

BEYOND CIP/CIL - A COMBINATION OF EXISTING TECHNOLOGIES UTILISING GRAVITY, FLOTATION AND INTENSIVE LEACH MAY HERALD THE FUTURE FOR GOLD ORE PROCESSING.

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ABSTRACT

With the burgeoning opportunities for new gold mines to be developed the opportunity now exists for a reassessment of the optimal processing path for these gold ores. Projects have traditionally followed the path of whole ore cyanidation with either Carbon In Pulp (CIP), Carbon In Leach (CIL) or Merrill Crowe. The challenge ahead is whether these traditional processing methods are the best option for stakeholders, or to go beyond CIP and use a combination of currently available technologies that can be used to provide gold recovery at a significantly reduced capital cost and minimal deleterious impact on the environment. Either stand alone or combinations of gravity concentration and flotation, can produce a gold bearing concentrate that can then be fed directly to a batch or continuous intensive cyanidation unit. Treatment of a gravity/flotation concentrate by intensive cyanidation may be processed by the InLine Leach Reactor (ILR) developed by Gekko Systems of Australia. The advantages of the technology combining gravity/flotation followed by intensive cyanidation are significantly reduced capital costs; improved safety due to reduced cyanide inventories; the majority of tailings un-contaminated by cyanide; less energy required due to an opportunity for an increase in grind size – reducing green house gas emissions; detoxification of concentrate tailings can minimise tailings disposal and containment requirements.

INTRODUCTION

With the opening of new frontiers to gold mining along with opportunities from existing and past operations there is now the technology and expertise available with their innovative use to significantly reduce both capital requirements and short and long term environmental liabilities. This paradigm shift will enable projects to provide a higher return to investors due to the reduced capital required, faster project completion coupled by a significantly lower long term environmental liability. Design advantages can be obtained by utilising a gravity and intensive

leach circuit only rather than the traditional full ore leach circuit such as CIP/CIL. The circuit incorporates crushing and coarse grinding to 200 μ m, then gravity recovery, possibly in combination with flotation followed by intensive cyanidation of the gold concentrate. The tailings from the gravity and flotation treatment are then stored in a tailings facility separate from the gravity/flotation concentrate. Therefore, typically 90% of the tailings will not be exposed to cyanide – a significant consideration for minimising long term liability. There is also a significant reduction in the perception of the public regarding the risks associated with the operation since only a minor amount of the ore is exposed to cyanide. The concentrates are then subjected to intensive cyanidation to leach the gold which when in solution is then recovered either directly with electrowinning or with activated carbon/resin in columns.

Overall the steps involve utilising proven processing paths (Refer to Fig 1).

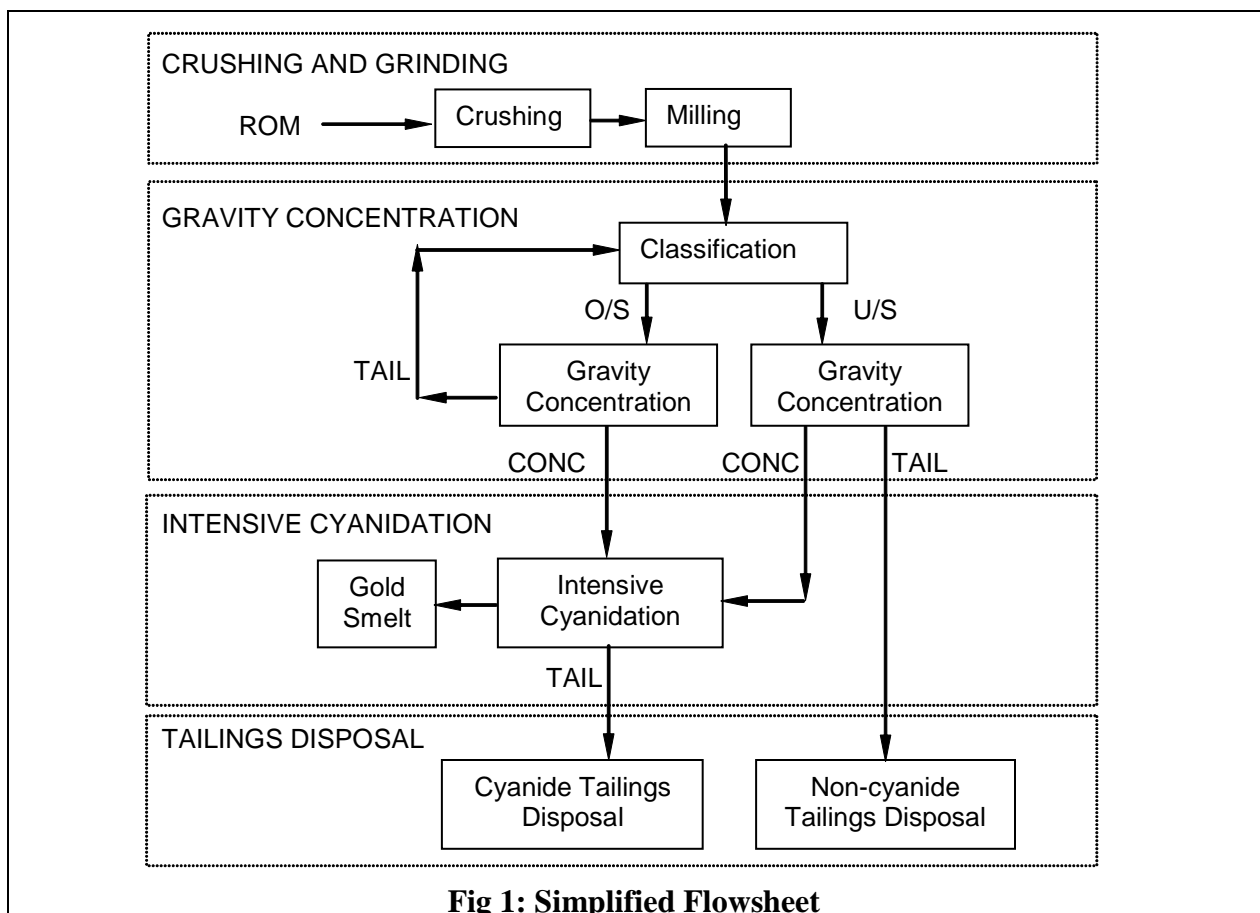


Fig 1: Simplified Flowsheet

The existing technologies utilised are:

- Size reduction utilising a combination of crushing and grinding – care must be taken to prevent over grinding. Over grinding may result in reduced recoveries during the gravity and/or flotation stage.
- Concentration is by gravity and/or flotation. The gravity concentration is by a combination of a continuous gravity concentration device such as an InLine Pressure Jig (IPJ) and a

bowl centrifugal concentrator such as an InLine Spinner (ISP) or a Falcon Concentrator. A bulk sulphide type flotation using a standard flotation cell.

- Intensive cyanidation using an InLine Leach Reactor (ILR) to leach the gold ore with cyanide as the lixiviant. Typically an oxygen source such a hydrogen peroxide or oxygen gas is used. Gold is recovered from solution using electrowinning/activated carbon or an ion exchange resin. Extreme care is required should a leach accelerant containing lead salts etc be used. This is due to the fact that it may severely inhibit the electrowinning performance.
- Tailings disposal allows for two separate disposal systems. The gravity/flotation tailings will be relatively benign and are able to be contained in a separate impoundment facility separate from the ILR tailings. The ILR tailings – which typically will be approximately 10% to 12% of the feed mass, are able to be contained in a higher grade impoundment facility. The ILR tailings undergo cyanide destruction using hydrogen peroxide – ensuring the environmental liability is minimised.

CONCENTRATION

Concentration is by gravity and/or flotation with the majority of the mass yield and gold recovered with gravity and the flotation system acting as a scavenger. The gravity recovery is best suited with a combination of high yield continuous machines in combination with a low yield batch machine.

The classifier oversize is treated via a continuous high yield gravity recovery stage. An example of a high yield continuous unit is the InLine Pressure Jig (IPJ)¹ manufactured by Gekko Systems in Australia (refer fig 2). The IPJ is a fully encapsulated, circular, moveable sieve jig. The feed slurry is generally fed to the jig under pressure which may be under gravity or via a pump and flows radially out across the deceleration chamber. The floor of the deceleration chamber is made up of a wedge wire screen which supports a dense media bed or ragging. The bed is submerged in water and slurry and is physically pulsed up and down by a hydraulic drive. A proximity sensor at the base of the wedge wire screen support frame registers the bottom of the pulse sequence. The control system registers the signal from the proximity sensor and changes the state of a hydraulic valve to drive the hydraulic ram up. A rubber/polyurethane diaphragm allows the wedge wire screen to move whilst the inner cone stays immobile and ensures the hutch water does not bypass to tails. The pulsing up and down of the submerged bed creates a fluidized media. Hutch water (process water) is added at the base of the cone which flows partially to the concentrate and partially through the bed to the tailings. The unit produces two products, a *sink* and a *float* product. Both products are pressurised and may be piped to the next part of the process without further pumping.

The major benefits of the IPJ are:

- Ease of installation and retrofit.
- Very low water consumption.
- High capacity per unit area.
- Low operating cost.
- Accepts large feed size (25 mm).

- Low installed capital cost.
- Simple operation.

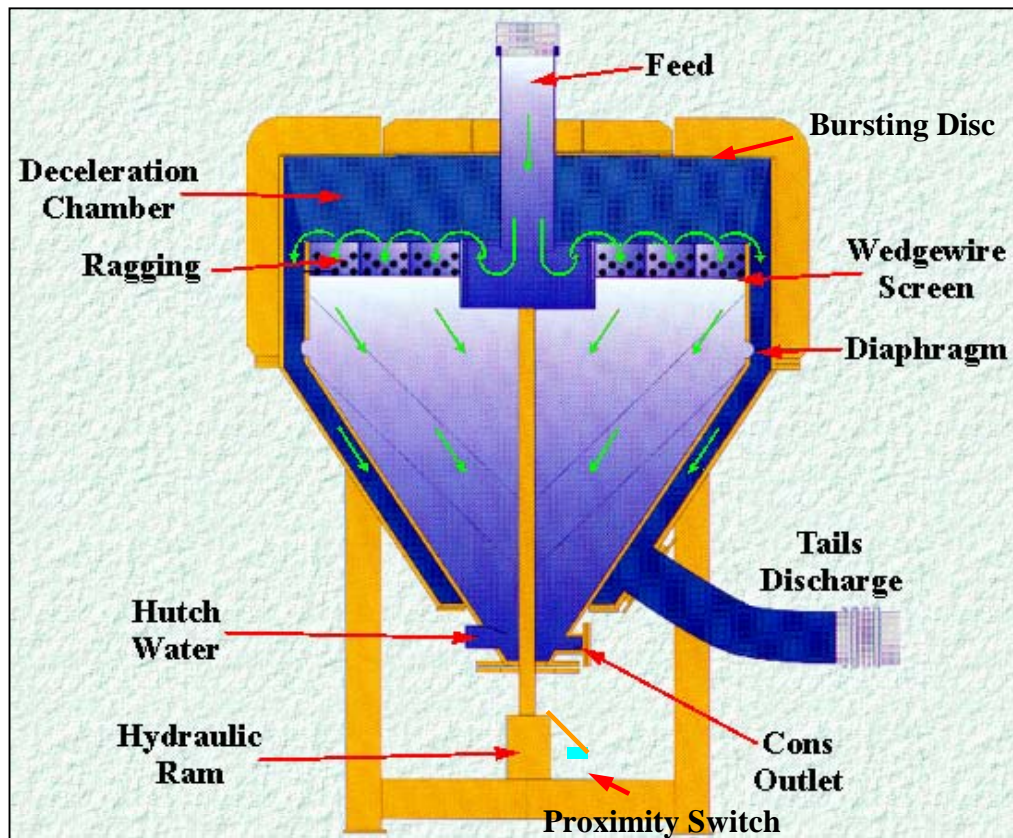


Fig 2: InLine Pressure Jig.

The IPJ produces a yield to concentrate of up 60% of new feed, however in a role of primary concentration this is generally 30% or less (typically 10%). Whilst as a secondary concentrator (cleaner) this yield may typically be as high as 60%².

The classifier undersize is the treated via a Batch Centrifugal Concentrator (BCC). Examples of low yield batch units are the InLine Spinner (ISP) manufactured by Gekko Systems in Australia and the Falcon Concentrator manufactured by Falcon Concentrators in Canada. Both units are referred to a BCC and generally will produce a yield of 0.05% and consequently of a higher grade than that produced by a continuous concentrator. The units require the feed to be pre classified with the feed sizing generally to be less than 4mm. Also they both have a 'bowl' with the sides inclined outwards with a series of 'riffles' used to capture the heavy minerals – both gold and sulphide minerals.

Generally the flotation stage is used more in the duty as a scavenger – with the primary purpose to recover any gold that may be associated with sulphide minerals. The flotation stage is generally after the BCC gravity concentration step owing to the fact that in the majority of ores tested at Gekko Systems Pty Ltd maximum gold recovery is at coarser grinds – over grinding being the single most adverse influence on gravity gold recovery. With the flotation stage, as discussed earlier in the duty of a scavenger the increased liberation of the sulphide minerals by further grinding enhances the overall recovery. The option is available to utilise the more traditional type of flotation cell, such as the Agitair, OK Cell, Denver etc with an external air supply or the Wemco cell that is self aerating.

INTENSIVE CYANIDATION

Leaching of the gold concentrate is via Intensive Cyanidation utilising the continuous InLine Leach Reactor (ILR) developed by Gekko Systems Pty Ltd. The continuous ILR currently the only such unit available – with the alternate models being offered batch units only. The ILR is based on the same principle as the laboratory bottle roll. It consists of a horizontal barrel, with internal baffles and lifters, rotating slowly on support rollers to ensure effective contact of the solids with reagents. Solids and solution are fed continuously and overflow continuously. The solution flow rate through the ILR is largely independent of the solids flow rate allowing solution grade to be controlled within fairly wide limits. Gray and Katsikaros³ have described the ILR in detail.

The ILR operates continuously in conjunction with a dedicated electro winning cell with the barren solution recycled back to the ILR to minimise reagent use. For mass balance reasons a small bleed solution is also produced carrying trace amounts of gold which can be recovered via a dedicated electro winning cell. The intensive cyanidation flow sheet shown in figure 3 includes ILR, electro winning cell and bleed solution electro winning cell.

Intensive cyanidation⁴ of a gravity concentrate typically gives leach recoveries of 90 % to over 98%. The aggressive leach conditions with high cyanide and oxidant levels are easily able to treat coarse particles and complex ores that under standard CIP/CIL conditions would give extremely poor leach performance. These conditions give high gold dissolution rates even when there is only minor exposure of the gold surface and in the presence of passivation sulphides. ILR's are successfully recovering gold from gravity concentrates containing free gold, pyrite, arsenopyrite, mixed sulphides and preg robbing carbon.

The size of the ILR is determined from the leach rates and the required throughput. Laboratory tests have proven to be very reliable in predicting full scale performance. The leached solids are dewatered continuously, washed if necessary, then transferred to the tailing storage or treatment facility. Dewatering is carried out using a combination of cones, screens and cyclones to take full advantage of the coarse nature of the concentrate. This minimises costs in this potentially very costly process step. Flocculant is added if required to collect slimes.

The use of an ILR increases security by removing the requirement to handle gold concentrates. The design means high value concentrates are only kept in a single closed vessel with any access and sample points padlocked for security if desired. Once the solids are fed to the reactor they are inaccessible until leached.

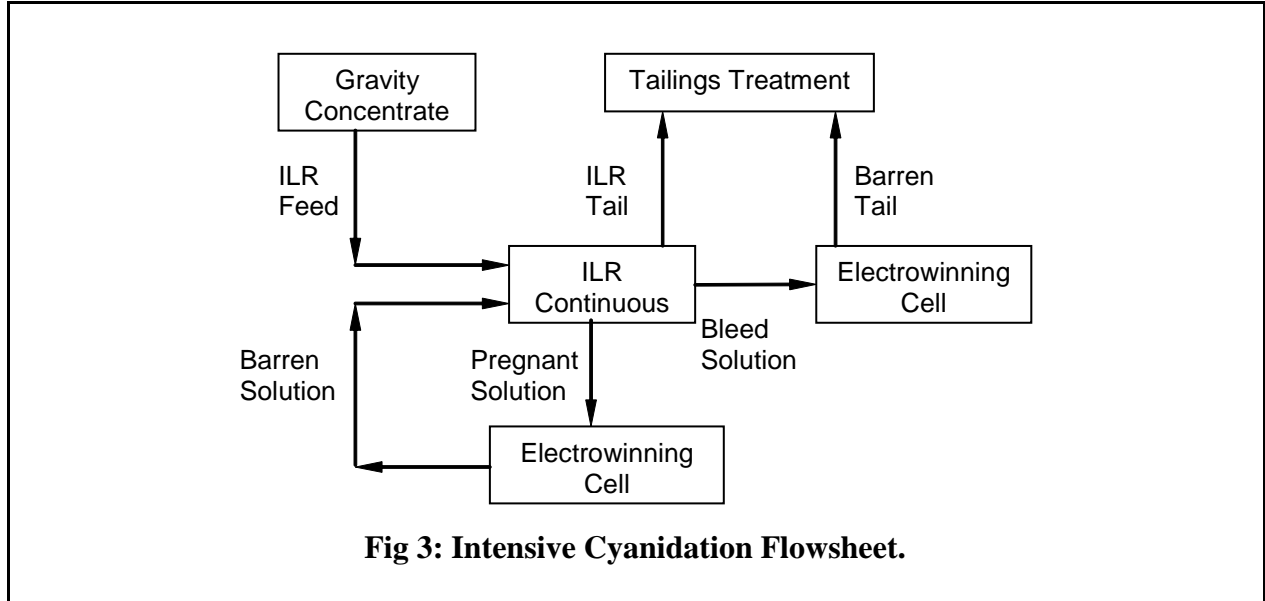


Fig 3: Intensive Cyanidation Flowsheet.

TAILINGS DISPOSAL

The detoxification of the tailings from the Intensive Cyanidation process is by the addition of liquid hydrogen peroxide. The liquid hydrogen peroxide is supplied with a concentration of 30% or 50% and may be obtained in containers of approximately 200lt, 1000lt or 20,000lts. Liquid hydrogen peroxide is readily obtained with a large commercial user being the pulp and paper industry. Hence there is usually a ready supply in developing countries. Addition of hydrogen peroxide has the added benefit of adding no additional harmful chemicals such as sodium hypochlorite to the tailings stream. In this case there are no tailing ponds containing cyanide residues.

Of increasing concern to both mining companies and society is the long term liability and risk associated with large tailings storage facilities containing cyanide residues. The gravity concentration and intensive cyanidation process will result in typically 80% to 90% of the tailings being relatively coarse with no cyanide residues contained. The ILR tails, being a much smaller volume, may also be stored in a facility that allows for encapsulation of the material to a higher standard than would normally be economic for the complete tailings stream.

The coarse grind and the sulphide mineralisation removed from the bulk of the tailing material, the potential for mobilisation of heavy metals and acid generation is significant reduced. The combination of gravity concentration/flotation results in the bulk of the tailings

residues have very low or even a negative acid producing potential – a very low risk for the organisation.

SITE EXAMPLE – SOUTH EAST ASIA

The results of testwork and the proposed processing flowsheet are discussed below – with the project being a oxidised gold ore in an area of traditional miners but no large scale operations. Historically the area has been mined by small traditional miners – often resorting to vat leaching of the ore in small open pits. The area currently is being drilled and explored by an overseas exploration company and have discovered several significant opportunities for operational gold mines.

The gold ore (Bond Work Index of 12.4 kWhr/t) was initially prepared for gravity recovery testwork and under went the tabling and progressive grind test (at 1000µm, 500 µm and 200 µm). The results in figures 4 and 5 show the increase in recovery as the yield is increased and the reduction in concentrate grade. A mass yield of 9% results in a ‘gravity only’ gold recovery of 83.9% with a concentrate grade of 77.5g/t (the head grade for the sample was 8.30g/t).

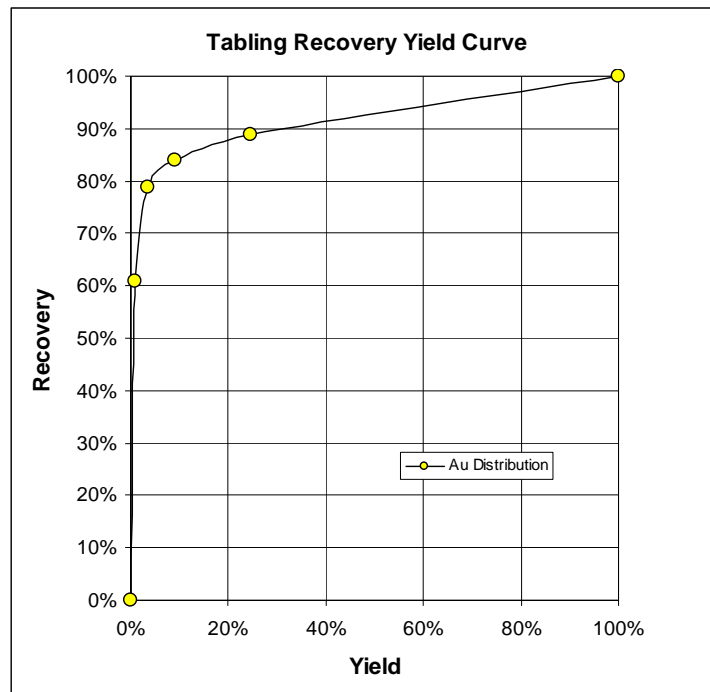


Fig 4: Gravity Recovery Yield Curve.

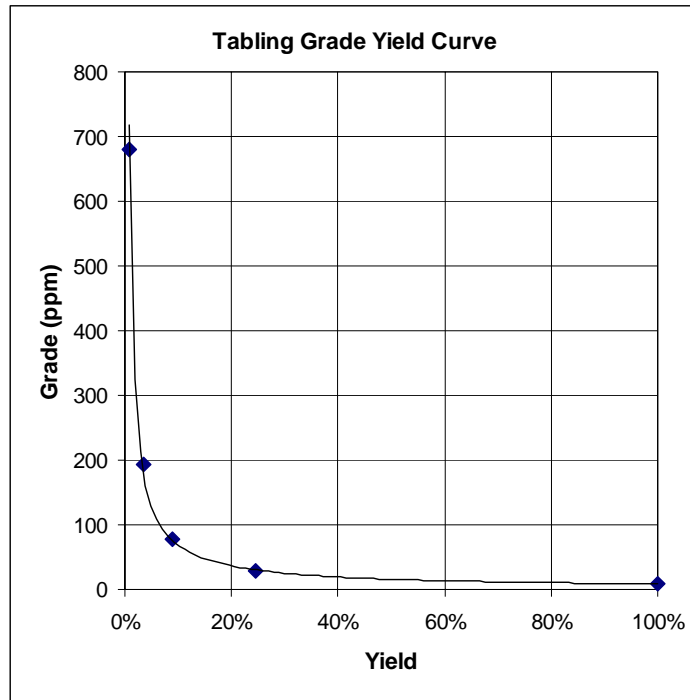


Fig 5: Gravity Grade Yield Curve.

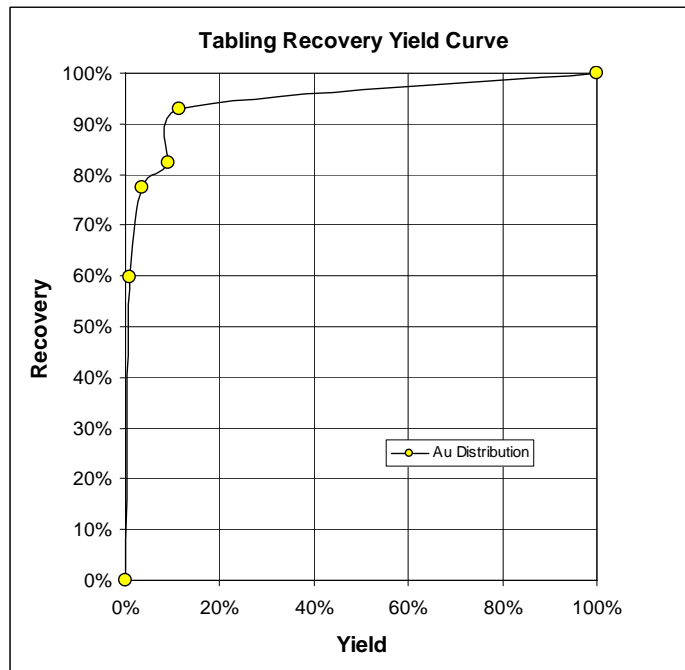


Fig 6: Gravity/Flotation Recovery Yield Curve.

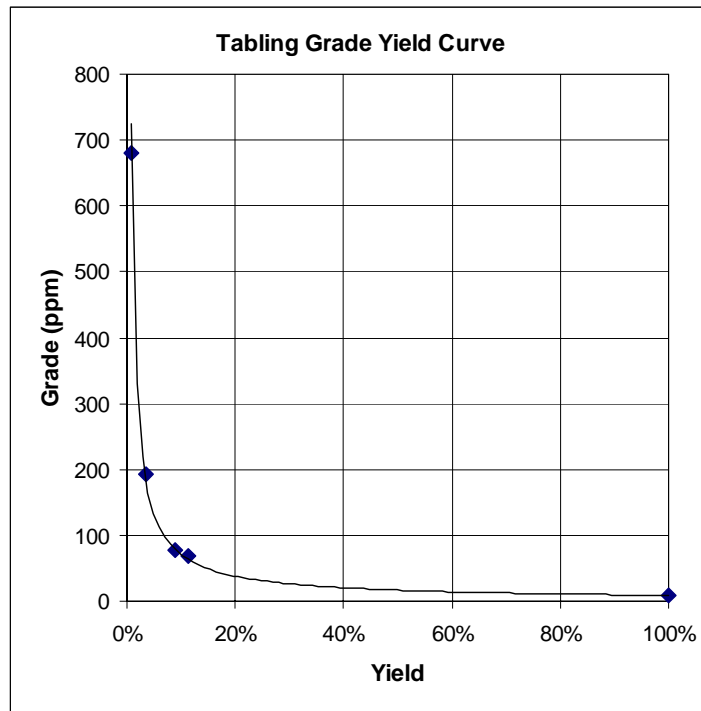


Fig 7: Gravity/Flotation Grade Yield Curve.

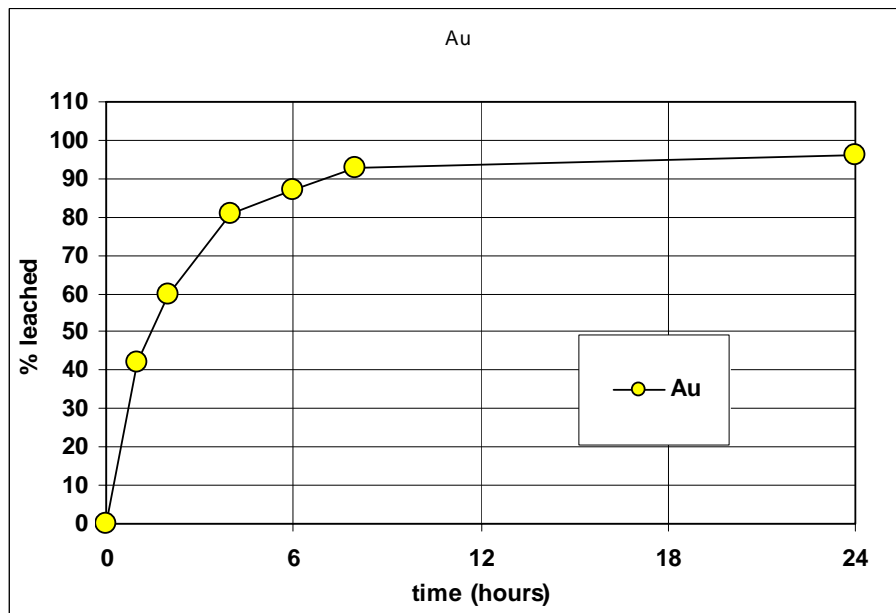


Fig 8: Intensive Cyanide Leach Recovery Curve.

To improve overall recovery a composite of the table tails and concentrate 4 underwent flotation with PAX, MIBC and CuSO₄ (flotation conc 3 only). The combined results are shown in figures 6 and 7. The flotation result yielded a mass of 2.4% with 10.5% of the gold – giving a combined overall gravity/flotation gold recovery of 92.9% into 11.4% of the feed mass.

The combined gravity/flotation concentrate gave an intensive cyanidation gold recovery to solution of 92.9% after 8 hours and 95.9% after 24 hours. The results shown in figure 8 are with a cyanide concentration of 0.5% and dissolved oxygen levels of 40ppm.

The mine area is subject to high tropical rainfall and the likelihood of acid mine drainage from the ore is high. The leach residue and the gravity/flotation tailings were tested for their net acid generation. The results shown in figure 9 clearly illustrate the benefits from having a benign gravity/flotation tail; with a negative net acid generation of minus 14. Also note is the very low sulphur content in the gravity/flotation tail. The potential is to construct two separate tailings compounds – one of low cost, primarily to contain the gravity/flotation tails and a higher cost facility to contain the detoxed leach residue.

Sample	Net Acid Production Potential (NAPP)	Acid Neutralising Capacity (ANC)	Total Acid Production Potential (TAPP)	Net Acid Generation (NAG)	%S
Table/Flot Tails	-	2.6	<1.5	-14.0	<0.05
Leach Residue	239	7.6	247	333	8.11
Leach Residue (Repeat)	-	-	-	359	7.77

Fig 9: Acid Mine Drainage Potential.

The flow sheet designed for this gold ore is shown in figure 10, incorporating a combination of crushing, ball milling, classifying, continuous gravity recovery, batch centrifugal gravity recovery, flotation, intensive cyanidation and detoxification. The new feed is crushed to minus 9mm prior to feeding into the Ball Mill, the Ball Mill discharge is pumped to the cyclone with a cut point of 200µm. Cyclone underflow under gravity, feeds to a IPJ1500 with the tails being recycled to the Ball Mill feed whilst a concentrate yield of 30% is fed to an IPJ1000 operating as a cleaner. The IPJ1000 tails is recycled to the cyclone feed whilst the concentrate – yielding approximately 10% of the new mill feed is fed to the ILR3000CA. The cyclone overflow – with 90% of the new feed mass is first directed to a SB750 Falcon Concentrator with the tails to a flotation bank. The low yield concentrates are both leached in the ILR3000CA whilst the now benign tailings are stored in a tailings dam. The leach residue from the ILR3000CA undergoes detoxification with hydrogen peroxide and discharged to a separate tailings dam.

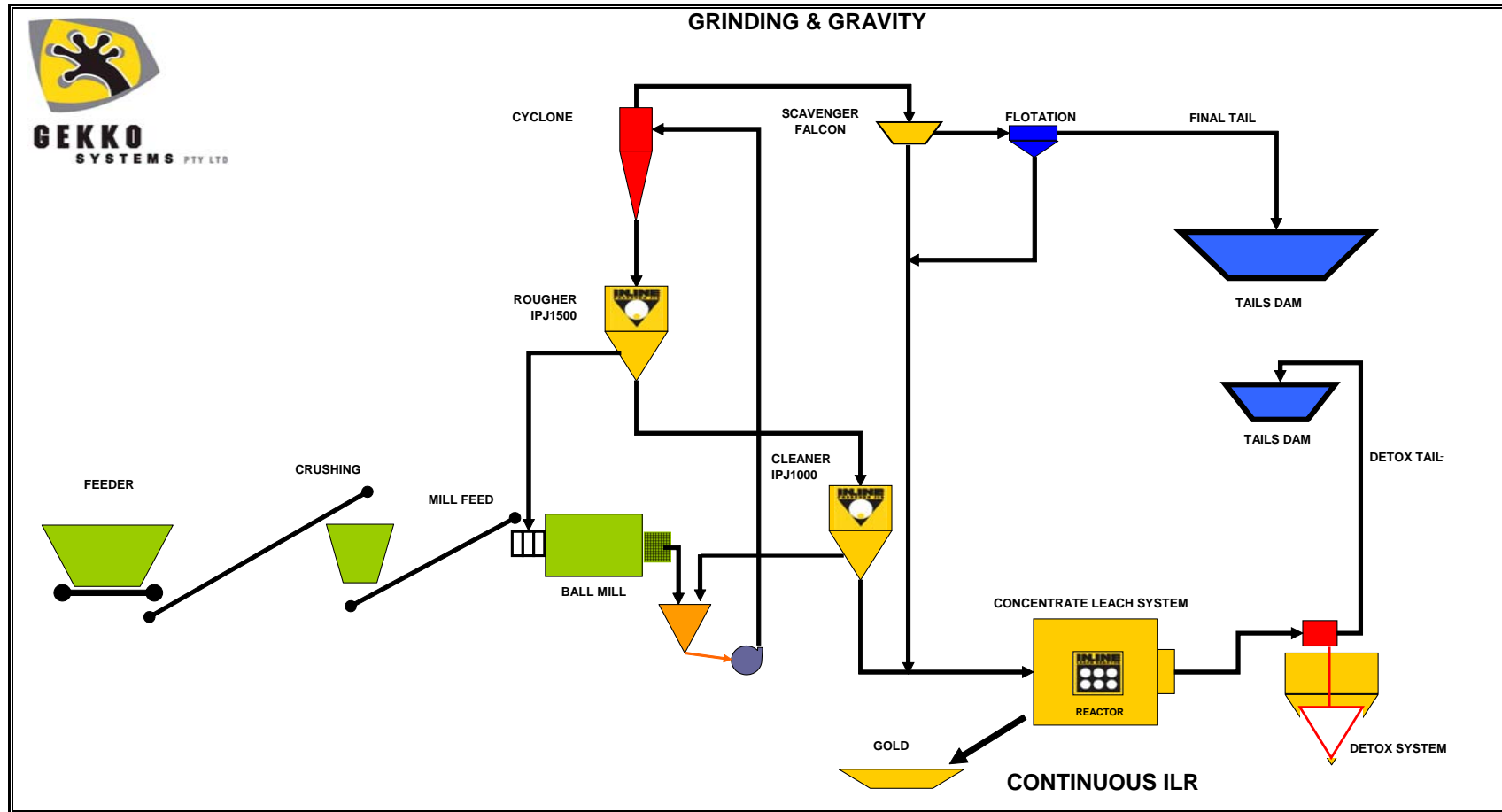


Fig 10: Flow sheet.

SUMMARY

The innovative flow sheet outlined above has the opportunity to unlock access to gold ore bodies in areas where environmental and or political factors have until now precluded access. There is also the opportunity to ‘stage’ develop an ore body by operating the ‘minimalist’ flow sheet – with minimal capital cost. The reduction in lead time, footprint, cyanide consumption, containment ponds, and energy consumption clearly have significant impact on capital, operating and environmental costs.

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