



# Application of ENTERPRISE OPTIMISATION considering Green Gold Technologies Pte Ltd.'s ReCYN™ process

Applied to

Assets Owned and Operated by



**PT Agincourt Resources** 

Authors

Gerald Whittle gerald@whittleconsulting.com.au

Jason Pan jason@whittleconsulting.com.au

Whittle Consulting

Revision v1.1, 1<sup>st</sup> June 2018

 Whittle Consulting Pty Ltd

 T: +61 3 9898 1755 | F: +61 3 9898 1855

 A: Suite 8, 660 Canterbury Road, Surrey Hills, Victoria 3127, Australia

 E: info@whittleconsulting.com.au | W: whittleconsulting.com.au

 ABN: 71 086 470 457

# **EXECUTIVE SUMMARY**

The ReCYN<sup>™</sup> process ('ReCYN') by Green Gold Technologies Pte Ltd ('Greengold' / GGT) is a worldleading approach in cyanide recovery, metal recovery and tailings detoxification. Based on an innovative resin-bead absorbent, ReCYN<sup>™</sup> reduces cyanide consumption by 50%, capturing free cyanide from the plant tailings and recycling it back into the leach circuit while recovering metal complexes and making them available for sale. In the process, ReCYN<sup>™</sup> detoxifies the tailings stream and guarantees 100%-compliant clean water discharge. ReCYN<sup>™</sup> is efficient, economical and environmentally friendly. It is the only cost-saving innovation of its kind that is generating results today on an industrial scale.

Whittle Consulting Pty Ltd (WCPL) worked with PT Agincourt Resources (PTAR) to assess the value benefits of incorporating the ReCYN<sup>™</sup> process into the existing processing plant at the Martabe gold / silver operation in Sumatra, Indonesia. This was the final stage of a wide-ranging Enterprise Optimisation (EO) suite of work with PTAR on the Martabe operation, based on the 2016 reserves. Subsequent to this EO work, further drilling and exploration work has led to a substantial uplift in both reserves ounces and mine life at Martabe.

A fully optimised comparable case using the current Martabe processing setup (without the ReCYN<sup>™</sup> process) was developed. This utilised strategic pit shell designs developed using Dassault Systèmes' GEOVIA Whittle<sup>™</sup> pit optimisation software (GEOVIA Whittle<sup>™</sup>) and optimised in Whittle Consulting's Prober<sup>®</sup> software (completed as *'Base Case Optimised Plan'*). This is already a highly optimised Base Case, calibrated using Whittle Consulting's EO philosophy and techniques. This includes Activity-Based Costing (ABC) and utilises Theory of Constraints (TOC), on Pits and Phase optimisation in GEOVIA Whittle<sup>™</sup>. Whittle Consulting's proprietary software, Prober<sup>®</sup>, was then employed to calibrate schedule, cut-off, stockpile and blending to maximise net value through the constraint of the operation – in this case, Mill hours (as a proxy for power usage). This approach allows valuation on true constraints, rather than processed tonnes. This means ore feed tonnage realistically flexes, depending on the grind size used and the hardness of the ore feed.

The notional value implications of incorporating the ReCYN<sup>™</sup> process into these base case designs and schedule was then calculated. This was demonstrated using a four-stage static analysis on the schedule outcomes (i.e. no change to mining schedule, cutoff or destination), revaluing progressively on:

- Recovering Cyanide and re-using in CIL;
- Reducing Detoxification costs;
- Intensifying Cyanide usage to increase Silver recovery; and
- The ReCYN<sup>™</sup> ability to creating a new copper cathode product via electrowinning

To demonstrate the benefit of conducting a full Whittle Consulting Enterprise Optimisation for a material change such as adding ReCYN<sup>TM</sup>, an end-to-end full re-optimisation using the ReCYN<sup>TM</sup> outcome was conducted. New strategic pit shell designs were developed for all four main sites at Martabe and were then optimised in WCPL's Prober<sup>®</sup> optimiser as '*ReCYN<sup>TM</sup> Optimised Plan.*' Included in the ReCYN<sup>TM</sup> NPV calculations for both the initial '*Static Analysis*' step and the '*ReCYN<sup>TM</sup> Optimised Plan.*' Included *Plan'* is a US\$5M 2018 capex charge for the installation of the ReCYN<sup>TM</sup> treatment plant and all opex as appropriate for each step. This does not include a royalty to Greengold that may be applicable at other projects. All results were optimised with Gold at US\$1,300 / ounce, Silver at US\$19 / ounce and

US\$6,061 / tonnes per payable tonne of Copper (97% of recovered Copper assumed payable; price based on US\$2.75/lb).

The following two pages shows the NPV uplift across these steps (Figure 1) and then in Table 1, some key metrics from the two Prober® bookend outcome and iteratively, the 'Static Analysis' steps inbetween.





Figure 1: NPV Movement between Base Case and ReCYN™ full Optimisations

NB: Y-Axis is truncated for confidentiality and emphasis on relative step NPV movement inclusive of the US\$5M capex



Table 1: Metrics for the key Whittle Consulting runs and iterative static analysis of ReCYN™ benefits on the Base Case schedule

	Full Drobor	Iterative Static Analysis on base Case Optimised					
	FOIL Prober	STEP 1				Full Prober	
	Case	CN Recovery	STEP 2	STEP 3	STEP 4	EO - ReCYN™	Overall Delta
	Ontimicad	(+ ReCYN™	Detox Savings	Silver Uplift	Copper	Optimised	
LOM Outcomes	Optimised	Capex)					
Cumulative NPV delta from Base Case Optimised (\$US M)	n/a	+\$24.4M	+\$48.4M	+\$60.3M	+\$73.4M	+\$126.9M	+\$126.9M
Year of Max NPV	2028	2028	2028	2028	2028	2030	+2 years
Gold Produced (MOz)	2.8	2.8	2.8	2.8	2.8	3.1	+10.0%
Silver Produced (MOz)	17.0	17.0	17.0	18.7	18.7	21.6	+26.7%
Copper Cathode product (t)	-	-	-	-	4,652	7,905	+7.9kt
ROM & Stockpile Tonnes Processed (Mt)	64.0					76.0	+18.9%
Average Cyanide-soluble copper (ppm)	85.86					122.33	

Iterative Static Analysis on Base Case Optimised

NB: Enterprise Optimisation work was based on 2016 reserves. Ounces and mine life at Martabe have subsequently been extended with resources and reserves updates

The redesigned '*ReCYN™ Optimised Plan*' Run pits resulted in a much larger LOM ore feed, including significant increases to Ramba Joring and Tor Uluala. These two sites in particular had economic shells pushing into high CuCN ore areas of these sites that were evaluated as uneconomic in the original WCPL '*Base Case Optimised Plan*' designs, with no change to the ore class allowed for consideration (Measured & Indicated at all four sites with the addition of Inferred only at Ramba Joring and Tor Uluala).

This modelled ReCYN<sup>™</sup> process allowed a more intense use of Cyanide at the Martabe Carbon-In-Leach (CIL), which in turn increased silver recovery. No change to base case gold recovery was incorporated in any of the ReCYN<sup>™</sup> results, despite the more intensive cyanide use.

The equipment also allows a portion of the cyanide consumed in the process to be recovered and reused, thereby reducing new cyanide costs. In addition, a copper cathode product could be created and sold via Solvent Extraction and Electrowinning (SXEW), detoxification costs could be significantly reduced – as well as removing the need for a restriction on the average Cyanide-Soluble Copper (CuCN) in the annual CIL feed.

Scheduling in these new pits in the '*ReCYN™ Optimised Plan*' run adds 26Mt to the resource and resulted in 12Mt more tonnes of processed material. Maximum NPV was a US\$127M increase on the comparison '*Base Case Optimised Plan*' run. The cash flow uplift is particularly notable in 2019, due to cash flow at Ramba Joring being brought forward. In addition, the larger economic pit shapes extend the economic life of the operation by two further years.

Based on the current assumptions, for a small capital investment (US\$5M), the installation of the ReCYN<sup>™</sup> technology would provide Agincourt Resources a material NPV uplift. The outcome would see a significant increase in silver recovery, a reduction in cyanide consumption and costs, as well as enabling US\$45M+ in new copper product revenue. This is even before considering any potential gold recovery uplift that may arise from the ability to use cyanide more intensively.

The annual cash flow across the two Prober<sup>®</sup> bookend cases follows overleaf, as well as comparison Gold, Silver and Copper production.







Figure 4: Comparison Silver Production of key ReCYN™ runs





Figure 5: Comparison Copper Production of key ReCYN™ runs



# Figure 3: Comparison Gold Production of key ReCYN™ runs

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# **1** INTRODUCTION

# **1.1 PURPOSE**

Whittle Consulting (WCPL) worked with PT Agincourt Resources (PTAR) to assess the value benefits of incorporating the ReCYN<sup>™</sup> process into the existing processing plant at the Martabe operation in Sumatra, Indonesia, as a final stage of an Enterprise Optimisation (EO) suite of work.

# **1.2 RECYN<sup>™</sup> INTRODUCTION**

The "ReCYN<sup>™</sup>"</sup> process is the name given to a specialist technology from Green Gold Technologies Pte Ltd., for the recovery of cyanide and dissolved metals from precious metal plant process streams. The process is based on the use of a functionalised resin bead, pre-treated to allow the dual duty of recovering free and complexed cyanide ions from solution with a high degree of efficiency. The GGT Treatment Plant is custom-designed for each operation to match the various solution chemistries and throughputs. The two areas of cyanide recovery and metal detoxification are balanced to achieve the desired compliance levels. Equally applicable to slurries and solutions, the process is technically and economically superior to all others currently available for the detoxification of gold plant tailings.

# 1.3 WHITTLE CONSULTING OPTIMISATION METHODOLOGY

The full benefit of ReCYN<sup>™</sup> technology cannot be assessed in isolation. Even a small change in one part of a mining operation affects, to a greater or lesser extent, the optimal operation of all other parts of the enterprise (cut-off grades, stockpiling, plant settings etc.). Therefore, a whole-system approach is required to fully estimate the effect of such an implementation. The approach must also take into account the time-value of money. The most common approach is to discount future cash flows to produce a Net Present Value (NPV) that can be directly compared between different cases.

Whittle Consulting's enterprise optimisation methodology is used for this purpose.

## 1.3.1 Whittle Consulting

Whittle Consulting are specialists in Integrated Strategic Planning for the mining industry. A team of highly experienced industry specialists, they are dedicated to adding value to mining businesses.

With technical expertise in a range of disciplines including geology, mining engineering, metallurgy, research, mathematics, computing, finance, operational/ financial modelling and analysis, Whittle Consulting has a thorough appreciation of practical, organisational and contextual reality of mining operations. As experts in embracing and harnessing complexity, Whittle Consulting is not bound by traditional thinking. By challenging existing paradigms and conventional wisdom, the real potential of a mining business is revealed.

Since 1999, Whittle Consulting has conducted over 150 Whittle Enterprise Optimisation studies around the world. These have repeatedly demonstrated that the comprehensive application of Whittle Integrated Strategic Planning and the concepts from the highly regarded Money Mining & Sustainability Seminar improves the economics of a mining project or operation by 15%, and in many cases substantially more. These results are achieved even after conventional mining optimisation techniques have already been applied.

Whittle Consulting operates worldwide and is represented in Australia, United Kingdom, United States of America, Canada, South Africa, Chile, Peru and Indonesia.



#### 1.3.2 Modelling

The whole mining operation from Resource to Market is modelled. While the pit and phase shapes are created in GEOVIA Whittle<sup>TM</sup>, a software package from Dassault Systèmes, the rest of the enterprise is modelled using Prober<sup>®</sup>, a proprietary optimisation algorithm that optimises for NPV. The role of the Prober-user is to *describe* the mining system mathematically and then let the optimiser produce the best mining and processing schedule. This is in opposition to *telling* the software how to schedule a mining system, as is the traditional approach.

Enterprise Optimisation (EO) is a methodology for maximising the life of mine value of mining and mineral processing assets. The methodology uses net present value (NPV) as the metric that is maximised. The technique involves simultaneous optimisation of the entire mining value chain from the mineral resource through to the end product market. EO employs the economic principles of the Theory of Constraints (TOC) and Activity Based Costing (ABC) and utilises the proprietary Prober<sup>®</sup> E software of Whittle Consulting.

EO involves simultaneously optimising all ten steps in the value chain shown in Figure 6.



Figure 6: Mining and mineral processing value chain

A full Whittle Consulting optimisation may include iteration between pit design in GEOVIA Whittle™ and rest-of-system optimisation in Prober<sup>®</sup>.

Whittle Consulting's Enterprise Optimisation approach has been founded on the following principles:

#### 1.3.3 Time Value of Money

Any methodology for optimising a mining operation, which may have a life of several decades, must take into account the time-value of money. Prober<sup>®</sup>, Whittle Consulting's proprietary algorithm for Enterprise Optimisation, discounts future cash-flows to produce a Net Present Value (NPV) that can be directly compared between different scenarios.

#### **1.3.4** Theory of Constraints

The Theory of Constraints (TOC) was introduced as a management philosophy by Eliyahu M. Goldratt in his 1984 book *The Goal*. It draws upon System Dynamics, Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM) developed in the mid-20<sup>th</sup> century. The central viewpoint of TOC is that a system managed towards a certain goal (e.g. a company managed to produce money) is limited in maximising its output of that goal by constraints. If constraints can be



relaxed, then the throughput in the system can be increased and a greater amount of the objective unit can be produced.

There may be many constraints in a system but of these only a small number, or as few as one, are the primary constraints or bottlenecks. These control the overall throughput through the system.

Common constraints in mining enterprises are plant capacity limits, plant concentration limits, mining tonnage limits, vertical rate of advance limits, stockpile or dump size limits, power and water supply limits, product specifications and pollutant limits.

In an optimised system, the bottleneck should be the constraint that the system operator *has the least ability to change*. This is most commonly the most capital-intensive part of the operation (e.g. an expensive piece of equipment such as a ball mill); though in some cases it may also be an externally imposed constraint (e.g. a certain product specification, a regulatory constraint, or a resource supply limitation).

If an Enterprise Optimisation finds that the bottleneck limiting the overall generation of cash by the system is relatively simple or inexpensive to alleviate, then that action should be taken. Cash generated by the operation will then increase until another constraint becomes the bottleneck.

#### 1.3.5 Activity Based Costing

Any model is only as good as its inputs, as per the well-known 'Garbage In, Garbage Out' adage. In Enterprise Optimisation, it is essential that all resource consumption costs are assigned to the activity that consumes that resource. This is called Activity Based Costing (ABC).

Furthermore, it is essential that all costs are split into variable (attributable) costs, incurred per unit of resource consumed, and period costs, incurred as a fixed cost to keep a process (e.g. item of equipment) operating over a period of time.

#### 1.3.6 Software

A mining enterprise has many elements and relationships between these elements that specialised software is required to implement modelling and Optimisation. Whittle Consulting utilises Prober<sup>®</sup>, a proprietary optimisation algorithm that has been continually developed by Jeff Whittle for over two decades.

Prober<sup>®</sup> is used to model the mining and processing operation from material inputs to market. This is then optimised for NPV, producing a schedule showing the path of all cash-flows and materials through the system over the life of the mine.

Prober<sup>®</sup> receives material inputs with specified sequence rules (e.g. start-afters, minimum leads and lags). However, it is not practical to provide block models (which often contain millions of blocks) directly to Prober<sup>®</sup> without prior aggregation of alike material (rock type, grade/value range, processing options).

In open-pit operations the mining shape selection (i.e. pits and phases) are sized using Geovia Whittle pit optimisation software. This utilises the Lerchs-Grossman algorithm to determine optimum pit size and shape. Whittle Consulting uses specific techniques to integrate Geovia Whittle with the Prober<sup>®</sup> schedule optimiser, including iteration between the two optimisers if necessary. Underground operations with alternate mining shapes or sequences (prepared by a mining engineer) can be evaluated using a similar approach.



#### **1.3.7** Non-Financial Goals

Prober<sup>®</sup> is only able to optimise for NPV; however non-financial objectives can be incorporated if they can be quantified. This may take the form of constraints on the operation (e.g. on tailings produced, dust disturbance or water consumption). The second approach is to produce scenarios that allow the trade-offs between socio-economic factors and NPV to be examined.

Whittle Consulting has partnered with the University of Queensland's Sustainable Minerals Institute to integrate Enterprise Optimisation with Sustainable Operations (SUSOP), taking into account Manufactured, Social, Human and Natural Capital.

#### 1.3.8 Uncertainty

All data inputs to Prober<sup>®</sup> have an associated uncertainty. Uncertainty cannot be incorporated into Prober<sup>®</sup> directly, so risk is typically quantified using a scenario-based approach.

#### **1.4 TERMINOLOGY**

Cut-off Grade <i>or</i> Cut-off Value	The material grade or material dollar value that differentiates material sent to one processing path to material sent to another processing path. The cut - off most commonly discussed is the cut-off between ore and waste. However, a cut-off exists for every decision point in the system. A cut-off value expressed as dollars per unit of bottleneck capacity of a
	system, can provide better material allocation decisions. However, this becomes overly complex in multi-mineral, multi-path processing systems that differently favour or penalise each mineral.
Enterprise Optimisation (EO)	An optimisation of an enterprise where the whole system (within control of the enterprise) is modelled. Contrast to an optimisation that only models a sub-system in isolation and ignores the effect upon the rest of the system.
Life of Mine (LOM)	The time period that the mine operates.
Ore	Material that is sent to the processing plant or is stockpiled so that it can be sent later to the processing plant. There is not a fixed mineral cut-off grade; instead the cut-off characteristics of ore and waste vary by material type and availability over the LOM.
Period Cost	A fixed cost associated with a certain process, over a specified period of time.
Variable Cost	A cost directly attributable per unit of consumption of a resource used by the system.



# **2** THE RECYN<sup>™</sup> PROCESS

The "ReCYN" process is the name given to a specialist technology, which is being offered for the recovery of cyanide and dissolved metals from precious metal plant process streams. The process is based on the use of a functionalised resin bead, pre-treated to allow the dual duty of recovering free and complexed cyanide ions from solution with a high degree of efficiency. The GGT Treatment Plant is custom-designed for each operation to match the various solution chemistries and throughputs. The two areas of cyanide recovery and metal detoxification are balanced to achieve the desired compliance levels. Equally applicable to slurries and solutions, the process is technically and economically superior to all others currently available for the detoxification of gold plant tailings.

The ReCYN<sup>™</sup> technology can provide a significant opportunity to reduce operating costs and at the same time improve environmental performance. The resin-based process offers a proven method for achieving virtually complete removal and efficient recovery of cyanide, dissolved base metals and precious metals from gold plant process streams.

For most tailings treatment applications, significant overall net revenue will be achieved. The cost of cyanide recovered is usually less than 50% of the cost of new cyanide and there are no expensive detox processes.

In addition to its applications in cyanide recovery and tailings detoxification, Green Gold Technologies Pte Ltd has also demonstrated major opportunities as an alternative to carbon in the main recovery section of precious metal plants.

The ReCYN<sup>™</sup> Process is owned by Green Gold Technologies Pte Ltd, a Singapore based company. Green Gold Technologies Pte Ltd has an exclusive engineering agreement with PT Green Gold Engineering (GGE), an Indonesian based company, for the key engineering aspects of the ReCYN<sup>™</sup> Process. GGE has full in-house capability for both design and construction.

#### **2.1** FLOWSHEET

- Eluted resin is added to the CIL tails and flows co-current through a series of adsorption tanks.
   A counter-current system is employed if very low residual values are required such as for direct river discharge from the Tailings Storage Facility (TSF).
- Loaded resin is separated from the ReCYN<sup>™</sup> plant tails and transferred continuously to the elution section of the plant.
- The loaded resin is split between the cyanide and metal elution columns with the ratio of flows dependent on the solution values.
- Metal elution and cyanide elution occur in separate continuous columns at ambient temperature.
- Metal recovery typically involves either electrowinning or precipitation to remove copper and other metals.
- Cyanide recovery involves volatilization and scrubbing to form a concentrated cyanide solution that can be returned directly to the leach and elution circuits.
- $\circ$   $\;$  The detoxified slurry is discharged to the tailings dam.
- A separate ReCYN<sup>™</sup> solution treatment circuit can be added to treat Tailings Storage Facility overflow for river discharge.

This process flow is visualised in Figure 7 overleaf:







## 2.2 Key Superiority Aspects of the ReCYN<sup>™</sup> Process

#### HIGH EFFICIENCY

• High recovery efficiencies of free and metal complexed cyanides, toxic metals and precious metals.

#### RESISTANCE TO POISONING

• Investigations have shown the resin to be barely affected by organic foulants or inorganic poisons, even after long term usage.

#### LOW ABRASION LOSSES

• Operations have shown that the mechanical strength of the resin results in low abrasion losses; an order of magnitude lower than carbon.

#### STABLE OPERATION

• Temperature variations and the presence of slurry solids have negligible effect on performance.

#### SIMPLE ELUTION

• The resin can be effectively eluted at ambient temperatures and at atmospheric pressure. Elevated temperature and pressure vessels are not required.



#### EASE OF HANDLING

• The close sizing and regular shape of the resin beads assist selection of screens and reproducible screening performance.

#### ECONOMIC CYANIDE RECOVERY

• Recovered cyanide costs 50% less than new cyanide; and the process eliminates detox requirement.

#### IMPROVED METAL RECOVERY

• The lower cost of cyanide recycle allows higher cyanide levels to be kept in the leach circuit, thereby potentially increasing silver recovery.

#### **2.3 PROVING THE TECHNOLOGY**

The steps used in the ReCYN<sup>™</sup> Process have been developed through extensive research and development programs over a 30-year period. A combination of laboratory test work and continuous pilot trials have provided detailed knowledge of the resin's capabilities and performance over a wide range of ore types.

#### 2.3.1 Pilot Plants

Several continuous pilot plant campaigns have been completed in Australia and North America, applying the process directly to effluent streams of operating gold mines.

Two pilot plants were used, each with a capacity of 10m<sup>3</sup>/day of pulp or solution. The plants were designed to closely represent the flowsheets of industrial operations. Features of the plants include:

- Multi-stage contactors
- Counter-current flow of resin and slurry
- Staged elution of loaded resin for metals and cyanide
- Cyanide recovery system.

Each campaign demonstrated the resin's high efficiency in recovering cyanide and metals. Typical pilot plant results are shown in Table 2 below.

SPECIES	Feed Slurry (ppm)	Treated Slurry (ppm)	Recovery (%)
CnFree	159	0.12	99.9
CNWAD	159	0.12	99.9
CNTotal	205	0.23	99.9
Copper	45	0.13	99.7

Table 2: Typical Cy	yanide and Copper	Recoveries from	ReCYN™ Pilot Plant
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#### 2.3.2 Commercial Operations

Commercially, the technology is proving itself effective on the job:

• Currently, an integrated full-scale operation at the Mirah gold/silver project in Indonesia has demonstrated the commercial viability of the technology. Mirah, in Central Kalimantan, Indonesia, has operated with ReCYN<sup>™</sup> for more than two years.



- The Mirah resin plant treats slurry from the CIL plant in a four-stage reactor circuit. The recycle circuit is particularly beneficial due to the high cyanide levels (+1000ppm CN) required to ensure good silver recovery. Since commissioning the resin plant in May 2015, no additional detox has been required to meet compliance levels and an average of 1t/day of NaCN is recycled directly to the leach plant.
- A second larger ReCYN<sup>™</sup> plant is being constructed at the Mt. Muro project.

#### 2.3.3 Laboratory Test work

The following table shows typical results from testing a gold plant slurry containing soluble copper. Many ore types have been tested.

SPECIES	Feed Slurry (ppm)	Treated Slurry (ppm)
Au	0.91	<0.01
Ag	0.85	<0.01
Cu	621	0.75
Zn	9.07	0.1
Fe	10.7	0.3
As	0.5	<0.1
Cd	0.12	<0.01
Cr	7.8	<0.005
Со	5.7	<0.004
Mn	0.15	<0.001
Мо	0.99	0.27
Ni	0.38	0.04
Pb	0.5	<0.01
Sb	0.5	<0.1
CNTotal	1060	0.3

Table 3: Typical Results from ReCYN™ Batch Adsorption Tests



# **3 MODEL AND SETTINGS**

All mining operations are different and any benefits from using ReCYN<sup>M</sup> will vary from case to case. As a subset of Whittle Consulting's Enterprise Optimisation consulting work with PT Agincourt Resources, Whittle Consulting assessed ReCYN<sup>M</sup> against a comparable fully-optimised '*Base Case Optimised Plan*' of current operations. The aim was to provide an indication of the magnitude of financial benefit.

# **3.1 GLOBAL SETTINGS**

All revenue and costs were priced in US Dollars. Given the nature of this document, only selected cost items from the base case and ReCYN<sup>™</sup> approach will be discussed.

All cost and physical modelling for the ReCYN<sup>™</sup> process were based on emails and discussions with Mr. Darryn McClelland, Deputy GM Operations at Agincourt Resources.

## **3.2 Ore Body**

The mine tested was the Martabe Operations. This operation is situated on the western side of Sumatra Island, in the North Sumatra province in the sub-district of Batangtoru, Indonesia. The mine operational area is centred on the Purnama open-cut mine. This is a conventional carbon-in-leach (CIL) gold ore processing plant with capacity of c5.5 million tonnes of ore per annum. Several neighbouring deposits – Barani, Ramba Joring and Tor Uluala – were also included in both the *'Base Case Optimised Plan'* and the *'ReCYN*<sup>TM</sup> *Optimised Plan.'* 

# 3.3 ACTIVITY-BASED COSTING (ABC) APPROACH

#### 3.3.1 Revenue

All GEOVIA Whittle<sup>™</sup> and Prober<sup>®</sup> modelling was undertaken with Gold at US\$1,300 / recovered ounce, Silver at US\$19 / recovered ounce and, for the ReCYN<sup>™</sup> work where a copper product is made, US\$6,061 / tonnes per payable tonne of Copper (97% of recovered Copper assumed payable after sales expenses etc; price based on US\$2.75/lb).

#### 3.3.2 Cyanide Physicals and Cost Modelling

The use of Cyanide, by both the current plant and a more intensive usage in a ReCYN<sup>™</sup> process scenario to increase silver recovery, was modelled by calculating consumption across four stages:

- Cyanide consumed by copper, calculated based on cyanide-soluble copper ppm in the CIL Feed, and this is available for recovery by the ReCYN<sup>™</sup> process
- Cyanide consumed by Sulphide Sulphur, calculated based on SXS % in the CIL Feed, and this is **NOT** available for recovery by the ReCYN<sup>™</sup> process
- Free Cyanide in CIL Tail, calculated based on tonnage, and this is available for recovery by the ReCYN<sup>™</sup> process
- Free Cyanide lost in Elution circuit, calculated based on tonnage, and this is a direct loss from the system, **NOT** recoverable by the ReCYN<sup>™</sup> process

This free cyanide in CIL tail usage had a more intensive application in the two runs with ReCYN<sup>™</sup> schedules. This was used to achieve a reduction in silver in the tailings of 1g/t and consequently heightened recovery, as is discussed overleaf.



100% of cyanide usage is required to be purchased in the 'Base Case Optimised Plan' run, with only the shortfall after ReCYN<sup>™</sup> recovery in the 'ReCYN<sup>™</sup> Optimised Plan' run.

85% of consumed cyanide was assumed to be recovered of the portion consumed by copper (first bullet point in the above list) and free cyanide in CIL tail (third bullet point). This recovery cost was modelled as US\$1,050/T Cyanide recovered.

#### 3.3.3 Copper Modelling

The cost of copper recovery used was US\$1,037 per copper tonnes recovered. 97% of recovered tonnes was assumed to be payable to model sales expenses, and a market price of US\$6,061/t based on US\$2.75/lb.

### 3.3.4 Detox cost modelling

The 'Base Case Optimised Plan' detoxification variable rate based on cyanide-soluble copper content in the CIL Feed was scaled down in the ReCYN<sup>™</sup> modelling runs. In cases where the ore block or parcel of ore had a cyanide-soluble copper ppm of >=50ppm, 20% of this 'Base Case Optimised Plan' detox rate was applied in ReCYN<sup>™</sup> optimisation. If less than 50ppm, no variable detox costs were applied in ReCYN<sup>™</sup> optimisation.

### 3.3.5 Capex

A capex cost of US\$5M for the addition of the equipment needed for the ReCYN™ process, incurred in 2018, was used in ReCYN<sup>™</sup> runs. This does not include a royalty to Greengold that may be applicable to other projects. The ReCYN<sup>™</sup> process was assumed to be available for all 2018 feed, despite the capex being incurred in the same year.

# **3.4 PHYSICALS MODELLING AND CONSTRAINTS**

## 3.4.1 Mining Physical Adjustments and Limits

Only Measured and Indicated material for Purnama and Barani sites were included, with the addition of Inferred only for the newer sites, Ramba Joring and Tor Uluala.

#### 3.4.2 Processing Physical Adjustments and Limits

'Base Case Optimised Plan' gold and silver recovery (before silver uplift due to ReCYN<sup>™</sup>) were derived from the various block-by-block recovery fields, used currently by PTAR in their resource models. With the increase in intensity at the CIL tail, PTAR identified the potential for a 1g/t reduction in silver in the tails. This equates to an uplift in recovery equivalent to:

Post ReCYN<sup>™</sup> Process Silver recovery (0-1%) = Original Silver recovery (0-1%) + 1 ÷ Silver Feed Grade

Given for combinations of grades and recoveries (particularly lower grades), this calculation would produce an adjusted recovery over 100%. A three-tier approach was implemented to practically model this with sensible outcomes. This caps maximum uplift to ensure recovery does not exceed 85%, where original recovery was lower than this:

- If the original Silver recovery in the resource model was greater than 85%, ReCYN™ Silver recovery is unchanged
- If calculated ReCYN<sup>™</sup> Silver recovery after uplift would exceed 85%, the recovery after uplift used is capped at 85%
- Otherwise calculated uplift recovery as above is used.



Mill Hours, which was calculated based on throughput, was the primary bottleneck. Mill Hours were calculated based on throughput or each portion of ore based on the ore's Point Load Index (PLI) hardness, with maximum annual hours available restricted to 8,147 (93% net availability). Overall Mill feed tonnage is restricted to the annual equivalent of the volumetric throughput limit 730tph - 5.95Mt. However, due to the hours being the bottleneck, annual feed varied from circa 5.3Mt up to this 5.95Mt level, depending on the hardness of the annual ore feed.

In the 'Base Case Optimised Plan' a maximum allowable average cyanide-soluble copper ppm was set as a hard limit in the annual CIL ore feed. This was removed in the ReCYN<sup>™</sup> run.



# **4 RESULTS**

NPV is the primary measure to compare between the cases, while other impacts on pit inventories and cash flow are also documented.

The key Prober<sup>®</sup> runs here for comparison are the 'Base Case Optimised Plan' and the 'ReCYN<sup>™</sup> Optimised Plan.'

Prober<sup>®</sup> in each case was able to optimise the schedule to maximise NPV within the given mining and processing constraints for each scenario. This included mining fleet limits, individual site-by-site BCM limits and individual phase Vertical Rate of Advancement limits, Mill throughput constraints (measured in hours rather than tonnes given variety of hardness of throughput) and output constraints (e.g. gold room capacity).

The core run aims were as follows:

• *'Base Case Optimised Plan'*: A comparable run to the ReCYN<sup>™</sup> runs using the base case WCPL pit designs, ABC costing and limits. This was fully optimised in all extents under the Whittle Consulting EO philosophy to maximise NPV of the current operations.

The schedule outcomes from the 'Base Case Optimised Plan' result were then manually adjusted in a series of iterative 'Static Analysis' steps. These steps mimicked the outcome of a desktop exercise to examine ReCYN<sup>™</sup>, as well as to quantify the relative benefits of each aspect of inclusion on a fixed schedule. This was achieved iteratively via a four-stage manual adjustment to the schedule outcomes (i.e. no change to mining schedule, cutoff or destination), revaluing progressively on:

- Recovering Cyanide and re-using in CIL;
- Reducing Detoxification costs;
- Intensifying Cyanide usage to increase Silver recovery given a portion is recoverable and detoxification issues are somewhat mitigated; and
- The ReCYN<sup>™</sup> ability to creating a new copper cathode product via electrowinning
- *'ReCYN™ Optimised Plan'*: Re-optimised in GEOVIA Whittle<sup>™</sup> using a ReCYN<sup>™</sup> outcome to produce new strategic shells, which then were optimised for schedule etc in Prober<sup>®</sup> also utilising a ReCYN<sup>™</sup> outcome. The benefits modelled include those shown in the static adjustments above as well as the Base Case cyanide-soluble copper (CuCN) maximum blend limit at CIL being removed;

The results of these runs are shown over the following two pages on Figure 8 and Table 4.





Figure 8: NPV Movement between Base Case and ReCYN™ full Optimisations

NB: Y-Axis is truncated for confidentiality and emphasis on relative step NPV movement

Table 4: Metrics for the key Whittle Consulting runs and iterative static analysis of ReCYN™ benefits on the Base Case schedule

	Eull Drobor	iterative Static Analysis on base case Optimised					
LOM Outcomes	EO – Base Case Optimised	STEP 1 CN Recovery (+ ReCYN™ Capex)	STEP 2 Detox Savings	STEP 3 Silver Uplift	STEP 4 Copper	Full Prober EO - ReCYN™ Optimised	Overall Delta
Cumulative NPV delta from Base Case Optimised (\$US)	n/a	+\$24.4M	+\$48.4M	+\$60.3M	+\$73.4M	+\$126.9M	+\$126.9M
Year of Max NPV	2028	2028	2028	2028	2028	2030	+2 years
Total Rock Movement (Mt)	144.7	144.7	144.7	144.7	144.7	170.2	+17.6%
Gold Produced (MOz)	2.8	2.8	2.8	2.8	2.8	3.1	+10.0%
Silver Produced (MOz)	17.0	17.0	17.0	18.7	18.7	21.6	+26.7%
Copper Cathode product (t)	-	-	-	-	4,652	7,905	+7.9kt
ROM & Stockpile Tonnes Processed (Mt)	64.0					76.0	+18.9%
Average cyanide-soluble copper (ppm)	85.86					122.33	

Iterative Static Analysis on Base Case Optimised

NB: Enterprise Optimisation was based on 2016 reserves. Ounces and mine life at Martabe have subsequently been extended with resources and reserves updates

The ReCYN<sup>TM</sup> pit designs, scheduled in the '*ReCYN<sup>TM</sup> Optimised Plan'* Prober<sup>®</sup> run, showed an increase in resource and ore tonnage at all sites, as shown in Table 5 below. The biggest change in the pit designs between the two cases was an increased tolerance for higher cyanide-soluble copper (CuCN) ore, with areas not deemed economic in the base case pit optimisation included in the ReCYN<sup>TM</sup> shapes. This was particularly evident in the deeper south west areas at both Ramba Joring and Tor Uluala, and, to a lesser degree, the north west of Purnama. This result was due to both the silver uplift in recoveries, as well as to some degree the reduced sensitivity to cyanide-soluble copper in the ReCYN<sup>TM</sup> pit optimisation.

Delta in Run outcome between Base Case and ReCYN™ EO Runs	Purnama	Barani	Ramba Joring	Tor Uluala	Total <sup>1</sup>
Total Material Movement (Mt)	9.3%	13.5%	27.1%	17.4%	17.6%
Processed Tonnes (Mt)	11.6%	19.6%	34.4%	21.3%	19.7%
Average Au g/t of ore Processed	-5.5%	-9.3%	-6.7%	-2.7%	-6.1%
Average Ag g/t of ore Processed	-1.2%	1.8%	7.0%	11.1%	-3.0%
Average CuCN ppm of ore Processed	10.4%	0.1%	108.3%	138.3%	43.0%
Average SXS % of ore Processed	6.4%	6.4%	13.2%	19.5%	9.6%
Au Product (MOz)	4.2%	8.1%	22.2%	15.4%	10.0%
Ag Product (MOz)	18.2%	43.1%	62.5%	65.4%	26.7%
Copper Cathode Product (t)	+4.0kt	+0.0kt	+2.5Kt	+1.4kt	+7.9kt
LOM NPV of site before Period Costs <sup>1</sup>	5.5%	-0.2%	21.2%	11.2%	

Table 5: Change in outcome between 'Base Case Optimised Plan' Prober<sup>®</sup> Run and 'ReCYN™ Optimised Plan' Prober<sup>®</sup> Run.

<sup>1</sup> Includes feed and product contribution from existing stockpiles not separately itemised

Overleaf, Figure 9 shows the effect on the pits of redesigning in GEOVIA Whittle<sup>™</sup> for ReCYN<sup>™</sup>. Redesigning the pits on the ReCYN<sup>™</sup> process. The benefits of the silver uplift and reducing sensitivity to Cyanide-soluble copper, showed significant increases in ore levels to most pits, while the overall mine life was extended by an extra two years.

Average Cyanide-soluble copper in the crusher feed increased markedly, as previously-discarded high Cyanide-soluble copper ore becomes economic in the pit design and the lessening of focus on Cyanide-soluble copper in the grade control, given the revised CIL costs in pit optimisation and no CIL Cyanide-soluble copper maximum feed limit. Average Gold Grade processed slipped slightly. This result was due to both the longer sustainable operational life-reducing average grade and the focus slightly adjusting to silver, given the revised recovery outcomes.

Figure 10 on page 25 shows average Gold, Silver, Cyanide-soluble Copper and Sulphide Sulphur (SXS) for both key Prober<sup>®</sup> runs. Later mine life in the ReCYN<sup>™</sup> pit schedules show high SXS and Cyanide-soluble copper. This results as the high Cyanide-soluble copper areas of Ramba Joring, Purnama and Tor Uluala, newly deemed economic with the ReCYN<sup>™</sup> pit optimisation, are mined out.

Overall Cyanide usage has increased from 49.5kt in the 'Base Case Optimised Plan' to 73.1kt in the 'ReCYN<sup>™</sup> Optimised Plan' Prober<sup>®</sup> run given a larger ore feed and more intensive cyanide usage to increase silver recovery. However, Cyanide required to be purchased externally has dropped by 25.7%, from 49.5kt to only 36.8kt, with the remainder of the Cyanide required recovered via the ReCYN<sup>™</sup> process.



#### Figure 9: Change in Ultimate Pit via ReCYN™ pit optimisation from comparison Base Case strategic designs





**Ramba Joring** 



Tor Uluala



Colour legend: **Blue** = only in 'Base Case' Designs, **Red** = in both ReCYN<sup>™</sup> and in 'Base Case' Designs, **Green** = in ReCYN<sup>™</sup> Designs only





2024

2026

2028

■ReCYN<sup>™</sup> Optimised Plan

2030

Figure 10: Comparison of processed ore metrics – key Prober Run results

30.0

25.0

20.0

5.0

0.0

2018

2020

Base Case Optimised Plan

2022

(1/2) 15.0 10.0



NB: Cyanide-soluble copper for ReCYN™ Optimised Plan of 286ppm in 2030 and 997ppm in 2031 omitted for clarity

Average Ag (g/t) of Crusher Feed

2024

2026

2028

■ReCYN<sup>™</sup> Optimised Plan

2030

2032

2032

0.0

2018

2020

Base Case Optimised Plan

2022



Figure 11 below shows total production for both key Prober<sup>®</sup> runs. This is illustrative of both the heightened overall production due to silver recovery uplift and the extra production life achieved by having larger economic pits.





*'ReCYN™ Optimised Plan'* Run





Figure 12 below shows Cyanide usage, and where available, the impact of the ReCYN<sup>™</sup> process on cyanide purchase requirements. The redesigned phases allowed Prober to economically include higher CuCN/SXS material at end of mine life, thereby deferring high Cyanide usage ore until later in the mine life. This is a good indicator that the phases and schedule are working well together.





<sup>&#</sup>x27;ReCYN™ Optimised Plan' Run: Cyanide partially recovered and reused via the ReCYN™ process







# 4.1 CONCLUSION

Based on the current assumptions, for a small capital investment (**US\$5M**), the installation of the ReCYN<sup>™</sup> technology would provide Agincourt Resources a material NPV uplift. Installation of the ReCYN<sup>™</sup> technology would significantly increase silver recovery and reduce overall external cyanide purchases and detoxification requirements, as well as enabling US\$45M+ in copper product revenue.

Even a static desktop revaluation of the optimised Base Case schedule, including the ReCYN<sup>™</sup> uplift in silver and copper revenue and change in cyanide and detoxification costs, resulted in a **US\$73.4M** NPV uplift. Conducting a full Whittle Consulting Enterprise Optimisation, including the redesign of pits, phases and schedule, resulted in a **US\$126.9M** NPV uplift, from an equivalent fully optimised EO of the current processing setup.

These NPV increases include all opex and capex required to install and run the Greengold ReCYN<sup>™</sup> equipment. However, this did not include a royalty to Greengold that may be applicable at other projects.

