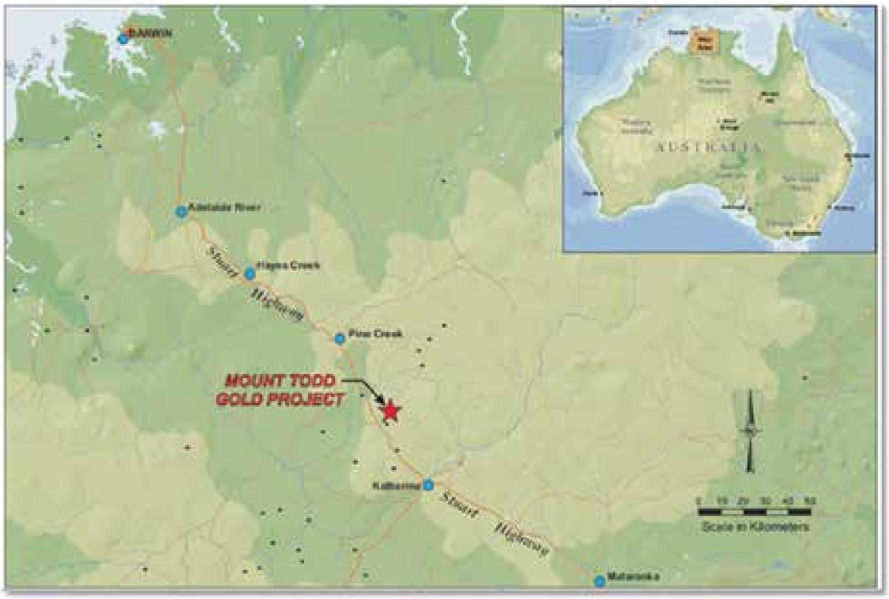
Pit lake water treatment assists with legacy acid rock drainage issue in anticipation of restart at Mount Todd gold mine

by P.B. Moran, J. Forbort and J.W. Rozelle

Figure 1

Project location.



The Mount Todd gold mine is located approximately 50 km (31 miles) north of the town of Katherine in the Northern Territory (NT) of Australia just off the Stewart Highway, and was operated in the 1990s until 2000 (Fig. 1). After cessation of mining operations, meteoric precipitation and acid rock drainage (ARD) associated with surface water runoff continued to report to the retention ponds across the mine site. In 2000, the mine site entered receivership and the NT government became responsible for the care and maintenance program. In 2006, Vista Gold Corp. (as Vista Gold Australia) acquired the rights to resume exploration on the mine site without the financial responsibility of the environmental liability. In January 2007, Vista Gold assumed the care and maintenance activities on behalf of the NT government, with the environmental liability remaining with the NT government, with the goal of reinitiating mining operations. A critical path component of the planned upgrades to the existing mine/milling facilities and infrastructure was the development of a cost effective treatment and dewatering program for the approximately 11 GL (2,900 million gal) of ARD stored in the Batman Pit (RP3), which has a maximum capacity of approximately 12 GL (3,200 million gal). The Batman Pit must be dewatered in order for Vista Gold to restart mining activities.

The Batman Pit Lake had reached a maximum water depth of 104 m (341 ft) when Vista Gold initiated water level monitoring. It is important to note that the ARD water in the Batman Pit has been pumped into it from 2000 to 2012 under an NT government-approved environmental control program. The Batman Pit has virtually no connection to the local ground water regime due to the intensive silicification that accompanied the mineralizing event. In October 2012, just prior to treatment, the pit lake profile was characterized by uniform acidic pH (approximately pH 3.2) and oxic conditions (dissolved oxygen greater than 7 mg/L with depth (Fig. 2). The temperature decreased by approximately 4 °C (39 °F) between the lake surface and approximately 20 m (66 ft) deep, and remained near constant with increasing depth. This temperature difference is believed to be associated with an existing shallow mine bench at approximately 20 m (66 ft) deep around the perimeter of the pit. Similarly, electrical conductivity, an estimate of total dissolved solids, decreased by about 85 microSiemens per centimeter (µS/cm) from 2,800 to 2,715 µS/cm between 10 and 20 m (33 and 66 ft).

The receiving waters are the Edith River and tributaries, which are protected and designated for beneficial use under the NT Water Act (1992) for aquatic ecosystem protection. Discharge of waste water from the mine is regulated by the NT Environmental Protection Agency (EPA) under a waste discharge license (WDL), which has been renewed several times since Vista Gold took on care and maintenance at the mine. Until February 2013, waste water discharges were only allowed under narrowly defined conditions;

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specifically, discharges, only from the waste rock dump retention pond, were allowed when the Edith River was flowing at 12 m^3/s (16 cu yd/sec) and the water level was above 0.81 m (2.7 ft) at the upstream Edith River monitoring point (SW4), (Fig. 3). This discharge limitation equated to more than 5,000 fold dilution in the Edith River, severely restricting the Batman Pit dewatering rate. Therefore, a range of water treatment options were investigated to increase the rate of dewatering for the Batman Pit that could be achieved in a reasonable time frame (to begin mining) and meet the discharge limitation.

Selection of the water treatment approach was conducted in a step wise fashion that started with an alternative analysis to weigh the pros and cons of different treatment approaches including:

- Micronized limestone (calcium carbonate, $CaCO_3$).
- Quicklime (calcium oxide, CaO).
- Hydrotalcite formation (magnesium-aluminum layered double hydroxide minerals).
- Bauxsol^{TM} (derived from red mud).
- Bioreduction by sulfate reducing bacteria.

Each alternative included limited "proof of concept" bench testing and prefeasibility level cost estimates to support advancement of key options to the next level. In situ neutralization using limestone followed by quicklime stood out as a cost-effective and low-risk approach to treating the Batman Pit Lake and other ARD across the mine. With in situ treatment selected, the next steps were planned and implemented to scale up from the bench level to full-scale.

Treatment approach

Historically, quicklime has been selected over limestone due to the perception that treatment is less expensive and will provide additional neutralizing capacity. However:

- Quicklime is a strong base and has a higher neutralizing capacity, but does not leave much residual alkalinity once the pH neutralization has occurred. The pH typically drops once the reagent is deployed because systems tend to be below saturation relative to atmospheric carbon dioxide.
- Limestone is a weak base, but can leave a higher residual alkalinity because it shifts the carbonate equilibrium. Further, the pH will not drop once the reagent has been deployed because it tends to

Figure 2

Pretreatment water quality depth (October 2012).

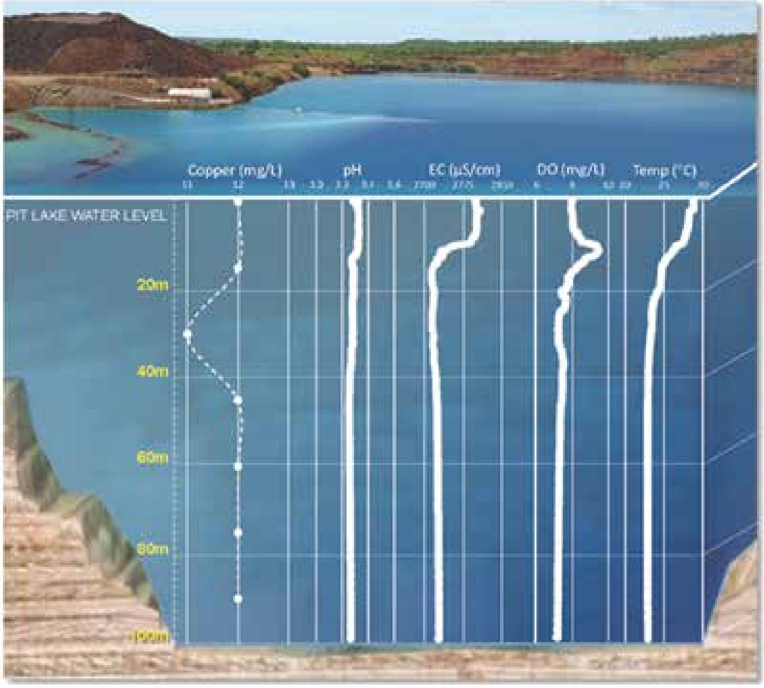

Figure 3

Mine facilities.

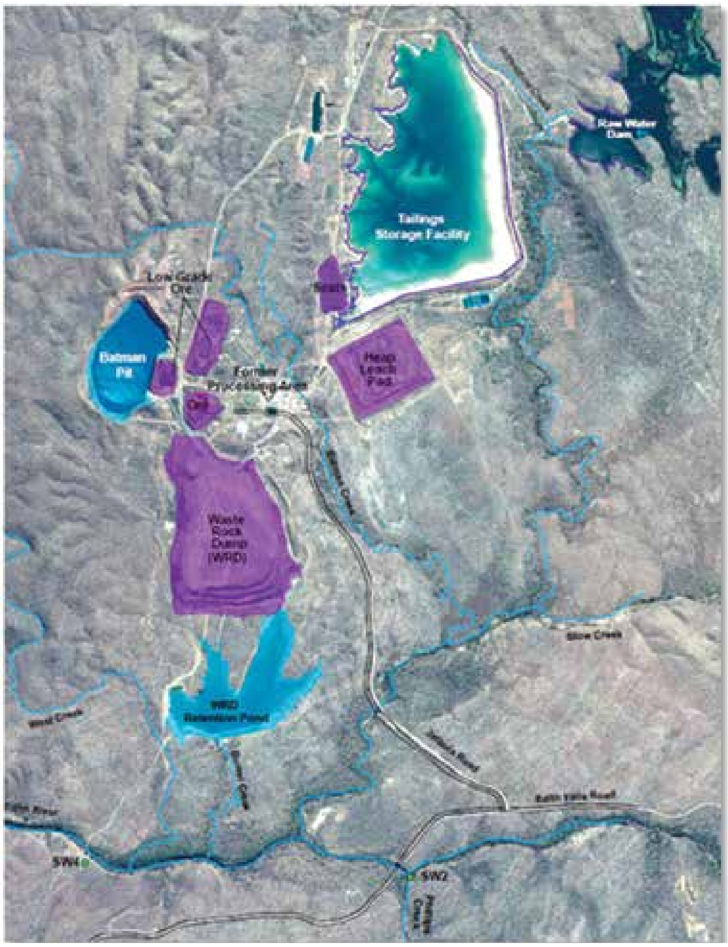

Figure 4

Pilot-scale test in decant pond.

Figure 5

Pilot-scale dry shear system.

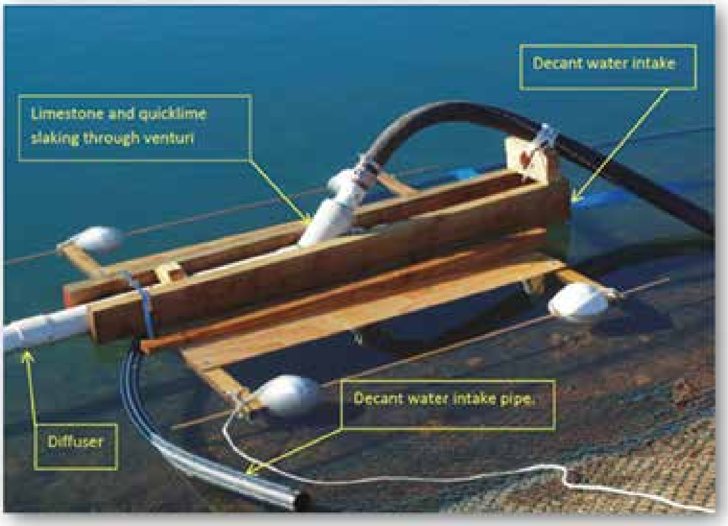

Figure 6

Full-scale dry shear system.

produce systems that are at or above saturation relative to atmospheric carbon dioxide.

At lower pH, limestone is an effective neutralizing reagent. At near neutral pH (approximately 6.4 to 6.8), solubility limits of calcium carbonate ($CaCO_3$) will limit the effectiveness of limestone. Hence, the selection of a two-stage in situ treatment approach using micronized limestone, which is finely ground (approximately 150 µm or 0.0059 in.) limestone, followed by addition of quicklime ground to nominal 500 µm (0.02 in.). In situ neutralization with limestone or quicklime is not a new treatment approach. However, treatment success has been widely variable due to inefficient reagent dissolution (e.g., rapid settling, inactivation caused by armoring, etc.). In the absence of large-scale slaking infrastructure and large volumes of high-quality water, the limestone and quicklime particle size was key to obtaining a suitable reaction time and minimizing armoring for efficient reagent use.

Pilot testing was conducted in May 2012 in a 30-ML (7.9-million gal) decant pond (Fig. 4) filled with Batman Pit water using 38 t (42 st) of micronized limestone (two semitrailer loads) and 8 t (8.8 st) of quicklime using a small-scale dry shear system (Fig. 5). The reagents were pneumatically conveyed to a floating eductor that facilitated the rapid mixing with the ARD. The pressure drop of the pneumatic stream across a venturi induced a vacuum that pumped water into the chamber and the micronized limestone was blended with the pond water passed through the venturi. This process was repeated using quicklime. The pilot test water quality was monitored for three months and was shown to be stable. Micronized limestone was initially used to raise the pH to approximately 6.4 and was limited from increasing beyond this range by kinetic effects induced by $CaCO_3$ solubility. The quicklime addition increased the pH to the treatment pH endpoint, which was established between pH 7 and 7.5 to balance removal efficiency and higher treatment costs associated with maintaining more alkaline pH values. Metals such as aluminum, copper and lead precipitated primarily as hydroxides due to the pH increase and flocculant formation with more than 99 percent reduction in concentrations observed. Close to a 50-percent reduction in cobalt, cadmium, nickel and zinc concentrations were observed (sorption/coprecipitation with aluminum hydroxide likely contributed to cadmium, nickel and zinc removal).

Full-scale treatment activities were initiated

Figure 7

pH trends during and following full-scale treatment (showing metal solubility).

in the Batman Pit in November 2012 and took five months to complete due to delivery constraints of the micronized limestone. Limestone addition was undertaken over several months (November 2012 through late February 2013) using a larger capacity dry powder shear and diffuser rig (Fig. 6) with the resident acidic water. Quicklime addition was initiated in early March 2013 and completed at the end of April 2013. Under full-scale conditions, pH increased more than expected based exclusively on hydroxide formation, consistent with removal via other mechanisms such as carbonate mineral precipitation, sorption and coprecipitation (Fig. 7). In early 2014, the NT Department of Mines and Energy (DME) required that additional untreated water be transferred to the Batman Pit, which was largely neutralized by the residual alkalinity but required additional treatment by DME to return the water to pH above 7 and achieve the previously observed metal removal. In 2015, data loggers were placed in the Batman Pit to provide real-time water quality monitoring to better support dewatering.

Regulatory requirements

As a result of the success of the in situ treatment activities, the WDL conditions were adjusted to meet an 80-percent protection limit rather than the 95-percent protection limit for drinking water, and include ecotoxicity testing (aka direct toxicity assessments, DTAs) to meet the ecosystem protection requirements at more reasonable discharge dilution ratios. Vista Gold conducted DTAs of the treated water, which resulted in a significant reduction in the required dilution to near 20 fold by 2015. To reduce the dependence on DTAs, which take approximately five weeks to complete at a cost of approximately A$30,000, Vista Gold developed an algorithm to determine the dilution ratio prior to each discharge event. The algorithm was developed based on DTAs of treated and untreated mine water from the Mount Todd gold mine and other nearby mines with wide ranges in water quality and

Figure 8

Full-scale dry shear system.

Figure 9

Discharge point in Barman Creek above Edith River.

Figure 10

Water level February 2016.

subsequently validate using treated Batman Pit water. The current Batman Pit water quality can be input into the algorithm at the time of discharge to determine the WDL required dilution ratio rather than conduct frequent ecotoxicity testing.

Pit dewatering

During the 2012 to 2013 time frame, four 500-kW, variable-speed centrifugal pumps were installed on floating pontoons (Fig. 8) in preparation for dewatering of the Batman Pit. Each pump is capable of outputting a range of flows from 100 to 250 L/s (1,585 to 3,963 gpm) at a hydraulic head of up to 85 m (279 ft). The variable speed and independent pump design permits the system to release water at total flow rates from 100 to 1,000 L/s (1,585 to 15,852 gpm), as measured downstream of a common manifold using a magnetite flow meter. The dewatering pump system is automated through telemetry based on the flow rate of the Edith River at the upstream (SW4) gauge station, which includes continuous stream water level, and water quality parameters, also connected to the telemetry system. The actual flow rate is based on the WDL conditions, which are incorporated into the pumping system using the dilution ratio set by the operator. Figure 9 shows the discharge point in Batman Creek above the Edith River.

Since full-scale treatment was initially conducted in 2012, increasing volumes of treated water have been released during controlled discharge events including 0.03 GL (7.9 million gal) in 2013, 0.22 GL (58 million gal) in 2014 and 1.4 GL (370 million gal) in 2015. Vista Gold anticipates that large-scale dewatering of Batman Pit will occur in 2016.

Conclusions

A range of in situ water treatment approaches were considered at the Mount Todd gold mine with the goal of achieving acceptable water quality at significant cost savings compared to traditional ex situ approaches. Highlights of the program include:

- Treatment using micronized limestone followed by quicklime is currently facilitating rapid dewatering while meeting the discharge limitations at the downstream compliance point.
- Working closely with NT EPA, Vista Gold has successfully reduced the initial 5,000 fold dilution required to allow discharge from the Batman Pit down to approximately 20-fold (Fig. 10).
- The associated discharge limitations have been optimized to meet required water quality protection standards.

The relaxed discharge dilution requirements (by relaxed the authors refer to meeting an 80 percent protection limit rather than the 95 percent protection limit for drinking water) will allow dewatering of the Batman Pit at an accelerated rate, and commencement of mining operations in a reasonable timeframe. ■