Reducing Water, Energy and Emissions through Grade Engineering®

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ABSTRACT

The Australian mining industry currently consumes 28% more water, 21% more energy and generates 19% greater emissions to maintain the same level of production achieved in 2000-01. These trends in declining energy, water and emission productivity have been attributed to increased development of lower quality resources as higher grade, easily accessed ore deposits are depleted.

Industry focus for managing rising water, energy and emission intensity of production is often limited to incremental improvements in energy and water consumption at operations, with little attention given to preconcentration strategies that improve the quality of ore processed.

Grade Engineering® employs coarse-separation techniques to improve the quality of ore delivered to mineral processing facilities and increase the value of an operation. Grade Engineering studies have shown that early intervention to preconcentrate ore streams and separate uneconomic material prior to energy, emission and water intensive stages of mineral processing, have a pronounced improvement on energy and water productivity, emission intensity and the profitability of metalliferous mining operations.

This paper describes the evaluation of water, energy and emission intensity of production, comparing the implementation of energy and water efficient technologies and Grade Engineering strategies at a Au-Cu deposit in Australia.

The results show that a focus on energy and water efficient technologies can produce sizeable reductions in the energy (-19%), water (-31%) and emission (-16%) intensity of production but comparatively low economic returns at the case study site. These results confirm that the cost of energy and water consumption at the operation was relatively low, despite energy costs contributing one-third of the total operational expenses of the operation.

Grade Engineering strategies were shown to provide significant reductions in the water (-21%), energy (-9%) and emission (-15%) intensity of production and a substantially improvement to the net present value of the operation (+13%). The implementation of Grade Engineering strategies in combination with water and energy efficient equipment and practices can further reduce the water (-45%) energy (-27%) and emission (-29%) intensity of production.

INTRODUCTION

The Australian mining industry doubled production between 2000-01 and 2016-17 (Australian Bureau of Statistics, 2017). Over the same period, the total net energy and water consumption of the Australian mining industry increased 2.5 times (Department of the Environment and Energy, 2017; Australian Bureau of Statistics, 2016). Mining in Australia currently consumes 28% more water, 21% more energy and generates 19% greater energy related emissions to produce a unit of output compared to 2000-01.

The deterioration in water, energy and emission productivity has been widely attributed to a decline in the quality of resources mined (Crowson, 2012; Mudd, 2009). This decline in resource quality and productivity is not isolated to Australia and extends throughout the global mining industry (Calvo et al., 2016).

Significant opportunities have been identified to reduce energy and water consumption in mining. The Office of Energy Efficiency and Renewable Energy (2007) benchmarked the energy efficiency of mining and mineral processing equipment employed in U.S. underground and surface operations against the most energy efficient equipment available. The study estimates a 17% reduction in the energy consumption of existing metalliferous operations could be achieved through deployment of the most energy efficient equipment available. While the early replacement of serviceable equipment at existing operations is unlikely to yield positive returns, the study highlights potential energy savings in equipment evaluated for greenfield projects and brownfield expansions.

Many energy efficiency opportunities that are easily implemented with positive economic benefits have been applied within the Australian mining industry (Energy Efficiency Opportunities Program, 2010). However, these opportunities focus on incremental improvements which resulted in a relatively minor reduction (3.2%) in the energy consumption of metalliferous mining.

One of the most promising opportunities to reduce water consumption in the mining industry is high-density tailings disposal. Substantial water losses occur in the entrainment, infiltration and evaporation of water in conventional tailings disposal (Wiertz, 2009). An evaluation of high-density tailings disposal at a South African platinum mine identified a potential water savings of 280L per tonne of tailings (Moolman & Vietti, 2012). However, this option was shown to be uneconomic at current water and energy prices.

Preconcentration techniques that improve the quality of ore treated by mineral processing activities receive little attention as a viable solution to improve the water, energy and emission productivity of the mining industry. Grade Engineering® uses coarse-separation techniques to remove uneconomic material prior to energy, water and cost intensive mineral processing activities to improve the water, energy and emission intensity of production and increase the value of an operation. Grade Engineering coarse-separation techniques include:

- Screening to exploit the natural deportment of valuable minerals to finer size fractions during coarse breakage of some mineralizations;

- Differential blasting to induce finer fragmentation in higher-grade regions of a blast and coarser fragmentation in lower-grade regions to be separated by screening;
- Sensor-based bulk sorting of run-of-mine (ROM) material on conveyors, trucks, hoppers, shovels or loaders;
- Sensor-based particle sorting for sized and screened material streams; and
- Coarse gravity separation using dense media, inline pressure jigs or reflux classifiers.

This paper performs a retrospective evaluation and comparison of the value proposition and production impacts from investment in energy efficient equipment, high-density tailings disposal and Grade Engineering at a Au-Cu deposit in Australia.

METHODOLOGY

The methodology uses the optimal cut-off grade policy for the development of a mineralized deposit to quantify the water, energy and emission intensity of production. The cut-off grade policy defines the quantity of ore and waste mined, the quantity and quality of ore processed, and the quantity of metal recovered and refined in each period over the life of mine. These material quantities are combined with economic parameters and the water and energy consumption of mining, processing and refining activities to determine the net present value (NPV) of the operation and the water, energy and emission intensity of production. Water, energy and emission intensity of production is defined as the total water and energy consumption and energy related emissions generated per unit of refined metal product.

The cut-off grade optimization is based on Lane's (1988) methodology and has been modified to incorporate Grade Engineering of mined material prior to mineral processing. The introduction of Grade Engineering creates additional cut-offs to classify optimal material to treat through coarse separation techniques considering the economics and constraints of the operation. The complexity of the cut-off grade optimization for material allocations at the case study site with Grade Engineering and the energy consumption of activities by energy input is presented in Figure 1. A comprehensive description of the methodology is provided by Scott (2013).

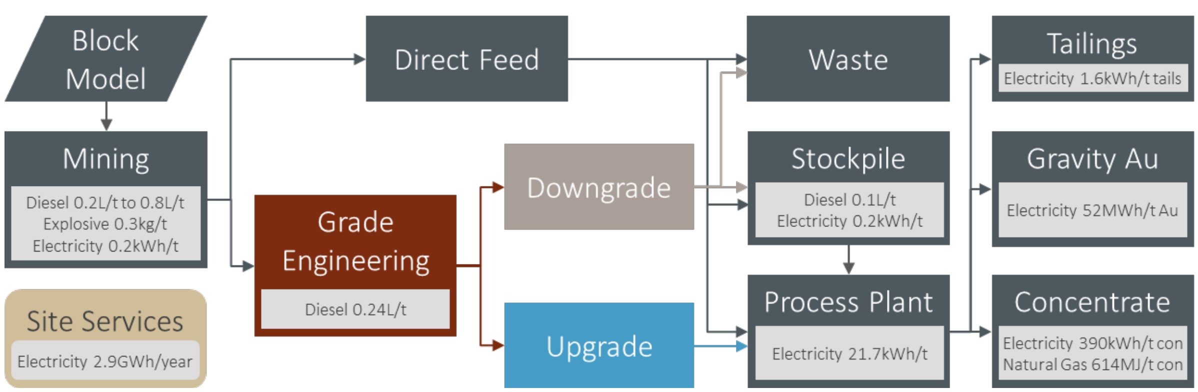

Figure 1 Material allocations with Grade Engineering and energy requirements at the case study site

The methodology provides a holistic framework to quantify all direct water and energy inputs consumed, and energy related emissions generated, in the transformation of insitu rock to refined metal product over the life of mine.

Case Study

The case study examined production from a large, low-grade, Au-Cu porphyry deposit in Australia. The mineralized deposit was developed between 1999 and 2013 using an open pit mining method. The ultimate pit contained 474Mt extracted at an average, annual mining rate of 19Mt ore and 25Mt waste. Mining employed four diesel-fuelled drilling rigs, two electric rope shovels, ten diesel-fuelled haul trucks and ancillary diesel-fuelled equipment.

Ore was treated at a processing plant with a nominal treatment capacity of 17Mt p.a. with low-grade ore deferred to a stockpile. The processing circuit consisted of a gyratory crusher and SAG mill feeding two ball mills with gravity recovery of free milling gold and flotation recovery of a Cu-Au concentrate. Gravity recovered gold was smelted to doré bullion at site and transported to a precious metal refinery. The Cu-Au concentrate was pumped as a slurry to a local town where it was dewatered and transported by rail to a port for shipping to a copper refinery.

Energy inputs at the operation included electricity, diesel fuel and ANFO explosive. Electricity was generated by a coal-fired power station and supplied by the Eastern Australian electricity network at a budgeted price of A$0.0548/kWh. The site had projected annual electricity consumption of 426GWh, of which 74% was consumed by the grinding circuit. Mobile mining equipment was expected to consume 13.4ML of diesel fuel each year at a budgeted price of A$0.27/L after allowance for the diesel fuel rebate. Blasting detonated 12.5kt of ANFO explosive each year at a budgeted cost of A$780/t. Total expenditure on energy inputs represented one-third of annual operational costs for production.

Water was sourced from surface catchments, site bores, tailings return and waste effluent from a local town. Site water costs were estimated at A$0.20/kL and site water consumption amounted to 0.9kL/t ore processed.

Water Efficiency Scenario

The water efficiency scenario evaluated the introduction of high-density tailings disposal at the case study site. The scenario assessed a reduction in the interstitial water losses of 280L per tonne of tailings disposal as reported at a PGM mine by Moolman & Vietti (2012). High-density tailings disposal increased electricity consumed in tailings disposal by 4% but reduced water consumption and associated electricity requirements for sourcing that water at site by 31%. Capital expenditure for high-density tailings disposal was estimated at A$5 million.

Energy Efficiency Scenario

The energy efficiency scenario evaluated production impacts of deploying the most energy efficient equipment currently available in mining and mineral processing activities. Estimated energy savings for each mining and mineral processing activity were published by the Office of Energy Efficiency and Renewable Energy (2007) and reproduced in Table 1. These energy savings reduced operating costs of mining and mineral processing activities but were estimated to increase total capital expenditure of equipment by A$20 million.

Table 1 Estimated energy savings from the most energy efficient equipment currently available

Activity	Energy Saving
Drilling	17%
Blasting	23%
Digging	17%
Material handling (diesel fuel)	33%
Crushing	37%
Grinding	15%
Flotation	22%
Tailings (pumps)	10%
Concentrator services	11%

Grade Engineering Scenario

The Grade Engineering scenario assessed screening options to exploit the natural deportment of grade by size in mined material at site. For simplicity, copper and gold mineralization were assumed to deport to finer size fractions with equal responses. The Grade Engineering scenario assumed a 75% metal recovery in 40% of the screened mass. Screening was performed at the mining face using two mobile screening plants powered by portable diesel-fuel generators and two additional front end loaders, increasing the annual energy requirements of the operation. The Grade Engineering scenario incurred estimated capital expenditure of A$17 million.

RESULTS AND DISCUSSION

The NPV and production impacts of individual and combined scenarios relative to the base case are presented in Figure 2.

Water and energy efficiency scenarios had a small positive increase in NPV but a significant reduction in the water, energy and emission intensity of production. When considering the competitive nature of capital projects, investments in water and energy efficiency at the operation may be difficult to justify due to the comparatively low NPV they returned. However, the economic value of water and energy efficiency is strongly dependent on the cost of water and energy inputs for production. It could be argued that the case study site experienced a relatively low cost for energy and water consumption which weakened the value of energy and water efficiency investments at the case site.

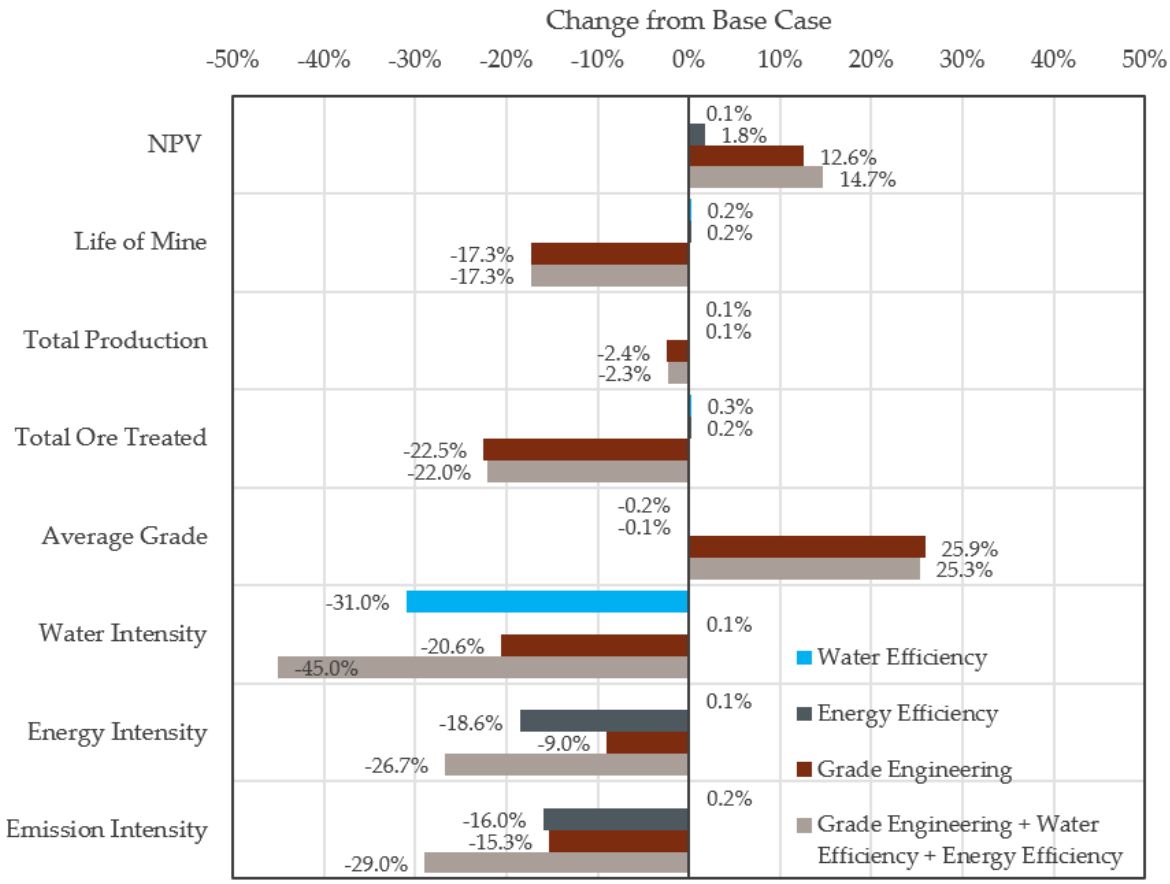

Figure 2 Percentage change relative to the base case for production impacts of scenarios

Furthermore, it is widely acknowledged that mining operates in remote areas where water and energy availability is poor or there is significant competition for water and energy supply (de Kretser et al., 2009; Wiertz, 2009). Therefore, investments in water and energy efficiency may be strengthened by considering the associated risk reductions in water and energy supply and improvements in social license to operate.

Grade Engineering significantly increased the NPV of the operation and reduced the water, energy and emission intensity of production. Grade Engineering increased the average grade and reduced the total quantity of ore treated at the processing plant by removing uneconomic material prior to mineral processing.

It should be noted that the optimization of Grade Engineering within the operation did not result in under-utilization of the processing plant. The early rejection of uneconomic material from low-grade ore was replaced with the upgraded component of ore previously stockpiled and treated upon completion of mining activities at the operation. This accelerated the rate at which mined metal was recovered and eliminated the need to stockpile material at the operation, reducing the total quantity of ore processed and the life of mine. The net result was a small reduction in total metal production (-2%) but a significant increase in annual production (+26%) due to the increased grade of ore delivered to the processing plant.

The reduction in the water intensity of production (-21%) with Grade Engineering, expressed as water consumption per unit of refined metal, is due to a reduction in the total ore processed and tailings generated (-23%) over life of mine, while maintaining similar total metal production from the operation (-2%). However, reductions in the energy and emission intensity were partially offset by the increased energy consumption of additional screening and loading equipment required for Grade Engineering.

The difference in the energy intensity (-9%) and the emission intensity of production (-15%) with Grade Engineering was due to a change in the quantities of diesel and electricity consumed by the operation. Electricity consumption at site generated three times greater carbon dioxide equivalent emissions compared to diesel fuel. Grade Engineering increased diesel consumption at the operation but significantly reduced the quantity of ore treated and electricity consumed by the processing plant. This change in the mix of energy inputs resulted in a disproportionate reduction in the energy and emission intensity of production with Grade Engineering.

Grade Engineering produced the greatest economic benefits for the operation with a 13% increase in NPV from a A$17 million investment. The implementation of Grade Engineering had a similar capital cost to the adoption of the most energy efficient equipment currently available (A$20 million) but returned 11% greater improvement in NPV. Dramatic improvements in the water (-45%), energy (-27%) and emission (-29%) intensity of production were achieved by combining Grade Engineering with energy and water efficiency scenarios.

CONCLUSION

This paper performed a retrospective evaluation and comparison of production impacts for energy efficiency, water efficiency and Grade Engineering at a Au-Cu operation in Australia. The results show that a focus on water and energy efficient technologies can produce sizeable reductions in the water, energy and emission intensity of production but comparatively low economic returns for the case study site. These results indicate a relatively low cost of energy and water inputs at the operation and confirm that investments in water and energy efficiency may be strengthened by considering associated risk reductions in water and energy supply and improving social license to operate.

Grade Engineering reduced the water, energy and emission intensity of production and significantly increase the value of the operation. Grade Engineering removed uneconomic material from low grade ore and replaced this material with the upgraded component of material previously stockpiled. This increased the grade of ore processed, accelerated the rate at which metal was recovered and eliminated the need to stockpile low grade ore. Elimination of the stockpile, reduced total ore treated by the processing plant and the life of the operation. Overall, Grade Engineering significantly increased annual production of the operation, reduced the energy, water and emission intensity of that production, and produced a similar quantity of refined metal over a shorter time period.

The combination of Grade Engineering with water and energy efficient equipment and practices dramatically reduced energy, water and emission intensity at the operation.

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