

Eureka Mine – Development and Implementation of a Novel Gravity/Heap Leach Process

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BACKGROUND

The Eureka Mine is situated in the Guruve district of Zimbabwe, some 150 km north of Harare. The mine was first worked in 1895 and until recently was operated as a typical Zimbabwean “smallworking” with a single owner-operator and small labour force mining at up to 50m depth and processing 50 tonnes per day of ore via grind, gravity recovery and CIP. The gravity circuit comprised a Knelson 12” Centre discharge Concentrator from which a significant but variable portion of production was recovered.

In 1996 exploration was commenced by Delta Gold Zimbabwe (Pvt) Ltd (DGZ), a wholly owned subsidiary of Delta Gold NL of Australia, with the aim of testing mineralisation and establishing a large-scale open pit operation. A feasibility study was completed in April 1998. Construction began in August 1998 and first gold was poured in June 1999.

The mine is designed to produce 65 000 oz/annum of gold from 1.5 million tonnes of opencast ore grading 2 g/t Au.

GEOLOGY & MINING

The mine is based on a mineralised sheeted-vein system in a granodiorite delineated over an area on surface 150 m wide and 450 m long, dipping at 50 degrees.

Currently defined reserve contains 450 000 ounces of gold, and total resource exceeds 1 million ounces.

Open pit mining will be carried out to a depth of 230 m – by far the deepest pit in Zimbabwe – over a 5-year pit life. Stripping ratio is approximately 4.5/1.

Grade improves with depth and the deposit has been drilled to 370 m below the maximum pit depth with a view to assessing the viability of underground mining.

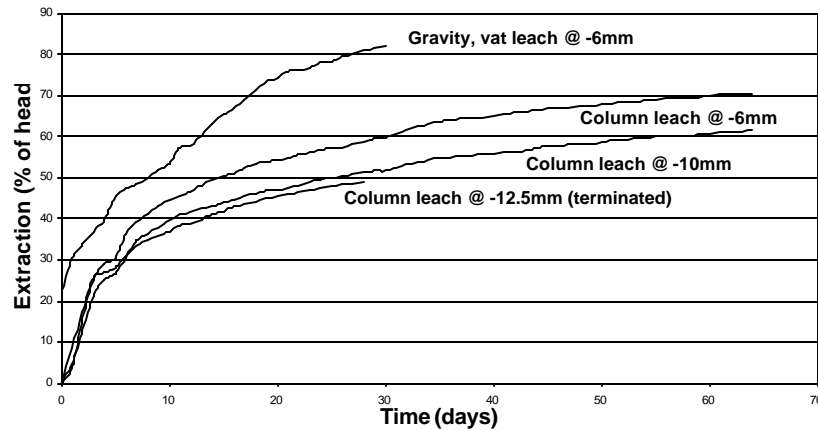
PRELIMINARY TESTWORK

Batch and pilot/bulk testwork for the open pit feasibility study was carried out by Peacocke Simpson & Associates (PS&A) of Harare and Mintek of South Africa. PS&A operates a fully equipped mineral-dressing laboratory that incorporates a registered Knelson Concentrator testwork facility.

Testwork for the feasibility study began in September 1997 and was initially intended to comprise only column heap leach simulation for determination of particle size/recovery relationship and usual design parameters such as irrigation rate, reagent consumption, heap slump, etc.

Early column leach tests on 300 kg samples were carried out in 250mm columns at various particle crush sizes. Results as shown in Figure 1 indicated a strong association of recovery with particle size.

Figure 1: Recovery Rate Curves, Column Leaching and Gravity/Vat Leaching (High Grade Ore)



*Notes: Soak time and lag time for first solution outflow from columns is disregarded.
Gravity recovery of gold is accepted to take place at time zero.*

From the early tests it was apparent that the unusually competent ore required fine crushing in order to achieve acceptable leach kinetics. This, combined with PS&A’s foreknowledge of the Eureka smallworking and laboratory experience with similar ores, led the company to investigate the potential for free gold release at this crush size. Sample availability was limited, but two tests were carried out using 10 kg aliquots of crushed ore at nominal 100% passing 6 mm. Each sample was first dry screened on 2mm, this being the limiting top size for a KC-MD3 laboratory Knelson Concentrator. The -2mm fraction was passed through the concentrator and primary concentrate was hand-panned down to a mass yield approaching that typical of Knelson Concentrators in a plant role. Concentrator and pan tails were recombined with the -6+2mm fraction for vat leaching. Results are shown in Figure 1 and Table 1 below.

Table 1: Test Results: 6mm crush, scalp at 2mm, gravity recovery on -2mm (High Grade Ore)

PRODUCT	MASS %	GOLD		
		Assay (g/t)	Units (g/t)	Distr’n (%)
-2mm Concentrate	0.07	1521.06	1.00	24.7
-2mm Gravity Tail	27.93	2.86	0.80	19.8
-6+2 mm “Oversize”	72.00	3.12	2.25	55.5
Feed	100.00		4.05	100.0

- Appreciable free gold was liberated at a 6mm crush. At this crush 28% by mass of the feed reported to the -2mm fraction, from which fraction 55.5% of contained gold was recovered by gravity. This equated to 24.7% of sample feed gold.
- Total recovery including vat leach of gravity tails and oversize is included in Figure 1. Although vat leach recovery is obviously not comparable to column leach recovery it could not be ruled out that the greatly enhanced leach rate was attributable to some extent to prior removal of coarse, slow-leaching gold.

It was also possible however that the anomalous high grade (± 4.3 g/tAu) of this bulk sample contributed to biased free gold content and recovery. A smaller bulk sample of low grade material was at that time in the PS&A laboratory for column leach tests and the same test program at the 6mm crush size was performed on this. Again owing to sample limitations – the bulk having been utilised for column leaching – it was possible only to use 2 x 10 kg aliquots for gravity work, and again leaching of tails and oversize was limited to vat leach.

Results are shown in Figure 2 and Table 2 below.

Figure 2: Recovery Rate Curves, Column Leaching and Gravity/Vat Leaching (Low Grade Ore)

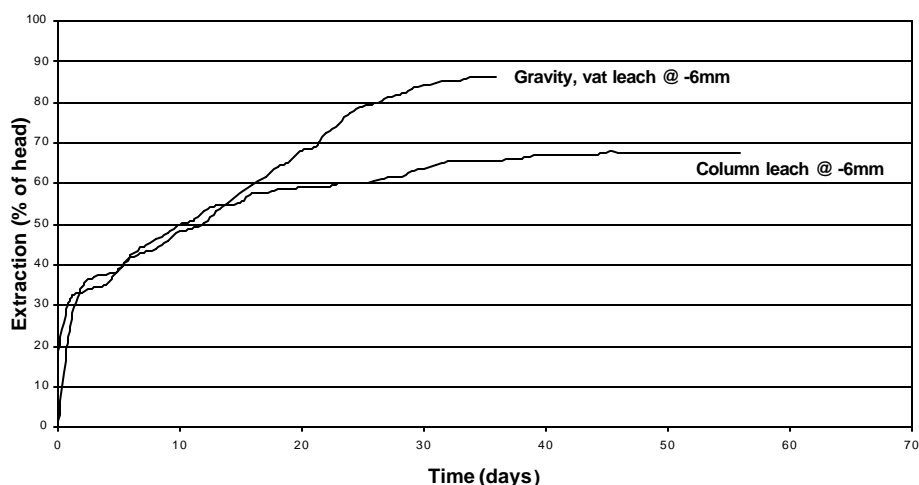


Table 2: Test Results: 6mm crush, scalp at 2mm, gravity recovery on –2mm (Low Grade Ore)

PRODUCT	MASS %	GOLD		
		Assay (g/t)	Units (g/t)	Distr'n (%)
-2mm Concentrate	0.07	370.86	0.26	19.3
-2mm Gravity Tail	23.23	1.36	0.32	23.7
-6+2 mm “Oversize”	76.70	1.01	0.77	57.0
Feed	100.00		1.35	100.0

A similar pattern is evident:

- In this instance slightly less material reported to the –2mm fraction, and gravity recovery from this fraction was 44.9% of contained gold, accounting for 19.3% of sample feed gold.
- Column and vat leach rates in this case were similar, but ultimate recovery from gravity/vat leach was 18.4% higher. This can probably be attributed to the better wetting in vat leaching but again enhancement due to prior removal of free gold could not be ruled out.

FINAL TESTWORK

By this time Delta Gold Zimbabwe had almost completed the geological and drilling phases of the feasibility study, and a 1500 kg representative bulk sample was made available for testwork.

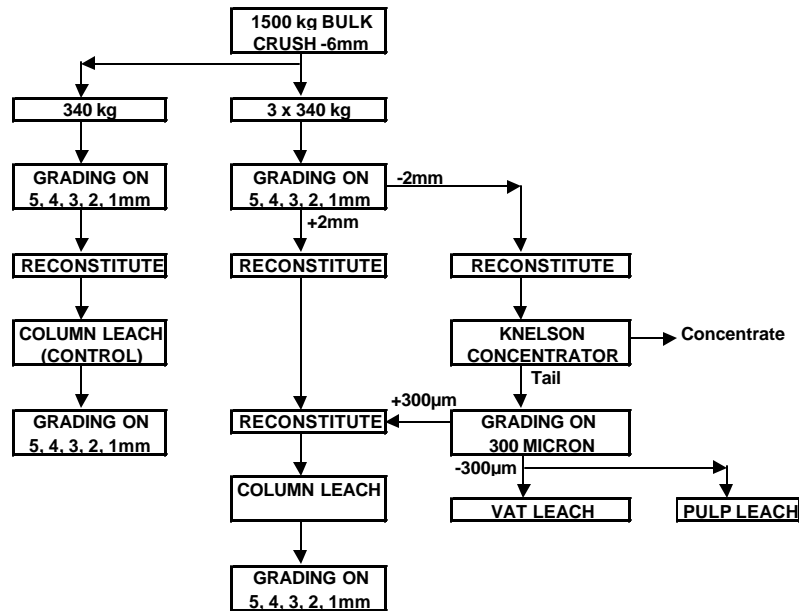
In addition to determining normal design parameters the final testwork program was designed to:

- Determine free gold recoveries at –6mm crush from bulk samples, using final concentrate mass yields associated with full scale Knelson Concentrators. Although PS&A have undertaken in excess of 4500 batch Knelson Concentrator tests and are confident of conservative plant scale-up from 10 kg batches, it was nevertheless necessary in view of the novel process to assess this at correct mass yield. Mass yields of <0.01% are not uncommon for Knelson Concentrators, requiring feed samples for a KC-MD3 laboratory machine of >500 kg.
- Determine the enhancements – if any - in leach rates and final recoveries from gravity/column leach verses direct column leach.
- Determine the proportion of –300 micron fines generated by fine crushing, and how best to treat these to avoid sealing of the heap. It was envisaged that this material could possibly be separately leached in a small, dedicated CIL plant.

The test program shown in figure 3 was agreed upon between DGZ, PS&A and Metallurgical Design and Management (Pty) Ltd, DGZ’s selected process and plant contractors.

It was felt that although the Knelson Concentrators were capable of accepting the entire proposed process feed at –6mm, negligible free gold liberation took place at that size as all visible liberated gold in previous tests was unusually fine at approximately 100% - 100µm. Proposed scalping size for the plant was thus 2mm, as reflected in the tests.

Figure 3: Final Testwork Flowsheet



Other tests were undertaken including conventional grind/gravity/leach, simulation of waterflush crushing for high fines generation, etc. They are however beyond the scope of this presentation and will not be discussed here. Post-gravity column leaching of sample A was terminated early to enable various design parameters to be calculated as flowsheet design work had already begun.

The results of the tests according to the above flow diagram are shown in Figure 4 and Tables 3.1-3.3 below.

Table 3.1: Test Results: 6mm crush, 2mm Scalp, Gravity Recovery, Heap Leach of -6mm + 0.3mm, Pulp Leach of -0.3mm (Final Sample A)

PRODUCT	MASS (%)	Distr'n (%)	GOLD Recovery (%)	
			Stagewise	Feed Basis
Gravity Concentrate	0.01	23.6	N/A	23.6
-6+0.3 mm Leach	92.30	73.8	40.9	30.2
-0.3 mm Leach	7.69	2.6	78.9	2.0
Total Recovery				55.8
Feed	100.00	100.0		100.0

Note: Column Leaching of the -6+0.3mm material was terminated early

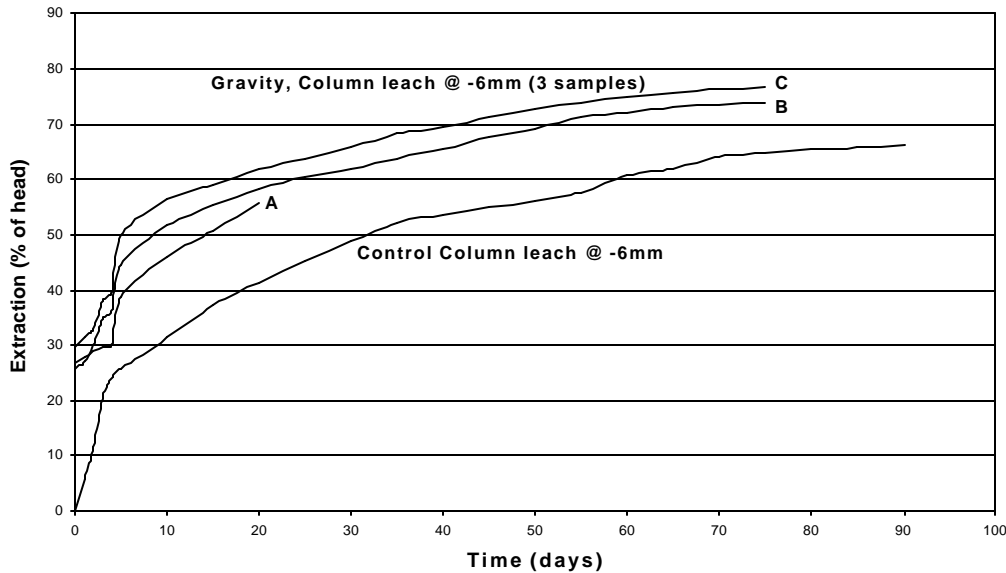
Table 3.2: Test Results: 6mm crush, 2mm Scalp, Gravity Recovery, Heap Leach of -6mm + 0.3mm, Pulp Leach of -0.3mm (Final Sample B)

PRODUCT	MASS (%)	Distr'n (%)	GOLD Recovery (%)	
			Stagewise	Feed Basis
Gravity Concentrate	0.01	21.4	N/A	21.4
-6+0.3 mm Leach	91.74	75.1	65.9	49.5
-0.3 mm Leach	8.25	3.5	84.5	3.0
Total Recovery				73.9
Feed	100.00	100.0		100.0

Table 3.3: Test Results: 6mm crush, 2mm Scalp, Gravity Recovery, Heap Leach of -6mm + 0.3mm, Pulp Leach of -0.3mm (Final Sample C)

PRODUCT	MASS (%)	Distr'n (%)	GOLD Recovery (%)	
			Stagewise	Feed Basis
Gravity Concentrate	0.01	26.2	N/A	26.2
-6+0.3 mm Leach	93.01	71.2	67.9	48.3
-0.3 mm Leach	6.98	2.6	80.6	2.1
Total Recovery				76.6
Feed	100.00	100.0		100.0

Figure 4: Recovery Rate Curves, Final Definitive Tests



- Gravity gold recovery continued to be high. The spread of results from 21.4% to 26.2% gravity recoverable gold is not uncommon in ores with appreciable free gold and nugget effect.
- Total recovery via this route averaged 75.3% in 75 days as compared to 66.2% in 90 days via direct heap leaching.
- It is quite probable that given even longer leaching, recovery by direct heap leaching would ultimately approach that of gravity/heap leach much more closely. Curve extrapolation – albeit presumptive – indicates that this might take place after about 170 days. Cashflow advantages and reduced leach times and costs with prior gravity recovery are obvious, and calculations showed that additional recovery of ±105 kg of gold could be expected within 3 months of start-up.

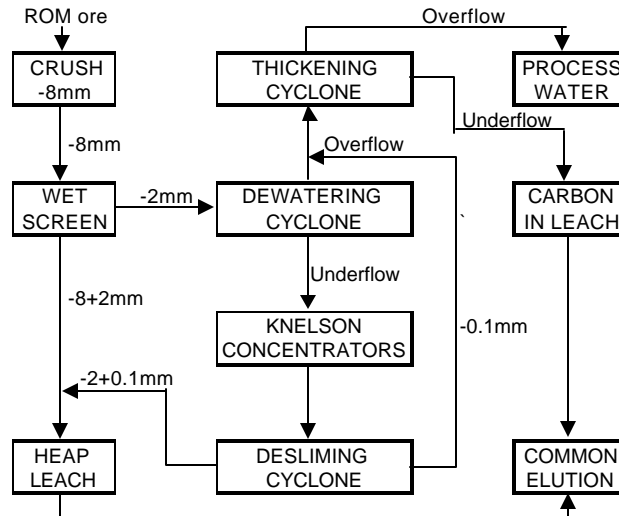
PROCESS FLOWSHEET

As a result of the testwork findings the process design incorporated a novel, hybrid gravity/heap leach flowsheet. The flowsheet (Figure 5 below) comprises:

- Crushing via primary jaw crusher and secondary and tertiary cone crusher to nominal 100% passing 8mm.
- Wet screening on 2mm with screen oversize to heap leach stockpile and screen undersize (approximately 42% of screen feed or 97 tph at design capacity) to a dewatering cyclone.
- Dewatering cyclone overflow (0-0.1mm) to thickening cyclone and underflow (approximately 90 tph at 52% solids) to 2 x Knelson KC-XD30 concentrators.
- Knelson tails to a desliming cyclone, Knelson concentrate to the gold room for secondary redress and smelting.
- Desliming cyclone overflow (0-0.1mm) joins the dewatering cyclone overflow to the thickening cyclone and desliming cyclone underflow (-2+0.1 mm) to heap leach stockpile.
- Ore reclaimed from heap leach stockpile and trucked to leach pad.

- Thickening cyclone overflow to dirty water pond (recycled to wet screening) and underflow to a novel two-tank CIL plant.

Figure 5: Process Flowsheet



PLANT PERFORMANCE

Since start-up of the mine a number of problems have been encountered, and design throughput and production has not yet been consistently achieved. In addition to the normal issues encountered when starting a new plant, particular problems included:

- Dilution in the mining process, resulting in depressed plant feed grades, initially excessive fines generation in weathered ore and associated screening and handling problems.
 - Mining through the old workings has been difficult, creating oversize and tramp metal which has caused crusher throughput and downtime problems.
 - The ongoing economic and fuel supply crisis in Zimbabwe which has severely curtailed pit operations.
- In the 8 months since the plant was commissioned a good deal of recovery data has nevertheless been gathered.

Table 4: Eureka Mine Recovery – Design versus Actual Recovery July 99- Feb 00

	Actual	Design
CIL	8.0%	2.3%
Gravity	10.4 %	10-20%
Heap Leach	54.3 %	50.5%
Total	72.7 %	68-73%

While total planned recovery has been achieved and is likely to be exceeded in the near future, the gravity contribution remains at the lower end of the expected range. There are a number of contributing factors for this:

- Although ore is subjected only to fine crushing, the free gold recovered by the Knelsons is unusually fine-grained and well liberated, and a large portion of it occurs as floating or paint gold. The small particle size coupled with an unusually coarse matrix of up to 2mm particles makes secondary redressing by shaking table somewhat inefficient, and gravity-recovered gold is lost in table tails returned to the plant. Investigations carried out indicate that less than 60% of free gold recovered by the primary Knelson Concentrators reports to table top-cut and bullion. In other words primary free gold recovery has averaged some 17-18% of plant feed gold, but only 10.4% has been recovered as bullion attributed to gravity. An exercise to improve secondary redress recovery is ongoing, with the replacement of the original shaking table by a Gemeni table and inclusion of a 7.5” Knelson Concentrator on table tails.
- In the testwork 2-3% of total recovery was accorded to pulp leaching of the fines *after* gravity recovery. In the plant the fines report to dewatering cyclone overflow before the gravity section. An appreciable quantity of very fine liberated

gold passes to dewatering cyclone overflow and thus bypasses the gravity step. It is significant that actual pulp leach recovery is 5.7% higher than the testwork/design figure. Were this excess exposed to and recovered by gravity, total gravity recovery would be about 16%, re-tabling inefficiency notwithstanding.

- Weighted average ore grade since start-up is 1.46 g/tAu, while process definition testwork was conducted on samples ranging in grade from 3-3.3 g/tAu. Reference to tables 1-3 above indicates higher free gold content at higher grade and it is for this reason that a reasonably wide range was allocated to the design gravity recovery figure. Since start-up plant feed has borne closer resemblance to the low grade test ore (table 2) which had a gravity recovery some 4% lower than the sample upon which the process design was based.

Despite the above and the depressed gravity recovery to bullion, there is strong evidence that without the gravity circuit heap leach recovery would not have exceeded 65%. This scenario was encountered in the early days of operation when a heap leach paddock loaded under these conditions failed to exceed 62% recovery in the allotted irrigation period.

On this basis indications are that cumulative gold production within 3 months of start-up was some 79 kg more than could have been expected by heap leaching only. At current plant feed grade, additional steady-state recovery of 14 kg/month is achieved.

The mine owners continue to acknowledge the benefit of the Knelson Concentrators at Eureka, and it is expected - as the factors outlined above are addressed, and as grade and plant operation continue to improve – that gravity contribution will rise to close to 20%.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the invaluable assistance of, and to pay tribute to MDM (Pty) Ltd and Delta Gold Zimbabwe Ltd – in particular Managing Director Frank Purcell and Technical Director Peter Bourhill – for the brave decision to break new process ground.