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Technical Memo

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cc:		**From:**	Gordon Doerksen
Subject:	Case Studies in Hydraulic Mining	**Project #:**	1CD003.079

1 Giant Tailings Retreatment Plant, Yellowknife, NWT

1.1 Background

Giant Yellowknife Mines Limited ran a 7,300 tonne per day, seasonal, hydraulic mining operation from 1988-90. Hydraulic mining was used to transport settled mill tailings from old tailings ponds to a Carbon-In-Leach (CIL) Tailings Retreatment Plant (TRP). The TRP and hydraulic mining systems were designed to economically extract residual gold from old Giant mill tailings. The project, when proposed, had a positive rate of return and the TRP was built on the strength of information gained from the results of a pilot plant operated in the summer of 1987.

Figure 1.1: Giant Yellowknife TRP Carbon-In-Leach (CIL) tanks

1.2 Hydraulic Monitoring

The hydraulic mining system at Giant utilized an undercut configuration mining the full height of the tailings in a single face (see Figure 1.2). Full face mining was very important to the TRP project economics. The Giant tailings were deposited over a period of over 40 years and the grade of the tailings varied significantly with depth. The lowest, oldest tailings had a very favourable grade of over 0.1 oz/ton. Subsequent layers of tailings were progressively lower in grade as mill head grades declined and as advances in mineral processing extracted more gold out of the ore. The TRP project would not have been economic if the tailings had been mined from the top down.

Figure 1.2: Hydraulic monitor washing frozen tailings

The Giant tailings were deposited in the tailings pond up to 27m thick, however, over 90% of the material was less than 20 metres in thickness. Because the depth of the tailings was not deemed excessive, it was decided to mine the full height of the tailings at once without any intermediate benching.

The first phase of mining was for the hydraulic monitors to cut their way down into the tailings from the side of the tailings pond, advancing to the bottom on ramps made of waste rock. Initially, production was stopped when the ramps were advanced. Once mining progressed far enough the ramp was split to allow one ramp to be advanced while the other continued to support mining.

The Giant operation utilized three English China Clay 4" automated monitors. The monitors were fed by two Mather+Platt seven stage mine dewatering pumps arranged in parallel. The monitors operated at up to 350 psi pressure depending on the nozzle diameter used (1"-1.5"). Giant machined their own monitor nozzles to provide the optimum water jet from the monitor. Maintaining a tight water jet was important as it allowed the monitors to be kept further back from the mining face for safety and because it assisted in cutting of the frozen tailings. The monitors were typically kept between 20 and 40 m from the face.

Figure 1.3 **Start of the first ramp at Giant – May 1888. Note frozen tailings deflecting high pressure water. Operators booth and trommel screen are on the right.**

Figure 1.4: **Mather+Platt multi-stage mine dewatering pumps connected in parallel used for high-pressure monitor feed water**

The monitors were controlled by one operator located in a booth well away from the mining face. The ECC monitors used at Giant were hydraulically controlled with joysticks. The monitors were run either on manual or automatic. The automatic mode allowed the operator to leave the control booth and with the monitor moving in a pre-set pattern. Pelton wheels, driven by the high pressure monitor feed water, powered the hydraulic pump for the monitor controls and an alternator to charged the battery used for the electronic controls.

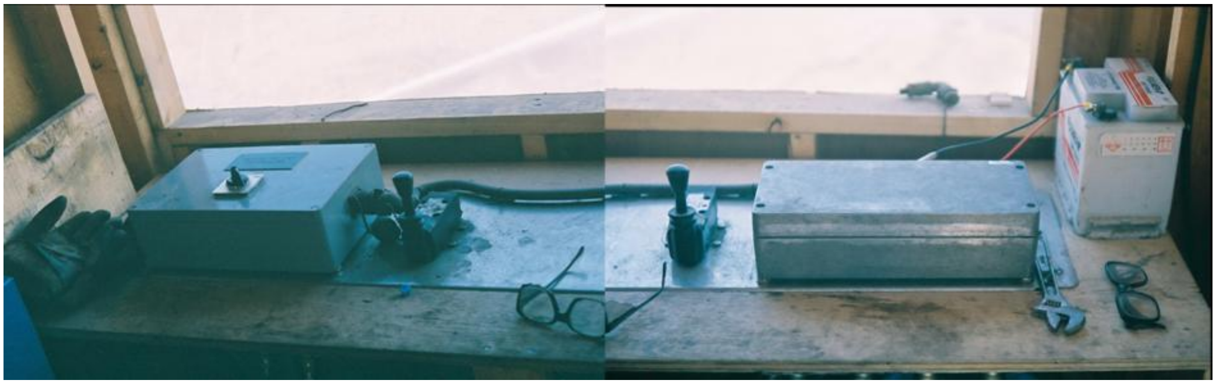

Figure 1.5: Inside of the operator's booth showing monitor controls

Figure 1.6: Crane and Toyo submersible sump pumps on rock-fill ramp

1.3 Slurry Pumping

The hydraulic monitors slurried the tailings it was washed from the mining face. The slurry ran back to the sump located near the monitors. 100 hp Toyo submersible pumps with agitators were used as the sump pumps and were suspended by a crane. The crane allowed the pumps to be moved easily and the pumps were raised and lowered depending on sump conditions. The Toyo pumps had an agitator on the bottom of them the stirred up the slurry in the sump. This pump arrangement actually allowed the pumps to dig themselves down into the sump by liquefying settled slurry prior to pumping. The Toyo pumps pumped tailings up from the sump to a trommel trash screen. The trommel allowed fine material to pass through separating the rocks and sticks from the slurry. The oversized debris was discharged into a pile to be scooped up with a front-end loader. The slurry that flowed through the trommel when to a 12 x10 Warman horizontal slurry pump that transported the slurry to the TRP.

The gradation of the tailings was very fine with 90% of the material passing the 400 mesh sieve. The specific gravity of the tailings solids was approximately 2.7.

1.4 Operating Results

The Giant TRP experienced several operational challenges during it existence. Difficulties associated with trying to hydraulically mine frozen tailings were the biggest challenges. It was determined after the project had started that permafrost was driven into the tailings very early in their deposition and caused them to be frozen almost through their entire depth. The target slurry composition was 40% solids by weight. While this target was reached on occasion, the percent solids in the slurry during the early part of the summer was very low and only improved as the mining faces thawed at an increasing rate (see Table 1.1 below). Slurry densities of >40% solids by weight were never maintained for long periods.

Table 1.1 Percent solids in slurry – Start of 1988 season

	Solids by Weight	*Tonnes Mined*
May	14%	49,547
June	32%	143,925
July	38%	207,970
August	36%	195,457

The hydraulic monitors proved unable to cut the tailings at a rate high enough to melt and liberate tailings solids to maintain high slurry densities. The attempt to mine frozen tailings hydraulically can be likened to the melting of an ice cube under a stream of cold water from a tap. A significant amount of water is required to melt the ice.

Table 1.2 Giant TRP Production Statistics 1988 and 1989

	Design	*Actual*
Design Flow Rate	2900 USGPM	Not available
Slurry Design	40% solids by weight	14-48%
Design Productivity	7,272 tonnes/day 310 tonnes/hour	Not available 263 t/hr (1998) 305 t/hr (1989)
Operating		89.9% (1988) 91.5% (1989)
Total Production	1,090,800 tonnes/year	858,852 tonnes (1988) 994,634 tonnes (1989)

It was very clear during the first mining season that production was going to be directly linked to the amount of natural melting of the tailings during the warm summer months. As mining advanced, more and more face surface area was opened up to melt and for the monitors to wash.

Table 1.3 TRP Mining Cash Costs

	1988*	1989**
Mining Operations	$577,000	$970,000
Mining Maintenance	$231,000	$273,000
General***	$164,000	$329,000
Total	$972,000	$1,572,000
Tonnes Mined	858,852	994,634
Cost per tonne	$ 1.13	$1.58 / $1.03 (ex. Dozer)

*June-December 1988
**Costs in last quarter of 1989 were forecast. 1989 costs included $552,000 for pushing tailings with a dozer
***Prorated from total general costs
Toyo submersible pump maintenance accounted for roughly 50% of maintenance costs.

To help increase production, a contract D9 dozer was placed on the top of the tailings pond to push melted surface material onto the hydraulic mining face. This arrangement lead to higher costs and lowering of head grade to the TRP, however, it assisted with raising the density of the slurry.

Low slurry densities associated with mining the frozen tailings had some major effects on the viability of the Giant TRP project.

1. The inability to move the desired volume of tailings meant that the actual tonnes of gold-bearing solids to the plant was reduced, lessening gold extraction.
2. The low density slurry in the plant hindered the dispersal of activated carbon in the leach tanks and therefore lessening the carbon's ability to adsorb gold.
3. To help improve the solids tonnage through the plant when low slurry densities where encountered, the total volume of water put through the plant was increased. The increased flow reduced the retention time in the tanks lessening gold dissolution time.
4. The use of a dozer on top of the pond pushing thawed tailings toward the monitors reduced the head grade going to the plant.

Figure 1.7: Dozer pushing thawed tailings to mining face

Figure 1.8: View of the Giant mining operation from on top of the tailings pond

Figure 1.9: View of mining face showing monitor and crane.

Figure 1.10: Toyo pump suspended from crane

Figure 1.11: Initial mining setup in the Central Pond showing crane, monitor and operator's booth

Figure 1.12: Toyo pump starting a sump in the Central Pond

2 ERG – Timmins, Ont.

2.1 Background

The ERG operation in Timmins was based on the same tailings retreatment philosophy as its sister operation in Yellowknife. Tailings in the Timmins area, however, were coarser than the Yellowknife operation and had a lower average grade of 0.43 g/t. Some of the 130 Mt of ERG's tailings resources were located close to downtown Timmins so not only could ERG reprocess the tailings and generate a profit, but the town of Timmins would receive reclaimed land previously made unusable by the tailings piles. That plan, along with the consolidation of tailings deposition sites into one remote site, made the project very attractive to all levels of government.

The project was scheduled to process 1,000,000 tons per month of reclaimed tailings, 8 months per year. The tailings in Timmins were not frozen.

A new processing facility was built to extract residual gold from the tailings and was configured with two open-circuit ball mills in series followed by a cyanidation and CIP/CIL circuit. The total capital cost of the ERG project was $120M.

As with the Giant operation, ERG only ran for a 2-3 years before being shut down in the early 1990s.

2.2 Hydraulic Mining

The Timmins operation employed 6" and 4" ECC automated computer controlled monitors fed at 300 p.s.i. Re-pulped tailings flowed at a gradient of 1% from the mining faces to either ditches or sumps. At least three separate mining areas were operated at any given time with a total flow of between 12,000 and 15,000 g.p.m.

Surface vegetation (mainly grasses and alder trees) was removed from the tailings surfaces prior to mining so as not to overload the trash screens.

When mining down into tailings ponds, ramps were built in a similar fashion to the Giant operation. Arterial ramps were established every 200 metres to keep the monitors and sump pumps close to the face.

Slurry mixtures varied between 40-55% solids by weight.

2.3 Slurry Pumping

ERG used two methods of slurry handling in the operation. The first method was used when mining well drained, stacked tailings (hills or dams). The method involved advancing through the tailings using monitors positioned at the base of the stacked tailings. Slurried tailings flowed from the mining face to ditches, transporting the slurry to the main pump station. At the main pump station, the tailings were screened and pumped to the treatment plant using horizontal slurry pumps.

The second method was required when the tailings were contained in a lake or depression. A method similar to the Yellowknife mode of operation was used including ramping down into the tailings and keeping a sump pump suspended from a crane as close to the mining face as possible. Submersible Toyo pumps and vertical cantilever pumps were used as the sump pumps. The sump pumps picked up the slurry reporting to the sump and moved it to the main pump station to be screened and further pumped. The trash removal screens used at ERG were 6.8m long x 2.6m wide with 1.5mm openings. As with the Yellowknife operation, it was essential to keep rocks and wood out of the retreatment system.

The best mining costs achieved at ERG were $0.30/ton.

3 English China Clays (ECC), Cornwall, England

ECC operates several hydraulic clay mining sites in Cornwall, England. The monitors are arranged in an undercut mining configuration and are used to liberate kaolin clay from fractures in the host rock. The host rock is drilled and blasted to allow the monitor water the greatest opportunity to clean kaolin from the natural rock fractures. The slurry formed from the monitoring operation is very light with only 15% solids by weight typically achieved. Slurry from the bottom of the pit is pumped up in stages to the top of the pit and then transported to the processing plant through a series of ditches.

Figure 3.1 Dozer and loader moving waste rock while a monitor washes kaolin

In the late 1980s ECC maintained a large engineering and fabrication division that made hydraulic monitors and monitor control systems. ECC supplied monitors and controls to both the Giant and ERG–Timmins operations. When the ERG operation shut down, Denison Environmental Services purchased the hydraulic mining equipment and used it at the Elliot Lake operation.

4 ERGO – East Rand, South Africa

4.1 Background

The East Rand Gold and Uranium Company (Ergo) was commissioned in 1977 to recover residual gold and uranium, as well as pyrite for the production of sulphuric acid, from slimes dams attached to old mine workings on the East Rand. Ergo was originally planned to operate for 15 years but its life was extended to 25 years in 1985 with the introduction of new technology in the form of a carbon-in-leach (CIL) process. The CIL plant at Ergo allowed for improved recovery and grade of tailings. In its heyday Ergo enjoyed a healthy financial performance, but over the last few years, the slimes dams available for treatment have had a much reduced grade and the plant's profitability has been gradually diminishing. Losses have now reached the stage where mine closure is scheduled for the end of March 2005.

4.2 Hydraulic Monitoring

South African tailings operations utilize both undercut and overcut methods. The overcut method is used mainly on top of well-drained tailings that have consolidated sufficiently to allow firm under-foot conditions. Undercut mining is done in locations where the tailings are higher in moisture content and therefore less stable.

Figure 4.1 Wheel mounted monitors on top of an ERGO tailings dam.

Typically one operator runs one monitor. Many monitors are operated manually without the aid of hydraulic controls or an operator's booth. Some of the monitors are mounted on wheeled carts that can be easily relocated on top of the well compacted tailings dams.

6" hydraulic monitors are the most common size and utilize pressures of 250-300 psi.

Figure 4.2 Undercut mining at ERGO

4.3 Slurry Pumping

Slurry from the mining faces runs down excavated ditches to central pumping stations located at lower elevations. Ditches are dug with rubber-tired backhoes. The ditches are dug 1-2 m wide, at a gradient sufficient to at provide adequate velocity to keep the solids in suspension in the slurry. Maintaining high slurry densities and keeping the ditches narrow to maintain a relatively high flow velocity are the two most important factors in keeping solids in suspension.

Figure 4.3 Slurry flowing from a mining face to a collection ditch at ERGO

The pumping stations, often located many hundreds of metres from the mining faces, are well-engineered, permanent structures that may contain several horizontal, centrifugal slurry pumps in series to provide enough pressure to pump tailings long distances to the treatment plants.

5 Denison Mines – Elliot Lake, Ontario

5.1 Background

Denison Environmental Services ran a hydraulic mining operation to relocate tailings from 1993 to 1996 in Tailings Management Area No. 2 (TMA-2) at the Denison Mines' Elliot Lake operation. The purpose of the tailings relocation was to lower the elevation of the tailings to allow them to be covered with water to mitigate acid generation. A total of 1.4Mm^3 of tailings was relocated with 60% of the material going underground into old workings and 40% deposited in the lower portions of TMA-1. The project was four years in duration, starting with a pilot year in 1993 (See Table 5.1).

Table 5.1 Denison TMA-2 Tailings Relocation Volumes

Year	Volume (m3)
1993	50,000
1994	187,000
1995	1,070,000
1996	130,000
Total	1,437,000

The normal Denison tailings gradation was 60% passing -200 mesh. Some cycloned tailings were much coarser and could only be maintained in suspension as a slurry when they were mixed with the finer mine tailings. The specific gravity of the dry solids in the tailings was 2.7.

The operating season at Elliot Lake was typically May to late October but was longer during years of mild temperatures. No operating problems relating to freezing were encountered as long as the systems were kept running.

Monitors, sump pumps and some valves were purchased used from the Timmins ERG operation. Other equipment was salvaged from the Denison mine site with a minimal amount of new equipment required for purchase. Denison still owns the equipment.

5.2 Hydraulic Monitoring

Hydraulic mining was done with a combination of 4" and 6" monitors located at the bottom of the reclaim face, similar to the Giant Yellowknife arrangement. Two monitoring areas were established and two monitors per area were typically used. The monitors were fed with 300 psi water from two 200 hp 6x8x18A-411 BF Aurora pumps connected in series. The Aurora pumps were fed from a pump house on Quirke Lake.

Monitors were kept as close as possible to the face and were often moved as close as 10-20' from the face. This arrangement yielded an average slurry of 28-32% solids by weight. This result was acceptable to Denison staff as there was ample water supply and power costs were minimal. If slurry densities needed to be increased, the sump pump was lowered. Slurry densities also increased when small amounts of low pressure water were used to erode unconsolidated tailings.

Figure 5.1 A hydraulic monitor being relocated closer to the mining face

Monitor discharge nozzles were changed to either open or restrict the flow of water coming out of the monitors to get the right volume and density of slurry for the sump pumps

Hydraulic monitors were outfitted with the automated control feature from ECC but this was rarely used as the operators had better success pointing the monitors at the bottom of a face when left unattended.

Figure 5.2 A hydraulic monitor working the bottom of a mining face

The cleaning of tailings down to original topography was found to be best done with low pressure water or trucks and excavators, where applicable. Hydraulic monitors were not used to do the final clean-up as they lifted up too much of the original ground with their high pressure.

Figure 5.3 Excavators and articulated trucks removing tailings from bedrock

5.3 Slurry Pumping

The slurried tailings flowed an average distance of 3-500 metres from the mining faces to a 10x10x26 Goulds VHS vertical cantilever sump pump. Each Goulds pump was configured with a 200 hp motor and was fed by two operating monitors. The pumps were fitted with fully recessed, hardened steel impellers. The fully recessed impeller allowed very large solids to be pumped. The metal impeller had to be replaced at least once per month as it wore out quickly in the highly abrasive Denison tailings.

The sump pumps were mounted in a box structure that had 9” holes cut into it. The box provided support to hold the pump up and also acted as a screen to keep debris (sticks, etc) out of the pump. Wood mixed in the slurry at times created build-up problems for the pump screens and had to be manually cleaned.

Figure 5.4 Goulds vertical cantilever pump and support box

No ditches were dug from the mining face to the sumps and there seemed to be little settling of the solids in the slurry as long as reasonable slurry densities were maintained. The sump pump locations were not moved during the life of the project.

The two Goulds sump pumps delivered the tailings to two different locations. One pump discharged tailings over 2 km away to TMA-1. The discharge into TMA-1 consisted of a discharge barge attached to cables that allowed it to be moved around the pond by means of winches.

The second Goulds sump pump took the slurry from the sump and transported it into a 5m x 5m tank connected to a 12x12x36 D-11-5G Envirotech-Galigher Ash horizontal slurry pump. The Ash pump was driven by a 450 hp motor and discharged into a 400mm HDPE pipeline leading into underground workings.

5.4 Manpower

The Denison tailings relocation operation normally ran 24 hours/day seven days/week from April to the end of October. Operating crews worked 12-hour shifts.

Manpower for the entire tailings relocation operation was done with 6 operators per shift covering 4 operating monitors. Generally, one operator walked between control booths to run two monitors. Other personnel were used to move monitors, pipes, booths, etc. A hydraulic excavator was used close to full-time to move equipment around. One millwright and one electrician were available on dayshift to cover routine maintenance and breakdowns.

Supervision was provided with a dayshift foreman and a night shift lead-hand.

The total complement, exclusive of management, technical and administration, was:

Table 5.2 Denison Tailings Relocation Operating Manpower

Operators	24
Electrician	2
Millwright	2
Supervisor	2
Total	**30**

5.5 Costs

The tailings relocation at Elliot Lake was done with the idea of keeping costs to a minimum. Used equipment, either from the existing mine or purchased, was utilized whenever possible. As a result, some mismatched or non-ideal equipment was put into service but overall the costs improved by using used equipment. Manpower appears to be kept to a reasonable level.

Table 5.3 Denison TMA-2 Tailings Relocation Costs

Year	Volume (m3)	Cost ($)	Unit Cost ($/m^3)
1993	50,000	$ 536,435*	$10.73
1994	187,000	$ 1,016,898	$ 5.44
1995	1,070,000	$ 2,922,190	$ 2.73
1996	130,000	$ 474,725	$ 3.65
Total	**1,437,000**	**$ 4,950,248**	**$ 3.44**

*Includes capital costs
Costs include all final clean-up

To keep lime addition costs down, reject Limestone from an adjacent operation was brought in and placed on the TMA-2 tailings prior to flooding to neutralize the acidity. The limestone was obtained at very little cost, except for transportation and placement.

6 Los Bronces - Chile

6.1 Background

A major tailings relocation project was undertaken at the Los Bronces copper mining complex in Chile to mitigate a safety/environmental concern relating to the location of the tailings in a valley.

The valley contained 72 Mton of tailings, divided into three compartments: Copihues (C), Perez-Caldera 1 (PC1) and Perez-Caldera 2 (PC 2) named from upstream to downstream.

An expansion of the mining project was approved and by the early 90's the mining company decided to construct a new tailings facility named "Las Tórtolas" that would contain all of the new tailings stream and the old tailings relocated from the C, PC1 and PC2 compartments.

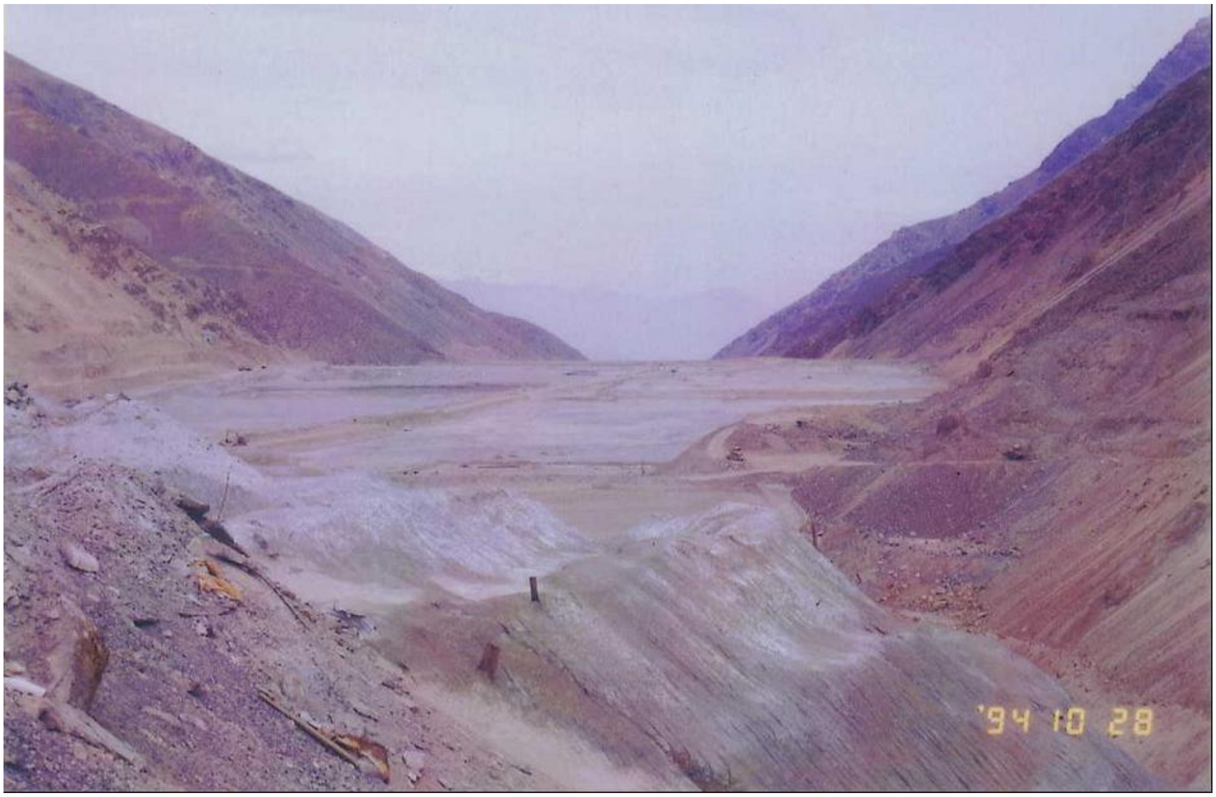

Figure 6.1: Copihues tailings dam prior to commencement of hydraulic mining

The initial project contemplated the use of hydraulic monitors to remove the old, "dried" tailings from Copihues - the smallest compartment situated at the upstream end of the complex - and PC 1, and thereafter continue with a dredge once the monitors would reach the pool level at PC2, if the pool were still there by that time.

The operation with monitors was successfully implemented and kept working until 2003 when the hydraulic head of the tailings stream was not enough to reach the pump station, which was relocated several times until it reached the toe of the PC2 wall.

The mining company decided to keep the pool at the PC2 compartment as a return water structure, in order to pump it easily from there to the plant. Thus, two dredgers were bought to carry on with the relocation works.

Fraser Alexander was the contractor retained for the works from the beginning, currently they have bid for a further 4-year period.

The contractor operates from September to May due to weather restrictions and its target production is 18 ktpd with a solid concentration of 40 to 45%.

The capital cost for each of the dredge barges is in the order of USD 1.5 million.

Figure 6.2: Monitor developing a channel for slurry flow

6.2 Hydraulic Monitoring

The monitoring procedure was revised occasionally to adjust to the project needs. Water pressure, and proper exposure time were determined to get the right mix to flow downstream for further pumping to the Las Tórtolas dam.

Figure 6.3: Operator controlling a monitor outside of the control booth.

The basic procedure consisted of progressively cutting a channel, using hydraulic monitors (See figure 6.2). The channel provided a confined path for the slurried tailings to run and maintain velocity to the pump station. Provided that an adequate gradient was built, the tailings and water slurry flowed downstream to the pump station where it was pumped away to the new tailings site.

The configuration of the system used 4 hydraulic monitors, strategically located along the channel. All four monitors are connected to a high-pressure water pump and valves were used to regulate the flow to each monitor. Normally only one monitor operated at a time.

The production rate of these monitors ranges from 17 to 22 kton per day with an average slurry composition of 42% of solids by weight.

The system required the gradient for the tailings stream to be high enough to conduct the tailings hydraulically to the point where it would be pumped.

Figure 6.4: Hydraulic monitor in operation cutting a slope

Figure 6.5: Copihues dam showing partial removal of tailings. Note the steps.

Figure 6.6: Current state of Copihues dam. Note the bottom of the basin is not completely cleaned as the monitors cannot remove it due to limitations of hydraulic head to make it flow down stream.

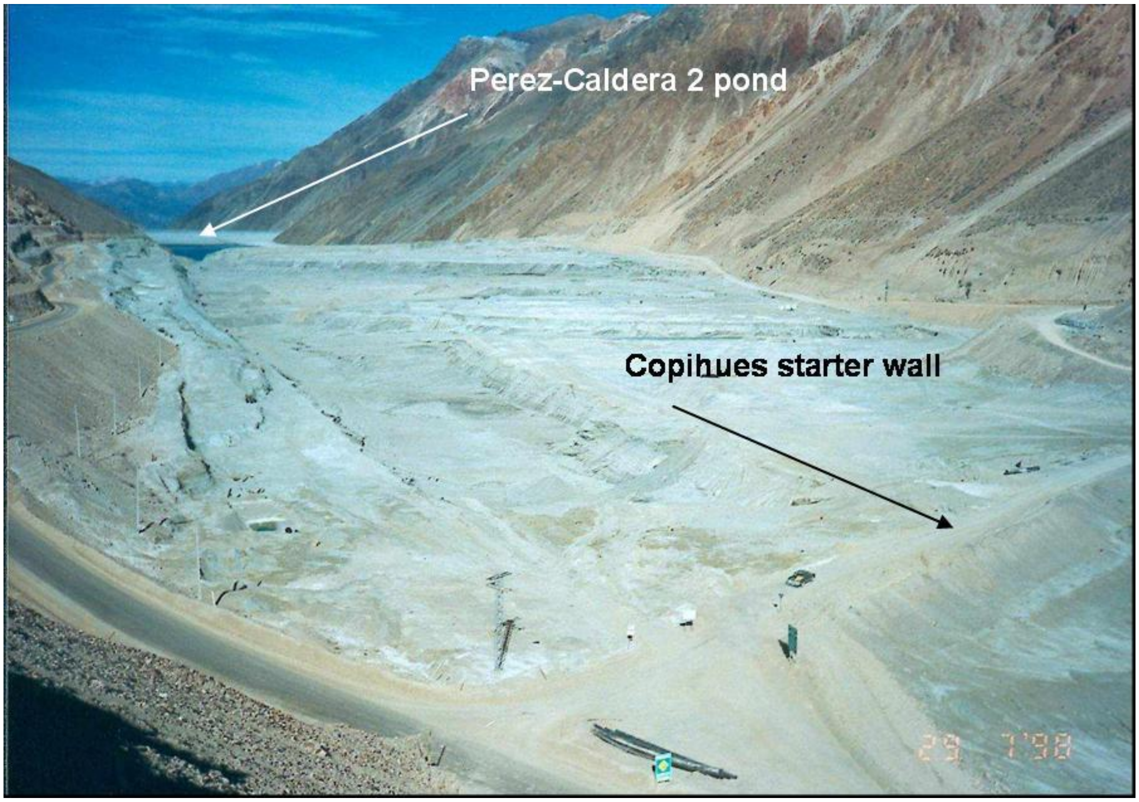

Figure 6.7: Initial mining in PC1 dam

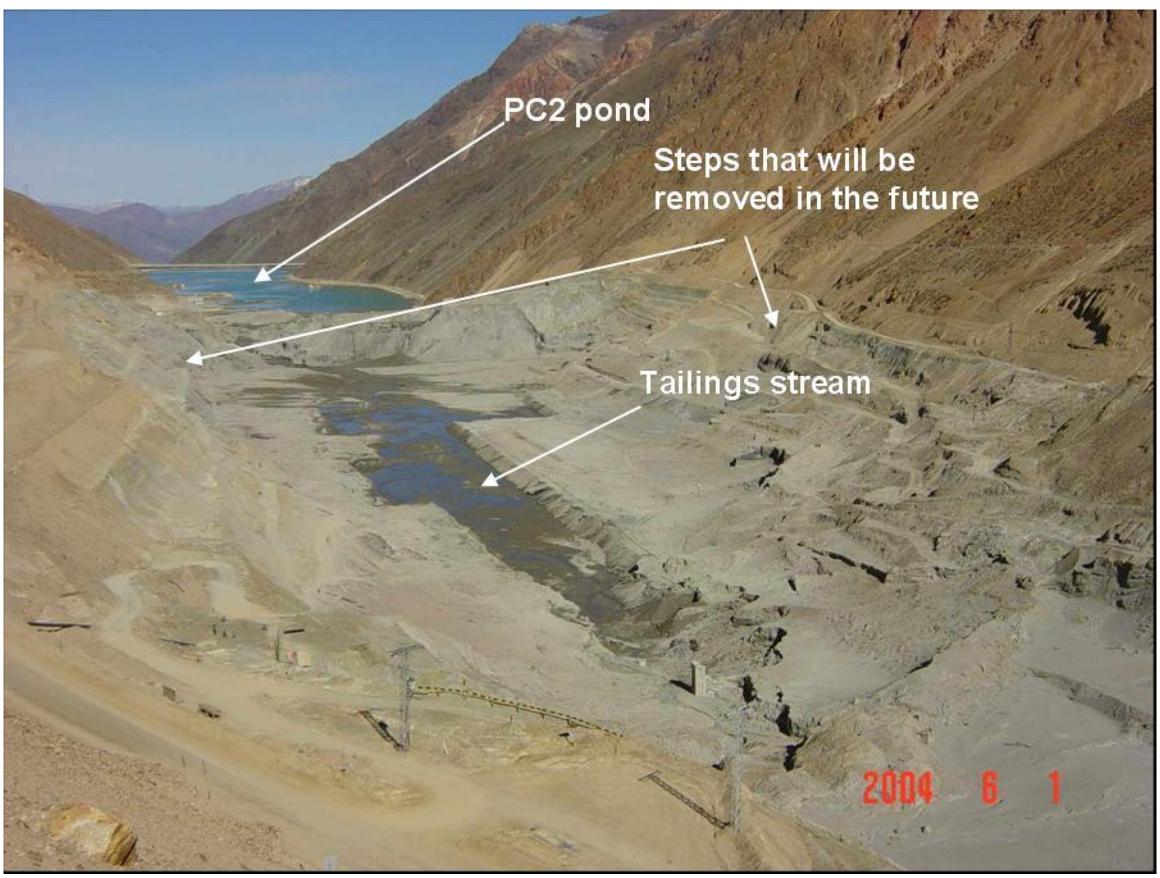

Figure 6.8: Current view of PC1 dam

Through the mining process, the hydraulic head of the slurry flowing to the pump site was progressively being reduced as the tailings level was depressed, forcing the pump site to be moved upstream to reduce the flow distance. Once the pump site reached the toe of the PC2 starter dam, and the tailings were not longer being able to flow to the pump site, a new strategy had to be implemented.

In order to keep the main road (which runs around the perimeter of the tailings dams) in working conditions, the monitors could not thoroughly clean the slope adjacent to the road and left a series of steps along the slope on which the monitors had to be installed to progress with the cut. Refer to Figure 6.7.

5.3 Dredging

The PC2 compartment is currently used as a water storage facility, and no other facility was planned to receive the water from that pond; since the monitors cannot operate under water, they could not be used to mine the tailings from PC2.

Figure 6.9: Suction dredge with cutter in action

Figure 6.10: Operation of the dredge with monitor assisting. In order to speed up the process, monitors were put in place to enhance the density of the slurry reporting to the dredge. A cyclone station will be installed to thicken the slurry

The dredging plan calls for the dredge to advance parallel to a slope, removing the toe of the slope and promoting the failure of it. Having this done, the dredge suction pump sucks up the sloughed material and conducts it through a pipe to a booster pump station that will transport the tailings to the new Las Tortolas dam.

Figure 6.11: Pump station during winter. The operation was stopped from June to August - the coldest time of year.

6.3 Dredge vs. Hydraulic Monitoring Comparison

It seems that both methods have been proved to have advantages and disadvantages; however, monitors are more versatile and compensate their weaknesses easier than the dredge.

- The hydraulic monitors have a much lower capital cost than the dredges.
- Operational costs are more difficult to analyze since the operation for both procedures is different. The dredge operates with only one person while monitors require 4 full time labourers. However, maintenance of the dredges is done on a daily basis while monitors seldom need it. Another operational difference is the mobilization to a different sector; the mobilization of the dredge takes 24 hours where production is completely stopped, on the other hand the monitors can be changed easily from point to point without interrupting the operation.
- Energy consumption is a very important aspect too. Monitors are less energy consuming devices; they only require the operation of a high-pressure pump by the use of a relatively small engine. The dredge has an 800 HP engine to sustain its operation.
- Maintenance of the dredges is vital for its operation, the engine needs a daily service and the suction system wears out very quickly in abrasive material. The monitors need very little maintenance because the system is not directly in contact with the material.
- Dredging does not recover a constant pulp density or constant flow discharge as it depends on the amount of material cut and failed from the slope. Slope failure under water is difficult to predict. Monitors are more flexible, pressure can be adjusted to meet certain density and flow discharges, however have limitations when the material becomes coarser, i.e. sand wall and/or starter wall.
- Both methods have limitations for a complete cleaning of the bottom of the basin. In both cases, mechanical methods will be required to finish the basin cleaning.

7 Conclusions and Recommendations

The operations summarized in this report, although very different in many ways from the Faro situation, offer some guidance to the design of the Faro Tailings Relocation Project. The most important ideas to come out of the reviewed work are as follows:

1. Submersible pumps are effective but expensive to maintain. The experience at Giant Yellowknife clearly indicates that the cost of maintenance of the Toyo submersible slurry pumps was high. The pumps were very effective in digging their own sumps and they were able to pump slurry well, but they had excessive seal wear and had high ongoing maintenance costs. The use of Toyo pumps at ERG in Timmins worked better than Giant as they learned lessons from Giant and did a better job of preventative maintenance. In spite of this, it is advisable to use vertical cantilever pumps vs. submersible pumps.

2. Pumps should be kept as close as possible to the mining face. The ability to move sump pumps close to the mining faces will improve the density of the slurry reporting to the sumps. The economics of the project are very dependent upon being able to maintain a high-solids slurry and therefore every effort should be made to improve the likelihood of keeping the solids in suspension to the sump pumps.

3. Gradients from the mining face to the sump or pump station must provide sufficient slurry velocity to keep the solids in suspension.

4. Final clean-up of tailings on top of original topography is not well suited for high-pressure hydraulic monitoring and is probably best done with low pressure water combined with excavators and trucks.

5. It is recommended that, if the hydraulic mining of tailings at Faro is further pursued, a trip to Chile and South Africa be arranged to gather more detailed information from major tailings relocation efforts, assuming they are still in operation. South Africa, in particular, contains the vast majority of the hydraulic mining examples in the world.

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