Recent Improvements to the Gravity Gold Circuit at Marvel Loch

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ABSTRACT

Gravity gold circuits have an important part in reducing operating costs and maximising recovery in modern gold plants where coarse gold is present in the ore body. The design and selection of equipment has a vital part in the overall effectiveness of the gravity gold circuit. There are a number of associated factors that need to be taken into consideration when selecting the most suitable equipment for gravity gold circuits including occupational health and safety, security and labour requirements.

This paper is a case study that outlines the validation behind the design, selection of equipment and subsequent benefits of the recent upgrade of the gravity circuit at the Marvel Loch gold mine with the main component to the upgrade being the installation of a Consep Acacia Reactor. Since the upgrade there has been a significant increase in gravity recovery, which has reduced the amount of gold reporting to the leaching circuit therefore reducing reagent consumption and overall operating costs. There has been an increase in overall gold recovery and therefore increased gold production. The benefits to occupational health and safety include the removal of toxic gases being released in the gold room during the previous practice of gold concentrate calcination and the removal of the arsenic and nickel from the gold doré, which poses a risk during refining. Manual handling and security has improved as there is no physical contact with gold concentrates during the automated process using the Acacia reactor. The total time for gold room personnel working in the gold room has also reduced from around six hours per day to less than one hour per day.

With the continuing development of low grade gold deposits, there will be an increase in demand for low capital, high recovery gravity gold circuits that can significantly increase overall production while reducing operating costs.

INTRODUCTION

St Barbara's Southern Cross Operations are centred at Marvel Loch, 30km south of the town of Southern Cross and 360km east of Perth, Western Australia. The current operations based at the Marvel Loch Underground mine as shown in Figure 1. Southern Cross Operations produced 121,870 ounces of gold for the 2010 financial year. The immediate strategic focus of the operation is to reliably deliver to the plan through to financial year 2013, while extending the mine life through expansion of reserves (St Barbara Limited, 2008).

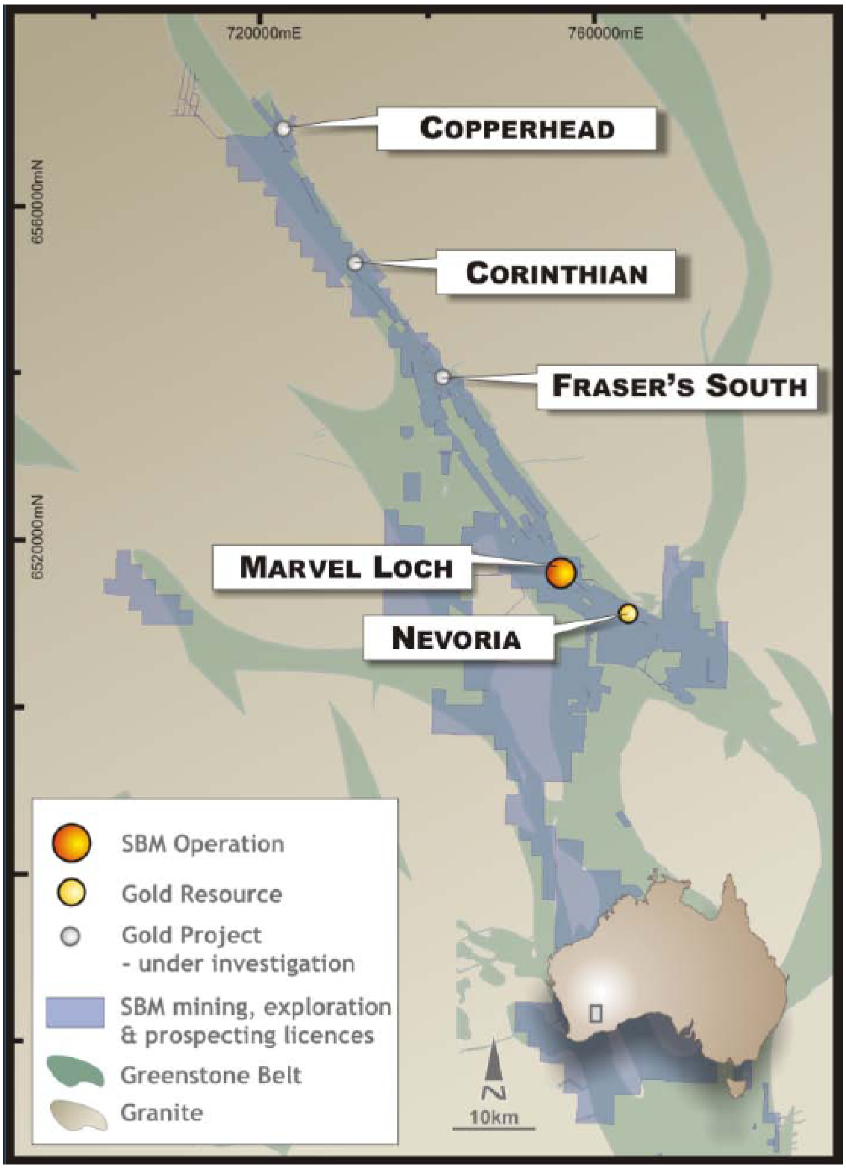

Figure 1: Location of Southern Cross Operations

Geology

Marvel Loch is the largest of the many shear-hosted gold deposits found within the Southern Cross greenstone belt. It lies in the neck of a mega-boudin formed by the mafic-ultramafic greenstone core of the Polaris domain. The Marvel Loch gold deposit is hosted by a steep westerly dipping package of ultramafic, mafic and sediments to the west, with gabbro, dolerite and sediments to the east.

Marvel Loch Underground Mine

The Marvel Loch Underground (MLU) mine is the mainstay of St Barbara's Southern Cross Operations. Gold mineralisation extends over a 1.3 km strike length and has been identified to depths of over 700 metres below surface. The ore body comprises multiple lodes. Those currently being mined include Sherwood and Undaunted at the North; Exhibition at the centre; and East and New at the South. These are shown in Figure 2. Mining methods include uphole benching and open stoping with rock fill where necessary. Ore production from Marvel Loch Underground mine for the 2010 financial year was 969,519 tonnes at an average grade of 4.0 g/t.

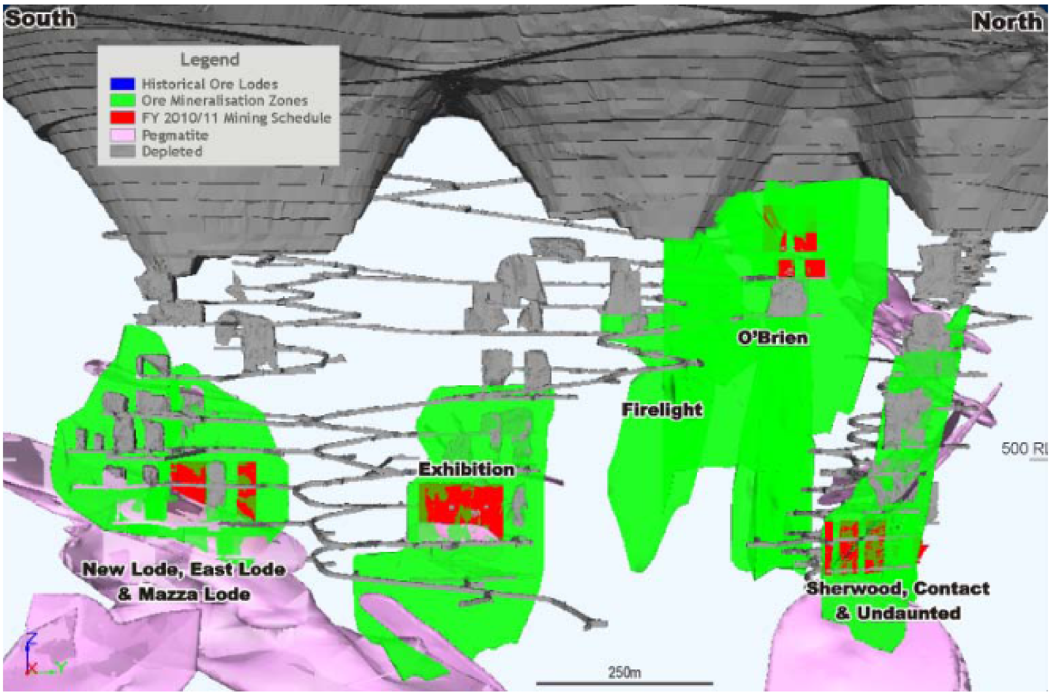

Figure 2: Marvel Loch Underground Ore Lodes

Other Mines

Open pit mining ceased at the Southern Cross Operations in July 2009. The most recent open pit mining was from the Mercury pit from the Transvaal region 4km south of Southern Cross. The recoveries from the Mercury ore ranged from 45-65% due to gold predominantly locked in Arsenopyrite resulting in lower overall plant recoveries. Processing of the Mercury ore ceased in May 2010. The Nevoria ore body is currently subject to a resource model and mining study. Elsewhere in the area, the company is seeking to leverage off projects with a significant amount of drilling and a track record of past production. The Frasers, Corinthian and Copperhead mines are yet to be fully evaluated following the St Barbara's acquisition of the Southern Cross land-holding. Extensive refractory mineralisation is present in the Transvaal region, which requires further metallurgical test work to assess its viability (St Barbara Limited, 2008).

Marvel Loch Processing Plant

The current Marvel Loch processing plant was commissioned in 1987 by Mawson Pacific Ltd with an original nameplate capacity of 1.2 Mtpa. The original plant consisted of single stage crushing, SAG milling, and conventional carbon-in-leach (CIL) circuit. Since that time, the plant has undergone numerous expansions and upgrades, including the addition of secondary and tertiary crushing, the replacement of a coarse ore stockpile with fine ore bins, a third ball mill, extra leach tanks, the conversion of CIL to carbon-in-pulp (CIP) and gravity circuit improvements.

The current processing plant arrangement consists of three stage crushing, fine ore bins, fine ore stockpile, two stage grinding, gravity concentration, CIP circuit, split AARL elution, electrowinning, smelting and a tailings storage facility.

The plant capacity is 2.5 Mtpa, however current annual mill throughput is 1.2 Mtpa with all ore mined from the MLU mine. Since September 2009, the plant has operated on a 1 week on / 1 week off campaign milling basis.

GRAVITY CIRCUIT PRIOR TO UPGRADE

The gravity gold circuit at Marvel Loch prior to the upgrade in April 2010 consisted of screening and primary and secondary gravity concentration of the cyclone underflow stream to recover coarse free gold. Specifically, two bleed streams of the cyclone underflow were fed to a gravity feed box where the slurry density was reduced prior to being screened in parallel over two 3.0 m x 1.5 m vibrating screens with an aperture size of 3 mm. The coarse fraction (+3.0 mm) was returned to the secondary ball mills for further grinding while the minus fraction (-3.0 mm) was collected into a hopper before being pumped to the magnetic separator for tramp iron removal prior to primary gravity concentration using two 30 inch Knelson concentrators (one CD model and one XD model). The gravity concentrate from the Knelson concentrators was then transferred to a 1 m^3 storage hopper in the gold room after regular intervals depending on Knelson concentrator cycle times. On a daily basis, the gravity concentrate was batch fed, using an auger feeder, to a 40 inch Mineral Cone for secondary gravity concentration. The concentrate was upgraded by the rejection of low specific gravity materials to produce a smaller volume of concentrate at a higher gold grade.

The final concentrate was filtered using a filter press to reduce moisture content prior to being calcined in an oven at 650^{o}C for around 12 hours. The calcine was then removed from the oven, weighed and stored for smelting. Figure 3 shows the flow sheet of the gravity circuit prior to the upgrade.

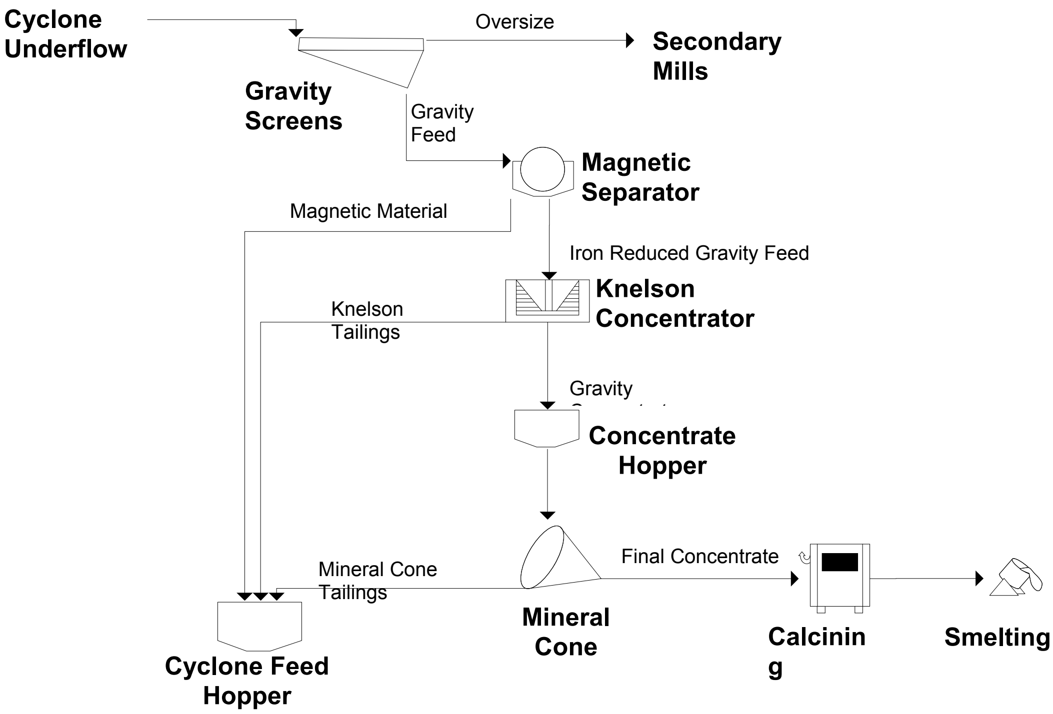

Figure 3: Gravity circuit flow sheet prior to upgrade

The gold recovery from the gravity circuit averaged 17% over the 18 month period (Oct-08 to Mar-10) prior to the gravity circuit upgrade. The gravity recovery was shown to be dependent on the ore sources being processed. As proportions of MLU ore in the blend fluctuated and changes in open pit ore bodies being processed, it was shown that the gravity recovery also fluctuated. An example of this is shown in Table 1 which shows reconciled monthly gravity and leach recoveries in the 9 month prior to the gravity circuit upgrade.

	Jul-09	Aug-09	Sep-09	Oct-09	Nov-09	Dec-09	Jan-10	Feb-10	Mar-10
Leach Recovery (%)	63.3	71.1	68.1	65.5	65.3	61.9	67.3	66.8	64.9
Gravity Recovery (%)	23.9	10.5	16.5	13.9	14.3	24.9	20.8	13.2	18.9
Overall Recovery (%)	87.3	81.6	84.6	79.4	79.6	86.8	88.1	80.0	83.8

Table 1: Plant Recoveries

Issues arising from the gravity circuit

Gravity Recovery

Gravity recovery averaged 18.9% of the feed gold to the processing plant for the 9 month period Jul-09 to Mar-10. Gravity recoverable gold (GRG) testwork on the ore sources being treated indicated that higher gravity recovery should have be achieved through the processing plant. The predicted gravity recovery versus actual recoveries is shown in Figure 4.

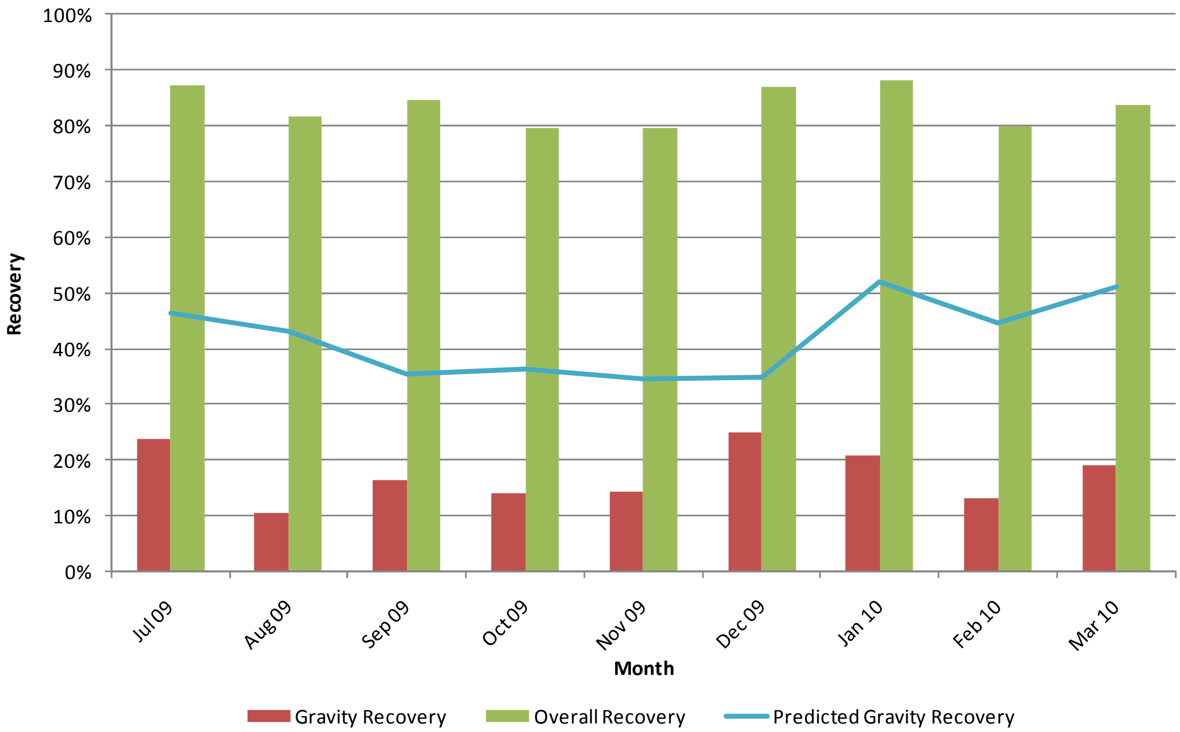

Figure 4: Predicted gravity recovery versus actual gravity and overall recovery

The cyclone underflow assay during this period averaged 30g/t indicating that there was a high probability of coarse gold that could be recovered through the gravity circuit. The overall plant recovery averaged 83.8% which was significantly lower than historical plant gold recoveries of around 86%. This was a direct result of the proportion of Mercury ore in the mill feed blend.

Mineral Cone Performance

Significant gold losses were experienced during operation of the Mineral Cone. Gold particles that were too small, uneven shaped or locked in gangue material were lost from the Mineral Cone through the Mineral Cone tailings which reported back to the grinding circuit. The performance of the Mineral Cone was strongly influenced by the gold room operator with several different settings which could be adjusted by the operator. These process variables included: water flow, water pressure, Mineral Cone angle, and feed flow rate to the Mineral Cone. All of these variables required re-adjustment whilst operating the Mineral Cone which depended on the quality of the concentrate being fed onto the Mineral Cone and therefore could not be unconditionally set. Furthermore, each gold room operator had slightly different set points and operating techniques depending on their individual experience and knowledge of the Mineral Cone which resulted in fluctuations in gold recovered from the Mineral Cone.

The low recovery of the Mineral Cone was observed in the 2-hourly leach feed samples. There was a significant increase in the leach feed assay whilst the Mineral Cone was operating as shown in Figure 5. This data is the average leach feed assay for August 2009 indicating an extra 16% of gold reporting to the leaching circuit that should be recovered in the gravity circuit.

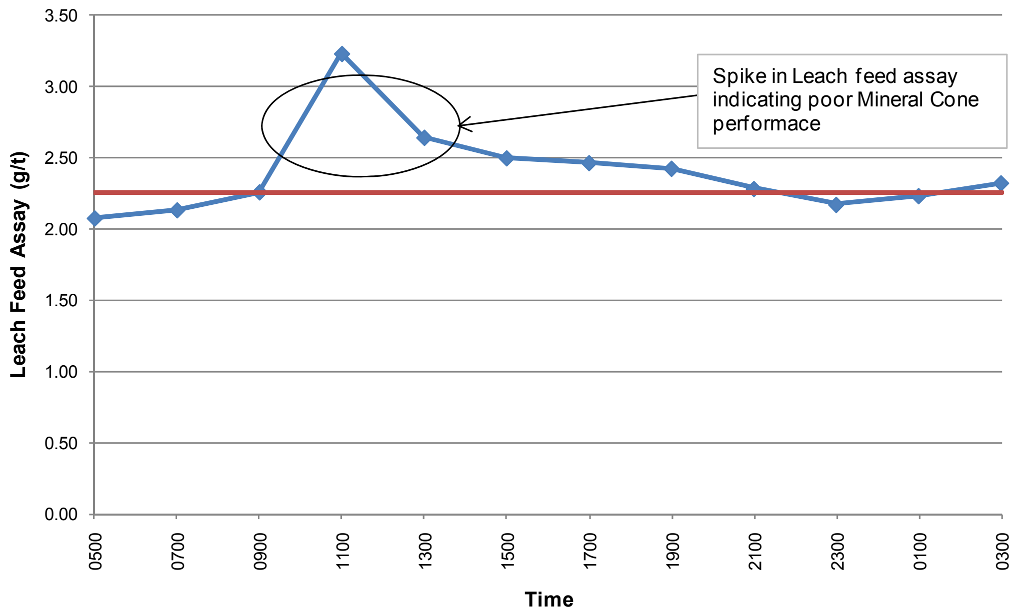

Figure 5: Two-Hourly average leach feed assay in August 2009

Occupational Health and Safety

Sulphide minerals such as Arsenopyrite, Pyrite and Pyrrhotite are present at varying concentrations in the majority of ore sources processed at Marvel Loch. Due to their higher specific gravity, sulphide minerals are recovered in the Knelson concentrators. As it was not possible to remove all sulphide minerals when processing the Knelson concentrate through the Mineral Cone, a significant amount of sulphide minerals reported to the final gravity gold concentrate. This can be seen in Figure 6. Steel chips and other magnetic material not removed by the magnetic separator would also be recovered in the Knelson concentrate and the Mineral Cone concentrate as shown in Figure 7.

The presence of sulphide minerals, particularly Arsenopyrtite, in the gravity concentrate made smelting of the concentrate problematic and resulted in contaminated gold doré bars. To overcome this issue, the concentrate was oxidised by calcining prior to smelting. During the calcination process, toxic fumes containing sulphur dioxide and arsenic trioxide were generated. The majority of these toxic fumes were removed through the gold room scrubber system but the risk of exposure to plant personnel could not be completely eliminated. Furthermore, the elevated levels of arsenic in the gold room and surrounding process plant areas also depended on the gold room scrubber system operating efficiently.

Figure 6: Gravity cone concentrates containing free gold and sulphides

Figure 7: Gravity cone concentrates containing free gold and steel

The presence of sulphides, nickel (from grinding media) and arsenic caused a high concentration of contaminants in the gold doré bars produced at Marvel Loch. Different flux mixtures were tested but the level of arsenic and nickel contaminants remained above the maximum levels permitted by the Perth Mint gold refinery and this resulted financial penalties imposed on St. Barbara Ltd.

During operation of the Mineral Cone, there was a risk of injury from exposure to rotating parts because the Mineral Cone was not fully enclosed or guarded. Manual adjustment of feed water, spray water and rotating angle were regularly required during operation to ensure optimum performance.

Significant manual handling of gold concentrate was required during filter pressing and handling the concentrate into and out of the calcine oven. There were numerous occurrences of concentrate spillage which resulted in a safety hazard as well as a potential loss of gold concentrate.

Security

As gold concentrate was filtered and manually transferred to the calcine oven there was an increased risk of theft of concentrate which typically contained a significant proportion of free gold. Industry standard gold room procedures were in place, such as the two person policy and CCTV security monitoring, to help mitigate the risk of gold theft. However, these procedures could not completely remove this security risk.

Metallurgical Accounting

Daily estimation of gravity gold recovery was difficult resulting in errors in the daily reporting of grades, recoveries and ounces produced. These could be reconciled once mint returns were received but this left it too late to identify fluctuations in mill head grade, plant performance or possible gold theft. In an attempt to alleviate this issue, several methods of estimating the percentage of gold in the concentrate were tested, but none were deemed effective for metallurgical accounting purposes.

Time Management

The length of time to operate the Mineral Cone on a daily basis was significant. For instance, it could take up to eight hours for all of the Knelson concentrate to be fed into the Mineral Cone and longer if there were any operational or maintenance issues. As a consequence, the gold room operators who also operated the elution circuit and other sections of the gravity circuit, had less time to manage those areas. This led to increased downtime and below average performance in these areas.

NEW CIRCUIT TESTWORK, EQUIPMENT AND DESIGN

A number of studies have been completed on the gravity circuit at Marvel Loch. AMIRA project P420B conducted by Laplante in September 2003 indicated that by replacing the Mineral Cone with an intensive cyanidation process, a gravity recovery of 45% could be achieved.

A further gravity circuit review in April 2007 indicated deficiencies in optimising Knelson concentrator feed flow rate and the performance of the Mineral Cone. Test work was performed on the Mineral Cone tailings indicating that the Mineral Cone recovery was between 60-70%.

Further modelling and simulation work completed on the gravity circuit showed that increasing the mass recovery from the Knelson concentrators would increase the gravity recovery from 17% to 21% and replacing the Mineral Cone with intensive cyanidation would further increase the gravity recovery above 25%.

Intensive Cyanidation

The proposed upgrade was to replace the Mineral Cone with an intensive cyanidation unit. Intensive cyanidation involved the use of relatively high concentration cyanide solution in favourable leaching conditions to leach gold from a gravity concentrate to produce a gold cyanide solution suitable for electrowinning.

Arsenopyrite is not dissolved by cyanide removing the requirement for calcining prior to smelting thus removing the exposure of personnel to sulphur dioxide and arsenic trioxide fumes. Intensive cyanidation units are fully automated, removing manual handling and physical contact with gold concentrate and thereby improving safety and security.

Two units were identified as possible secondary treatment options: the Gekko InLine Leach Reactor (ILR) and the Consep Acacia Reactor.

Gekko ILR

The Gekko ILR was trialled by the previous mine owner - Sons of Gwalia in 2003 as a means of improving gravity recovery. The Gecko ILR consisted of a concentrate hopper to collect and dewater concentrates from the Knelson concentrators. The main reactor works on the principal of a laboratory bottle roll, with a horizontal drum rotating at low speeds with baffles and aeration inside the drum to maximise leaching performance. The solids remain inside the drum while the solution is circulated from a holding tank through the drum and back to the holding tank. The barren solids are removed back to the grinding circuit and the pregnant electrolyte is filtered and gold recovered in the electrowinning circuit.

A trial of an ILR 100 was conducted onsite for a number of tests on the Mineral Cone tailings and Knelson concentrate batches. The results from the test work are summarised in Table 2.

Test no.	1	2	3	4	5	6	7	8	9	10	Average *
ILR Feed (g/t)	2126	2897	3216	1626	2669	2263	6406	2897	3216	1626	2971
ILR Tails (g/t)	1134	764	111	141	763	356	366	764	111	141	398
ILR Recovery (%)	46.7	73.6	96.5	91.3	71.4	84.3	94.3	73.6	96.5	91.3	86.6

Table 2: Summary of ILR Trial Results (* tests 2-10 only)

The gravity recovery from the Mineral Cone tail was shown to be 46.7% (Test 1). The average ILR recovery of the Knelson concentrate was 86.6% (tests 2 to 10). ILR recoveries ranged between 73.6% and 96.5% from the Knelson concentrate. The highest recovery was achieved on one particular sample following 22 hours of leach time. The results from this trial showed how poorly the Mineral Cone was performing and how intensive cyanidation could significantly increase the recovery.

Although the ILR demonstrated a significant improvement in gravity recovery, the capital request for installation of an ILR 2000 was not approved at the time of the trial in 2003.

Consep Acacia Reactor

The Consep Acacia Reactor was developed by Anglogold Australia at Union Reefs gold plant in 1998 (Watson and Steward, 2002). The main component of the Acacia Reactor is the fluidised bed reactor where the leaching of gold occurs. It has the same concentrate storage hopper and similar electrolyte storage tank to the ILR. The Knelson concentrate is transferred from the storage hopper into the fluidised bed reactor, where electrolyte solution is pumped up through the bottom of the reactor to fluidise the solids and promote mixing of the electrolyte and concentrate. Once the leaching cycle is finished the barrens solids are rinsed and discharged back to the milling circuit and the pregnant electrolyte is transferred to the electrowinning circuit.

During a gravity circuit review by Consep it was determined that the current gravity circuit was operating below optimum performance. Inefficient secondary treatment of the gravity concentrate was seen as a major contributor to the mediocre performance. Following the audit report a survey and trial of a pilot Acacia reactor was conducted.

The pilot Acacia Reactor CS50 trial was conducted to examine the amenability of Knelson concentrates to the intensive cyanidation process. The first test was conducted on tailings from the Mineral Cone to determine the quantity of recoverable gold being recycled back to the leach circuit. Subsequent tests were conducted on samples of untreated Knelson concentrates. Table 3 summaries the findings from the pilot Acacia Reactor test work (Wren, 2008).

	Mineral Cone	Acacia Reactor			
		Test 1	Test 2	Test 3	Test 4
Acacia Feed (g/t)	8061	2567	8061	6194	5857
Acacia Tails (g/t)	2567	4.37	40.64	15.7	20.3
Recovery (%)	68	89 to 99.8	99 to 99.5	98 to 99.7	99.7
Operating time (hr)	3	5 to16	2 to16	4 to 24	23

Table 3: Summary of Acacia Pilot Plant Trial

The test work demonstrated that Mineral Cone's gold recovery was 68% compared to 89% – 99% recovery from the Acacia Reactor. The lowest Acacia Reactor recovery (Test 1) was 89% which was achieved using the tailings from mineral cone after five hours of intensive cyanidation. Test 2, 3 and 4 were conducted on the Knelson concentrates and achieved significant leach recovery results.

New Circuit Flow Sheet

With the promising results of the intensive cyanidation trials, a gravity circuit flow sheet was developed to replace the Mineral Cone with intensive cyanidation. Due to the financial constraints of adding an extra electrowinning module, Marvel Loch processing management decided to use the existing electrowinning circuit on site to recover the gold from the pregnant electrolyte, which introduced a number of new issues.

Firstly, gold doré from gravity production was not separated from leach circuit production. Instead, the pregnant liquor assay and volume was used to calculate the gravity production making gravity recovery calculations reliant on aqua regia assays rather than on bullion assays. Secondly, as the intensive cyanide operation relied on the existing electrowinning operation and combined the pregnant liquors, it increased the gold concentration thus requiring longer electrowinning times and as the previous electrowinning cycle dictates the elution timing, there was a risk of delaying the next elution cycle.

These issues could be reduced by cleaning out the electrowinning cells more frequently, increasing the efficiency of the electrowinning process and reducing the electrowinning time. The final gravity circuit flow sheet is shown in Figure 8.

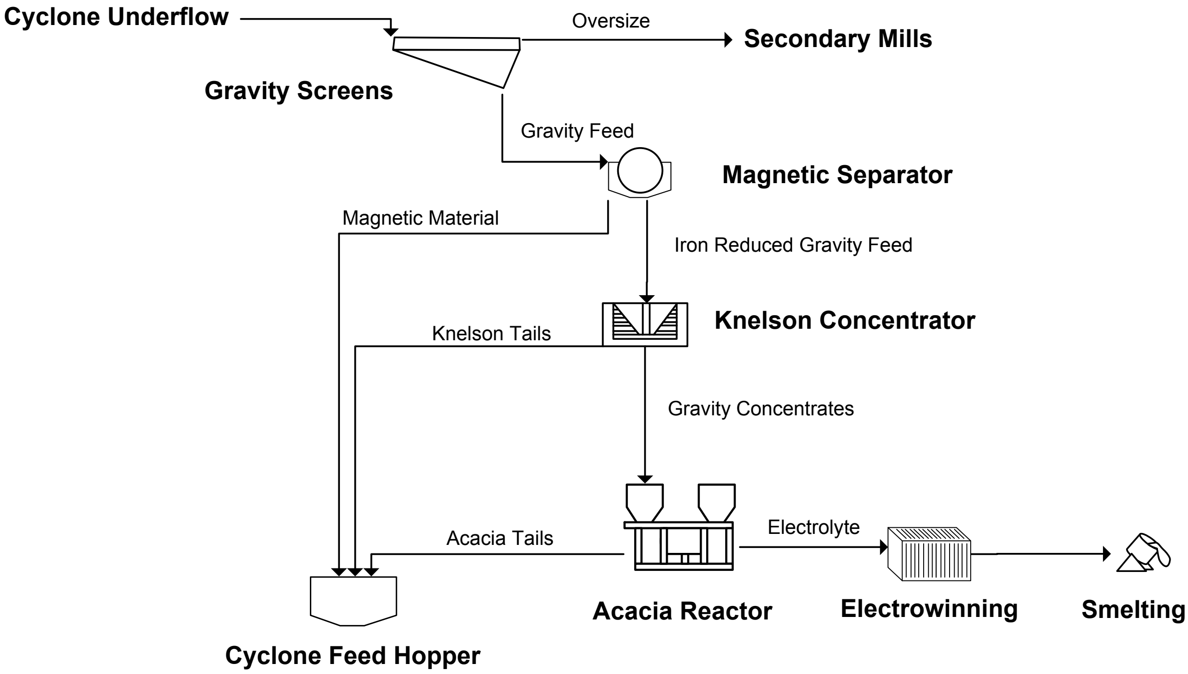

Figure 8: Final gravity circuit flow sheet

Selection of Intensive Cyanidation Unit

There are some significant differences between the two intensive cyanidation units that were tested. The capital cost of the two units were similar leading us to investigate the unit characteristics and operating costs of the two units to determine the best option. These are summarised in Table 4 below.

Gekko ILR	Consep Acacia Reactor
Pros • Lower operating cost • Less installed power • All gold particle sizes treated • Ability to be upgraded to larger batch unit	Pros • Higher Recovery • Robust leaching chemistry • Simple de-sliming system • Heating provides additional leaching flexibility • No moving parts
Cons • Produces more pregnant liquor • Clarifying pregnant liquor more difficult • Larger footprint • Rotating equipment needs guarding • Higher maintenance costs • Higher risk of downtime	Cons • Fluidised bed not flexible to feed variations • System not expandable • Gold fines lost in de-sliming process • Leach reagents can effect electrowinning

Table 4: Pros and Cons for Intensive Cyanidation Units

The decision made by Marvel Loch processing management was to choose the Acacia Reactor due to its higher gold recovery, simplistic design and less moving parts compared to the Gekko ILR.

OTHER GRAVITY CIRCUIT UPGRADES

There were a number of other issues identified in the gravity circuit which required further improvement. These included the inefficiency of the gravity feed screens, electrowinning and acid digestion with mild steel wool, and relatively low availability of the gravity circuit resulting in poor gravity circuit performance.

Gravity Screen Changes

The gravity screens that fed the gravity circuit were proved to be inefficient. There was a significant portion of undersize reporting back to the grinding circuit thereby reducing the flow to the gravity circuit and causing the Knelson concentrators to be under fed. The screen panels were made from hard polyurethane that would easily peg causing a majority of the feed that fed the screens to just pass over the top of the screens. Plant operators would have to pressure clean and de-peg the screens daily to ensure adequate efficiency but would become pegged again after a few hours of operation. The size of the screen panels (1480 x 600 mm) were heavy and cumbersome, which created manual handling issues during change outs. Due to the continuous pegging and scale build up, the screen panels had to be changed out every three months.

Due to the efficiency and manual handling issues with the gravity feed screens, different panels were investigated to improve the efficiency and reduce the maintenance to the screen panels. A softer polyurethane panel (2.5 x 18 mm slotted) was supplied having increased elasticity that would not allow rocky material to peg up the screens. As the screens were clear there was no scale build up below the screen so the efficiency of the screen was very high, as can be seen in Figure 9. The size of the screens was significantly smaller (484 x 305 mm), allowing easier installation and only requiring replacement of a few panels when worn which reduced the operating costs of the gravity screens. The new screen panels were installed in mid-2009 for a capital cost of $12,000 and has resulted in a significant improvement to the gravity screening efficiency.

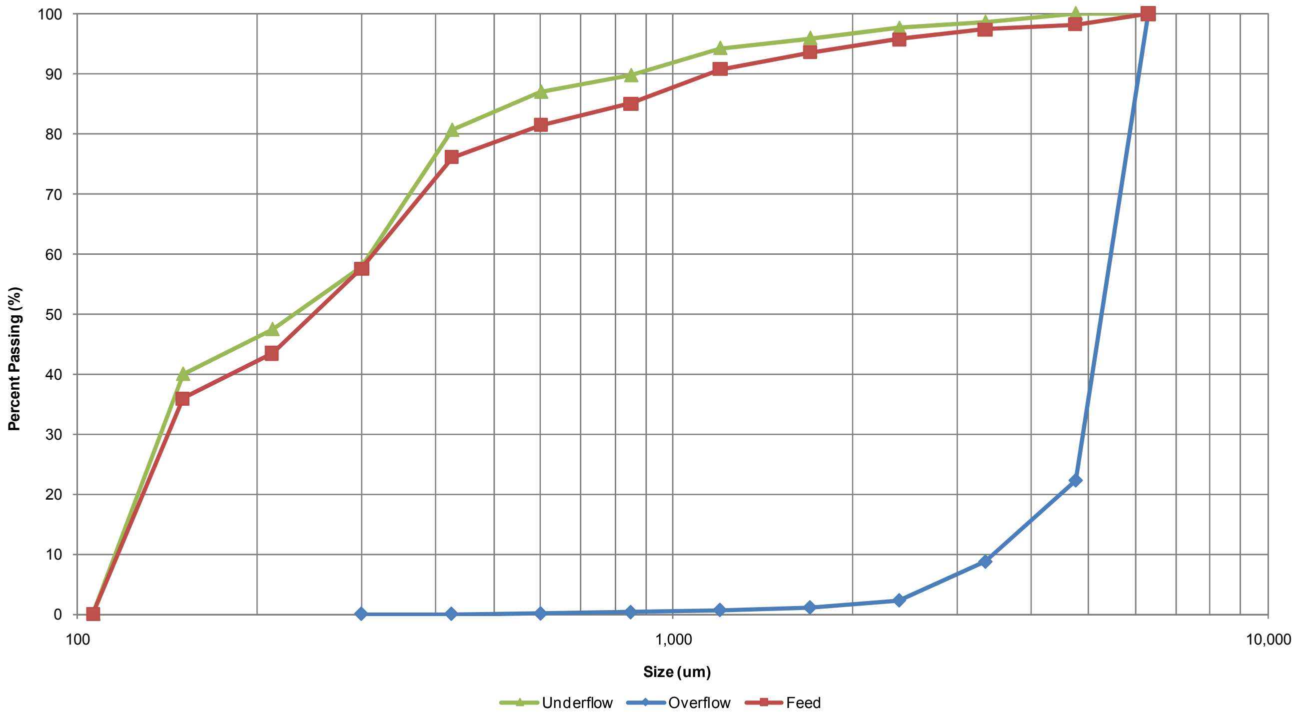

Figure 9: Gravity screen efficiency

Gold Room Modifications

During the process of upgrading the gravity circuit, upgrades to the gold room processes also occurred. The main upgrade involved converting the mild steel wool cathodes to stainless steel mesh cathodes.

The previous process using the mild steel wool cathodes involved operators pulling mild steel cathodes contained inside baskets. The baskets would be broken down and the loaded steel mesh removed and placed into large bins. Hydrochloric acid (30%) would be added to the bins to dissolve the steel wool. During the acid digest process the gold room would have to be evacuated resulting in operators being unable to continue other tasks, such as operating the Mineral Cone. There was a risk of exposure to hydrochloric gas and other fumes and there was also a risk of fire due to the heat generated from the acid digest process.

The introduction of stainless steel mesh cathodes removed the requirement for acid digest in the gold room. There was no longer a requirement to have baskets with the wool inside, just a barrier to prevent the cathodes and anodes from touching. Modifying this process reduced the time that was required to remove gold from the electrowinning cells. As a result, the gold room operators could pull cathodes more often, increasing the efficiency of the circuit and reducing the electrowinning times.

Knelson Concentrator Spares

A major issue with the gravity circuit was the availability of the two Knelson concentrators. If one concentrator was offline there was a significant increase in the circulating load of gravity gold through the secondary grinding circuit which would result in extra feed to the leaching circuit, reducing the gravity recovery. Significant time was spent collating all of the spare Knelson concentrator parts and ordering critical spares that were not stocked on-site. This resulted in a significant improvement in the Knelson concentrator availability which consequently reduced the cyclone underflow and leach feed assays.

GRAVITY CIRCUIT AND ACACIA REACTOR OPERATIONS

Installation & Commissioning of the Acacia Reactor

The Marvel Loch processing management decided to install the Acacia Reactor as part of the existing gold room to minimise the effect the installation had on normal gold room operations and to reduce the possibility of gold theft. Modification to the gold room and supply of services occurred over several months, with the final steps being the installation of the Acacia Reactor and rebuilding the gold room surrounding the Acacia Reactor.

Commissioning of the Acacia Reactor occurred in April 2010 and went very smoothly with only a few minor issues arising. The main issue was rearranging the program sequence to allow the discharge of the barren solids before the discharge of the pregnant electrolyte due to the constraints of the current elution setup and the impact of campaign milling. Another issue was rearranging the direction of the sampling valve to prevent bypassing during normal operations.

During the first four days of the Acacia Reactor operation, one Knelson concentrator was directed to the Mineral Cone and the second Knelson concentrator was directed to the Acacia Reactor. During that trial period gold recovered from the Acacia Reactor was very promising. Table 5 compares the gravity gold recovered from the Mineral Cone and the Acacia Reactor.

	9 April	10 April	11 April	12 April
Gold recovered from Mineral Cone (g)	1 984	1 404	1 212	1 429
Gold recovered from Acacia Reactor (g)	5 440	6 396	5808	6 092
Gold in plant feed (g)	21 553	1 831	17189	16 491

Table 5: Gold recovered from the Acacia Reactor

After four days of running both secondary gravity recovery options, the second Knelson concentrator was redirected to the Acacia Reactor. This resulted in a significant increase in gold recovered with the Acacia Reactor in the circuit. Figure 10 shows the significant difference in the gold recovered through the gravity circuit from before the change, during commissioning and at full production. Gravity recovery increased from around 20% to over 50%.

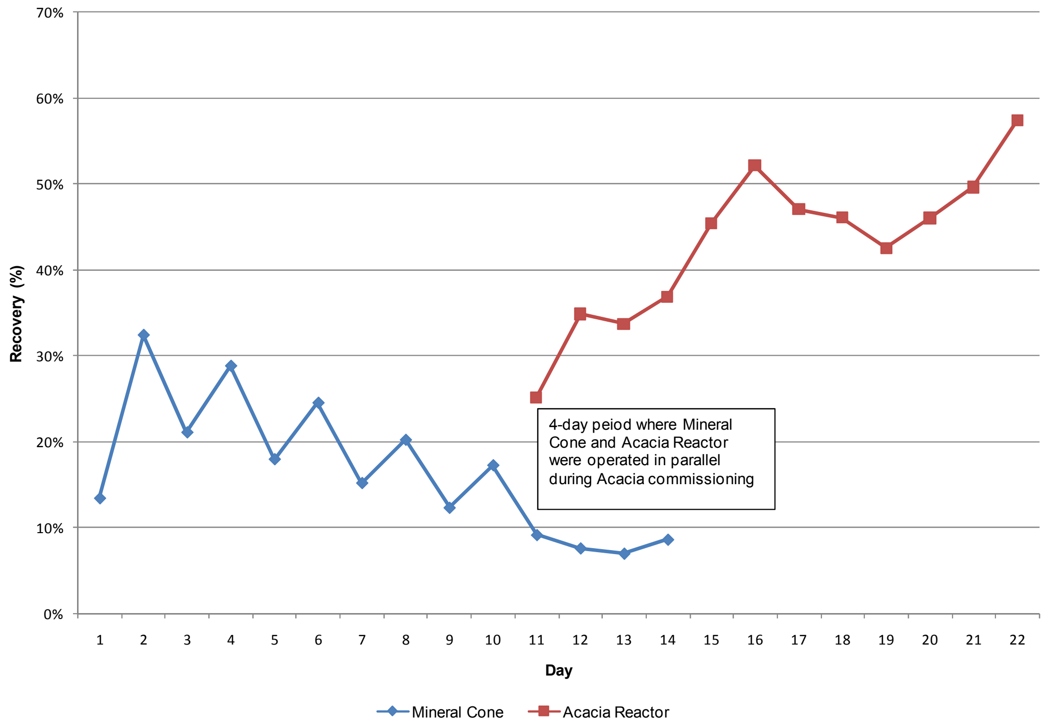

Figure 10: Increase in gravity gold recovery from the Acacia Reactor

Recovery figures for the barren solids samples taken from the Acacia Reactor average 96%. There are issues with taking an accurate sample of the Acacia Reactor barren solids due to the nugget effect resulting in some large variances in barren solids assay but overall it shows a very good performance as shown in Table 6.

Acacia Batch No.	153	154	155	156	157	158
Feed Grade (g/t)	4 969	3 884	3 638	4 933	3 202	3 285
Tails Grade (g/t)	238	43	60	401	23	183
Recovery (%)	95.2	98.9	98.4	91.9	99.3	94.4

Table 6: Typical Acacia Reactor Recoveries

Figure 11 shows the leaching profile during an Acacia Reactor batch. It demonstrates the favourable leaching conditions created by the Acacia Reactor producing fast leach kinetics. This makes sampling during the batch reliable in giving a final estimation of the gold recovered allowing a daily grade and recovery figure to be estimated before the Acacia Reactor batch is complete.

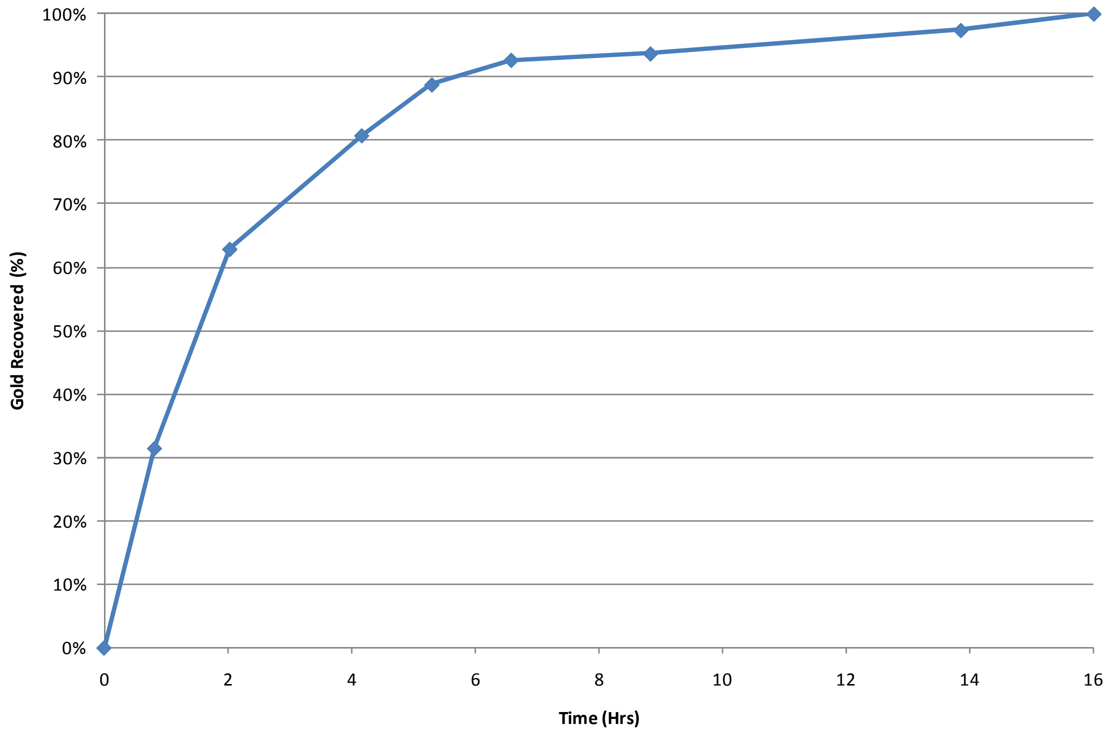

Figure 11: Leaching profile of an Acacia Reactor batch

Overall Effect on Gravity Circuit

Since the installation of the Acacia Reactor there has been a reduction in the mass of barren gravity concentrate returning to the grinding and leaching circuits. There has also been an increase in gold recovery through the gravity circuit as shown in Table 7.

	Jan-10	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10
Leach recovery (%)	67.3	66.7	64.8	50.1	42.9	44.5	42.8
Gravity recovery (%)	20.8	13.2	18.9	41.5	49.7	50.3	52.0
Overall recovery (%)	88.1	79.9	83.7	91.6	92.6	94.8	94.8

Table 7: Increase in Gravity Recovery

The increase in overall recovery partially coincided with Mercury ore being removed from the mill feed blend. The blend percentage of Mercury ore in the blend was 10% over the first two months the Acacia Reactor was in production (April and May 2010). The increase in gravity gold production over these two months is significantly higher than the changes in Mercury ore blend percentage, indicating that the Acacia Reactor had significant impact on the overall plant recovery.

Figure 12 shows the increase in overall plant recovery from 84% up to 92% once the Acacia Reactor was installed. The gravity recovery increased from 17% to over 45%. Reviewing recent plant data, the overall plant gold recovery is 86.3% indicating the improvement to recovery as a result of the Acacia Reactor is between three and five percent.

The GRG test work on the ore sources being treated indicated that the gravity recovery with the upgraded gravity circuit was similar to that predicted by the test work.

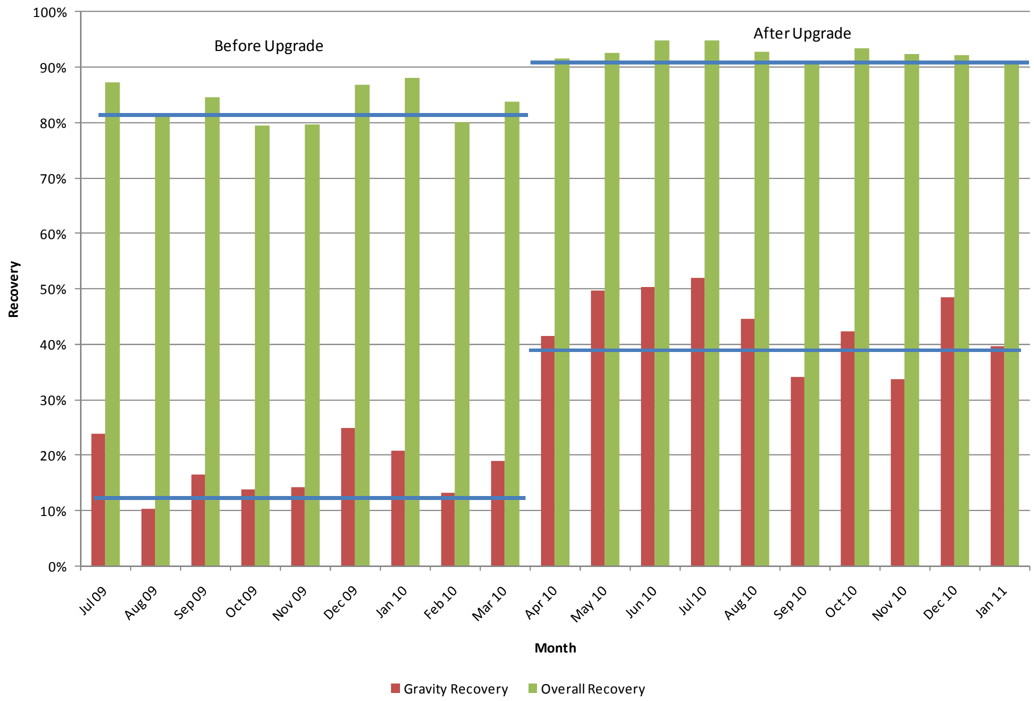

Figure 12: Overall plant and gravity recoveries

There has been a significant decrease in the variability of the assay in the cyclone underflow stream. Prior to the upgrade the cyclone under flow averaged 30 g/t, after the upgrade it decreased to around 18 g/t. This represents a significant amount of gold being removed from the circulating load of the secondary grinding circuit. Figure 13 shows the reduction in cyclone underflow assay before and after the upgrade.

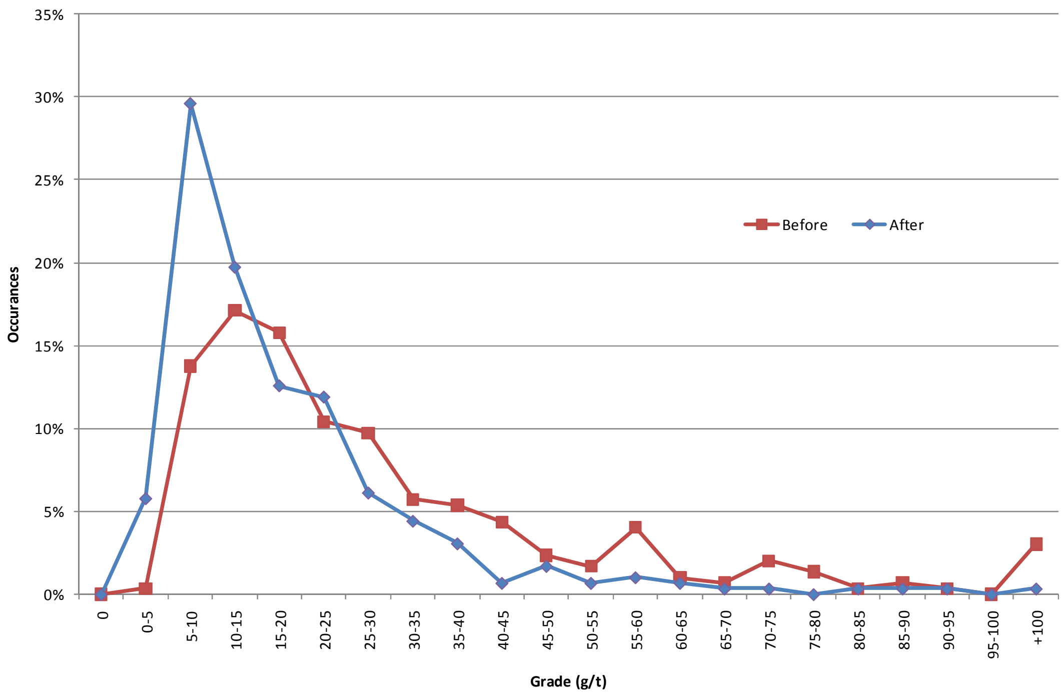

Figure 13: Cyclone underflow assay before and after upgrade

There has also been a significant decrease in the amount of gold reporting to the leaching circuit, with a decrease in the gold losses to tails as shown in Figure 14. The tails grade has reduced from 0.40g/t to 0.24g/t after the upgrade. Some of the reduction of tails grade may be attributed to the removal of Mercury ore from the blend. For one month either side of the upgrade, the tails grade dropped from 0.32g/t to 0.23g/t indicating there was a significant reduction due the upgrade of the gravity circuit.

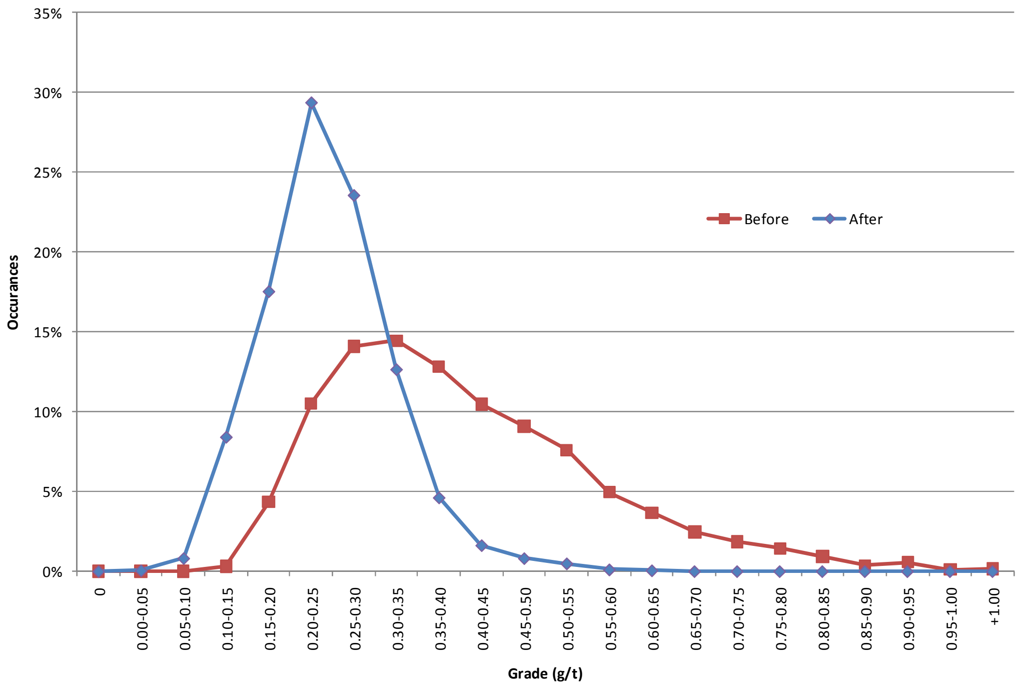

Figure 14: Tails grade before and after upgrade

Impact on Leaching and Elution Circuits

Reagent Costs

With the reduction of gold reporting to the leaching circuit there has been a reduction in reagent costs (particularly in cyanide) required for leaching as shown in Figure 15. Removing the two outliers one from before and one after the installation, cyanide consumption has reduced from 0.89 kg/t to 0.78 kg/t representing an annual saving of around $310,000.

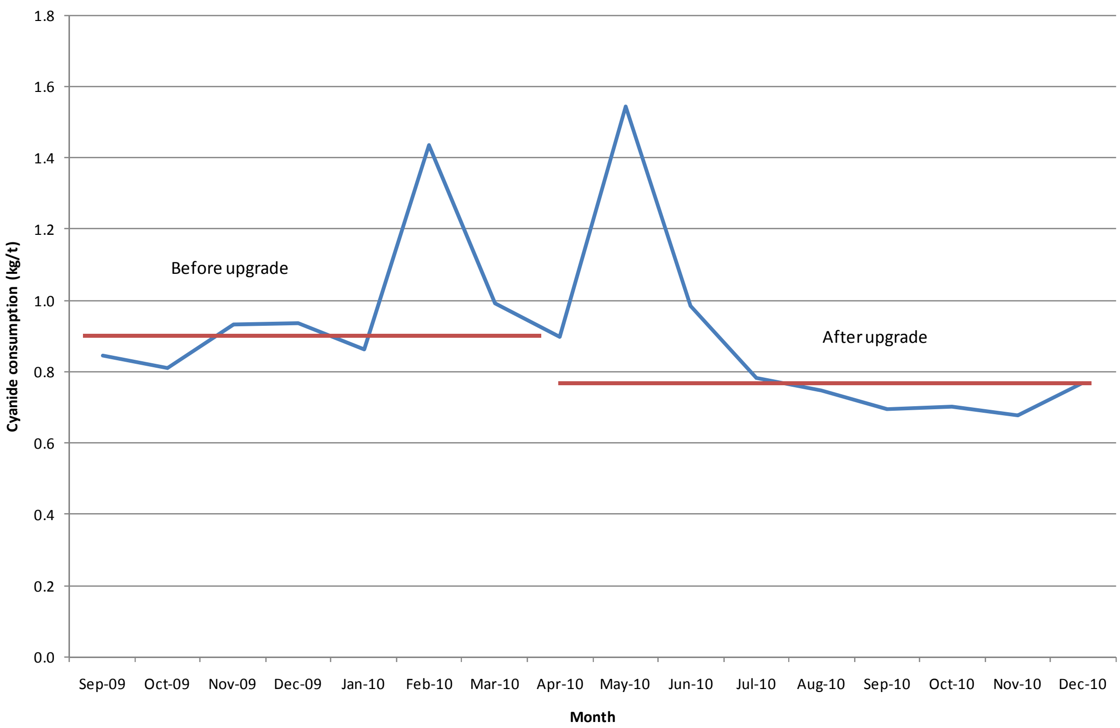

Figure 15: Cyanide consumption for leaching before and after upgrade

There has also been an operating cost reduction associated with consumables required for the elution circuit. Costs of activated carbon, caustic soda and hydrochloric acid have all been reduced due to less gold reporting to the leaching circuit as a result of less elution strips required after the gravity circuit upgrade.

Overall Operating Costs

With the reduction of cyanide consumption and other operating costs there has been a significant reduction in overall processing operating costs as shown in Figure 16. The plant operating cost before the upgrade of the gravity circuit was $29.02 per tonne of ore treated compared with after the upgrade the operating cost reduced to $27.39 per tonne representing an annual saving of $1.96 million. There have been other process improvements to the Marvel Loch plant during this period resulting in lower operating costs so the reduction in the processing costs cannot all be attributed to the Acacia Reactor alone.

Figure 16: Plant operating costs before and after upgrade

With the cost of the upgrades to the gravity circuit and the associated reduction in operating cost the payback period for the installation is estimated to be between three and six months.

ASSOCIATED BENEFITS OF THE UPGRADE

Occupational Health and Safety

With the removal of the requirement to calcine gravity concentrate, no sulphur dioxide or arsenic trioxide fumes can be produced in the gold room. The automated process of the Acacia Reactor has significantly reduced manual handling requirements and spillages requiring physical labour to clean up. There has also been a reduction in moving parts reducing the associated hazards and possible pinch points.

Security

Due to the reduction in free gold being handled by the gold room operators, there is no physical contact with the gravity concentrate resulting in decreased opportunities for gold theft within the gold room.

Labour

Labour hours have been significantly reduced throughout the gravity circuit as a result of the above mentioned gravity circuit upgrades. Prior to the gravity circuit upgrade, it took on average three to six hours to process the Knelson concentrate over the Mineral Cone but with intensive cyanidation the labour hour requirement is reduced to less than one hour. Adding in the improvements to the maintenance of the gravity screens, reduction in time to replenish the electrowinning cells and other process improvements, this allows the gold room operators more time to concentrate on optimising other sections of the process plant.

Metallurgical Accounting

The benefits to the metallurgical accounting system onsite have been quite significant. There is now estimation of gold recovered through the gravity circuit once each Acacia Reactor batch has been completed. An initial sample is taken daily four hours after start up to give an estimation as to what the final Acacia Reactor assay might be to allow metallurgical performance to be progressively monitored and the final grade and recovery calculations follow once that batch has finished and assay is confirmed. Having an assayed value and volume reading has allowed increased precision for gold in circuit calculations and this makes the daily reporting and weekly reconciliation process more accurate. Calculation of total gravity recovery is easier with a definite amount from the gravity circuit, although there is no reconciliation from gold doré concentrations from the gravity circuit.

FURTHER IMPROVEMENTS

Further improvements to the gravity circuit will occur with further optimisation of the Knelson operating parameters and optimisation of the gravity feed flow from the cyclone underflow. Determining size by size gold recovery and modelling through the gravity circuits will indicate if further optimisation is possible and if there are any major losses of fine gold to the leaching circuit.

Possible installation of a separate electrowinning cell and electrolyte tank to alleviate pressure and allow further flexibility from the current elution and electrowinning capacities is considered. Consideration has also been made to reduce the Acacia reactor cycle time from 24 hours to 12 hours (i.e. 2 cycles per day) to process a larger mass of primary gravity concentrate to further increase gravity recovery and overall plant gold recovery.

Another area identified for improvement is the removal of the magnetic separator from the gravity circuit. Magnetic material currently recovered by the magnetic separator would be processed through the gravity circuit instead of being recycled back to the grinding circuit. This will also reduce the maintenance and operating costs of this unit.

CONCLUSION

The benefits of good circuit design and continuing operational improvements can not only be shown to reduce operating costs of a processing plant but result in other operational benefits such as removing occupational health and safety hazards, improving metallurgical accounting, increase gold room security and considerably reduce manual labour hours of plant operators to allow them to focus on obtaining overall increased plant performance.

Specific benefits from the gravity circuit upgrade of the Marvel Loch processing plant include a significant increase in gravity recovery, an increase in overall plant recovery and a reduction in plant operating costs. Other benefits that have been realised through this project have been the removal of toxic fumes (sulphur dioxide and arsenic trioxide) and hydrochloric acid in the gold room, an improvement in gold room security, the removal of manual handling and equipment hazards, the removal of labour intensive tasks thus improving overall efficiency of the gravity, elution and gold room circuits.

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