow the production goals to be met. The tailings facility has also been designed with flexibility such that should things not go as planned, the tailings could still be safely stored and the facility managed.

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