AMD Passive Treatment System: A Case Study – Escarpment Mine, Denniston Plateau

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Abstract

The Escarpment Mine is located on the Denniston Plateau north east of Westport within an area of historic coal mining dominated by underground mining activities within the Brunner Coal Measures. Bathurst Resources Limited (BRL) is the operator of the open cast Escarpment Mine, which is currently under care and maintenance due to low export commodity prices.

Prior to moving into care and maintenance, a small amount of mining was undertaken as part of the construction phase of developing an initial mine infrastructure area resulting in the excavation of Pit 3 and the construction of the Barren Valley Engineered Landform (ELF). These disturbances provided the opportunity to determine acidity loads derived from a waste rock dump constructed in 2 m lifts, acidity generated from highwalls, and acidity generated in the pit lake created by the excavation of Pit 3.

Modelling was undertaken, which determined that a passive treatment system (mussel shell bioreactor) would be the most cost effective and practical solution to treat the acidity and dissolved metal loads prior to discharge. When the site went into care and maintenance the ideal opportunity presented itself to construct and trial the mussel shell bioreactor to demonstrate the benefits and opportunities for water treatment once mining recommences.

Construction was completed with limited machinery and personnel, minimal cost, and an expectation of minor ongoing maintenance inputs. The results to date have been convincing with median pH from the ELF increasing from ~3.5 to ~7.9 and dissolved metals decreasing by two orders of magnitude after the waters passed through the mussel shell bioreactor. Results also demonstrate that the excess alkalinity produced by the bioreactor has been sufficient to neutralise the acidity present in the pit lake as well as ongoing acidity contributions from the highwalls.

It appears that, based on the data available to date, the approach of a well-constructed ELF and downgradient passive treatment can manage the acidity and metal loads generated by the operation. This bodes well for the greater project expansion and serves as a template for the greater project.

Keywords: Acid Mine Drainage, Passive Treatment, Mussel Shell Reactors, Denniston Plateau, Brunner Coal Measures.

Introduction

The Escarpment Mine is located on the Denniston Plateau (the Plateau) north east of Westport within an area of historic coal mining dominated by underground mining activities within the Brunner Coal Measures.

Acid Mine Drainage (AMD) on the Plateau remains a legacy from the underground mining that commenced approximately 100 years ago and continued up until the mid-1980's. There are many discharge points from old workings across the Plateau, some of these are within the Escarpment Mine footprint.

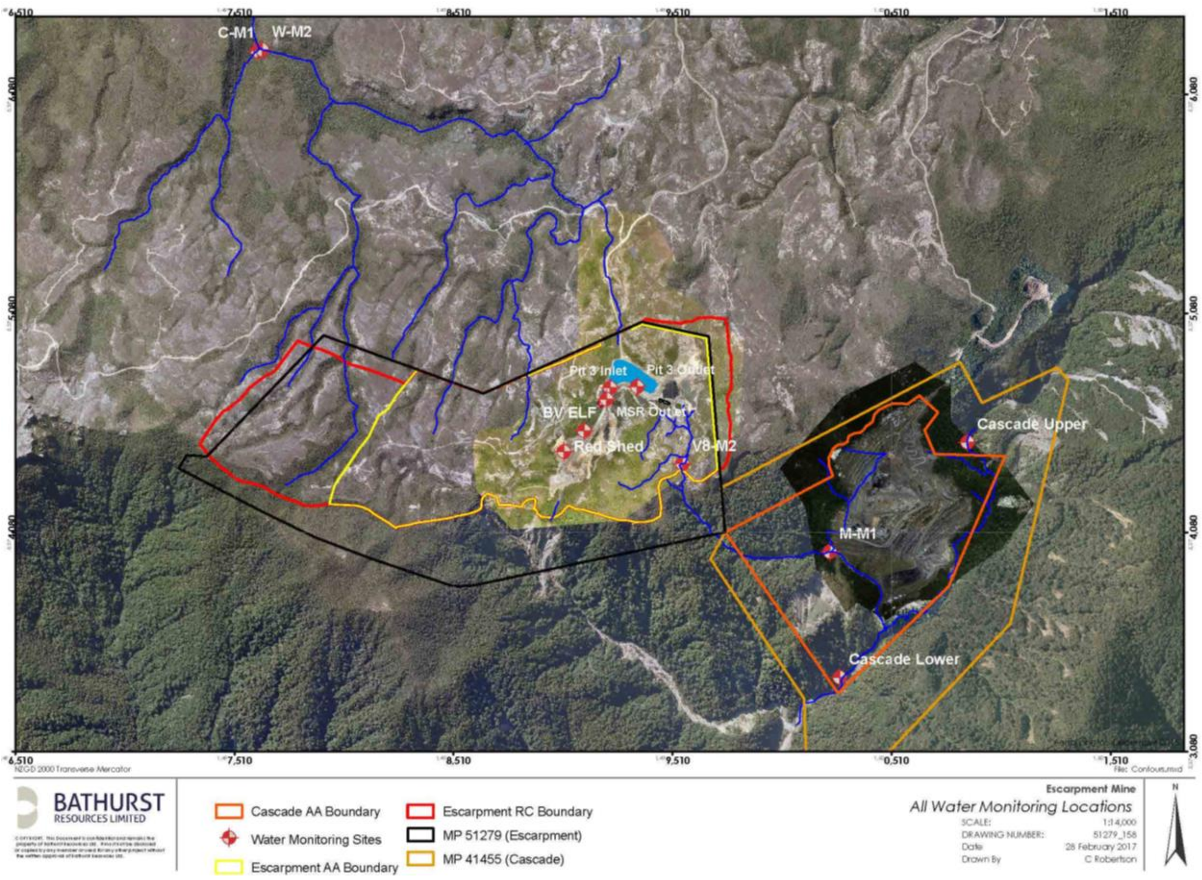

Figure 1. Escarpment Mine and Denniston Plateau

While many of the waterways on the Plateau are impacted from historic mining activities, those that are not impacted remain naturally acidic. This is partially a result of the highly acidic pakihi soils and rain run-off over exposed pyrite-bearing rock associated with the sandstone surface. There is a rapid drop in pH in the Conglomerate Stream following a rainfall event. Conglomerate Stream is outside of any influences from historic or present mining activity and is therefore representative of the natural receiving environment. This site is a monitoring control site for water discharges from the Escarpment Mine.

While there is a history of mining disturbance and human activity across the Plateau, the Escarpment Mine was the first significant open cut operation on the Plateau and therefore the first to be subjected to a consenting and approvals processes under the Conservation Act (1987) and Resource Management Act (1991) (RMA).

The original consent application included a concept for AMD management that required an Engineered Landform (ELF) having low net percolation at closure with an active water treatment plant during operations and a passive treatment system at closure. It is also expected that water quality leaving the Plateau would be improved by mining large areas of historic workings and subsequently treating the water associated with these workings as part of the project. Originally all AMD generated by the mine was proposed to be treated prior to discharge into the Whareatea Stream (Fig. 1). The original plan involved rapid infrastructure construction and installation of a water treatment facility so that mining could commence at approximately 500,000 tonnes of coal per annum and ramp up to over 1 million tonnes per annum within 3 years.

The consent conditions required establishment of an independent peer review panel to provide advice to the regulators on AMD, mine planning, biodiversity and rehabilitation. This panel identified that technical improvements could be made to the consented AMD management philosophy. Consequently, a full review of AMD management was completed prior to any mining related activities on site.

Between obtaining approval for the project, and getting the management plans signed off, the economics of the project were adversely impacted by falling international coking coal prices. As a result a much smaller and slower construction phase was initiated. Despite a smaller scale start-up, all the obligations for consent compliance remained. The smaller scale and slow construction rate did however provide a good opportunity to prove up the AMD management approach, including the trial passive treatment system.

Mine Construction

The original AMD management philosophy proposed discharging all water into the Whareatea Stream. A review of the site layout and designs resulted in a proposal to treat and then direct all water into the Cascade Creek which is already severely influenced by AMD from historic underground workings. Three years of monitoring results have shown that the discharges and the water quality downstream of the discharge point are better than above the discharge point.

Pit Lake

Construction commenced in the area known as the Barren Valley (Fig. 2). This area was used as the starting point as it had been disturbed previously, and was accessible for establishing the mine infrastructure required at start-up. Construction commenced with the pit surge sump and water treatment facility (Pit 3). Overburden excavated in creating this 150,000 m^3 lake included both non-acid forming (NAF) and potentially acid forming (PAF) material. All material was characterised and either stored for rehabilitation purposes or placed in the Barren Valley ELF.

Once excavation was complete the Pit was allowed to fill. Given that the PAF material in the exposed pit walls were producing acid, all surface water was directed away from the Pit to slow the rate of filling and prolong the time until treatment was required and minimise sediment inflows. Minimising the water flowing into this pit enabled an estimated six to twelve-month window before the pit would overflow and the acidic water would require treatment. This established a time window to model, design and construct a water treatment facility.

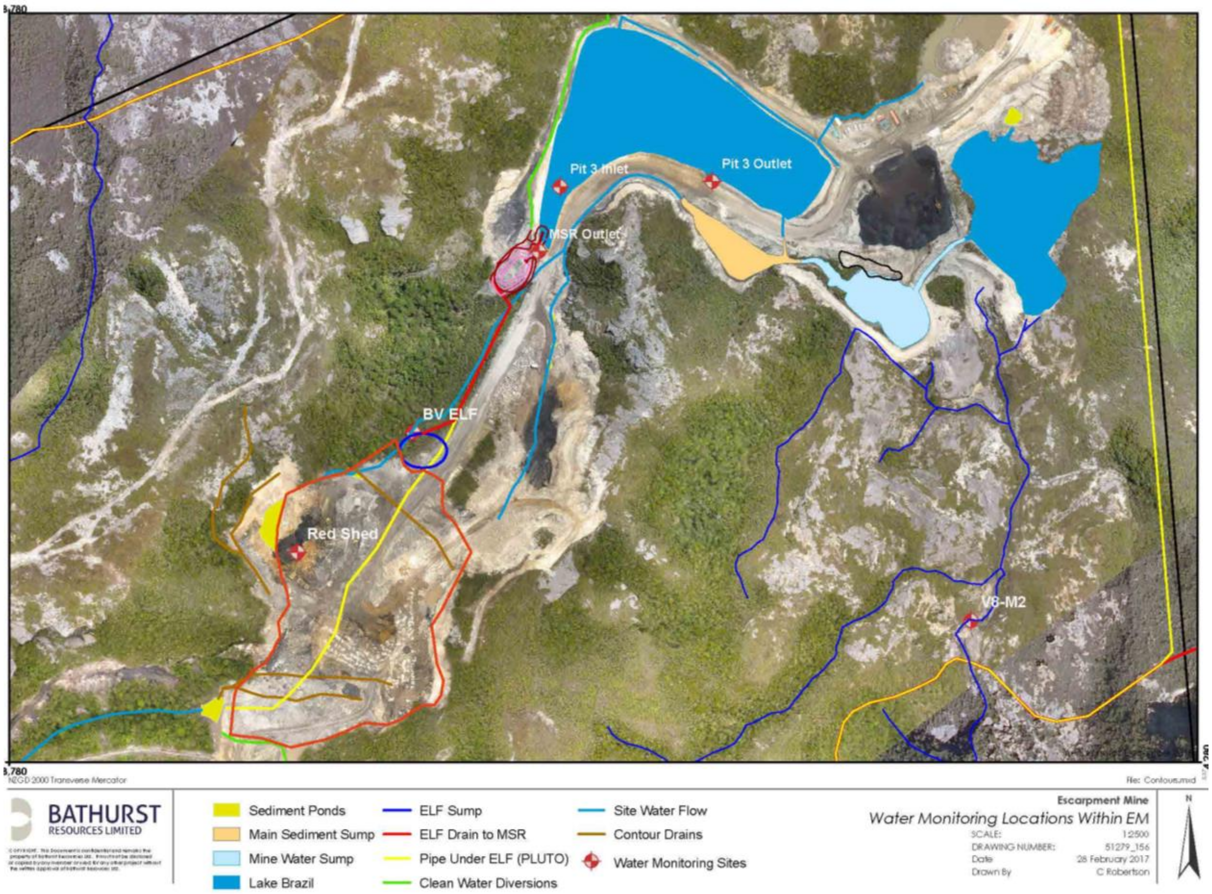

Figure 2. Escarpment Mine and water flows

Engineered Landform (ELF)

The original ELF concept involved placing a low permeability capping layer (10^{-7} to 10^{-8} m/s hydraulic conductivity) over end-tipped waste rock. Laboratory testing indicated this could only be achieved with a geosynthetic clay liner, which comes at considerable cost.

The revised ELF construction concept for minimising AMD production relied on minimising oxygen and water ingress and adding a neutralent to the acidic material in the ELF. Materials were characterised for their acid producing capacity (e.g. Olds et al., 2015) and their placement in the dump managed by a quality control process. Material with the highest acid forming potential was placed within cells in the centre of the ELF.

The ELF was designed to be built in 2m high lifts by either paddock dumping or short lift heights to minimise grainsize segregation and this ingress of oxygen long rubble layers. Each lift was treated with neutralent and the volume was determined by the acid generating potential of the overburden being dumped. The objective has been to minimise oxygen and water ingress into the ELF.

The ELF was also constructed with a basal drainage network, to direct all leachate to a single collection point. An engineered dam at the base of the drain was constructed to prevent oxygen ingress back along the basal drainage network into the core of the ELF. The Barren Valley also had some historic discharges. Most of these discharges are now covered by the ELF and the leachate is directed to the collection point via the underdrain.

Care and Maintenance

Following the downturn in the export commodity prices and closure of the Holcim Cement plant in Westport, the Escarpment Mine was placed on care and maintenance. Neither the DOC Access Arrangement, Resource Consent conditions, nor the Mining Regulations anticipated a care and maintenance scenario. Therefore the statutory obligations remain in force as if the mine were operating.

As part of placing the mine on care and maintenance further earthworks were undertaken to ensure that all water controls were in place to avoid the need for an active sediment dosing system. Periodic silt pond maintenance is required, and this occurs every 3-6 months, depending on the number and intensity of rainfall events.

At the point in time when the site moved into care and maintenance, the ELF was only one third of its planned height. As a best-practicable management approach, a layer of non-acid forming material was spread overtop to minimise acid production from surface run-off and to assist with shaping for sediment control. Water monitoring results from two sediment ponds below the ELF show that surface run-off was not impacted by acid formation from the surface of the ELF confirming that the rock is non-acid forming on the surface.

The total disturbed mine footprint at the time that the site was placed in care and maintenance was 15.3 ha. The part of the ELF that contains acid forming material covers 2 ha with the remaining area of the ELF used to stockpile non-acid forming material to be used as either a capping or protective layer over the ELF or as a foundation for further infrastructure.

AMD Treatment

Going into care and maintenance, AMD treatment was identified as the highest environmental risk and likely ongoing cost. While the ELF had been built to specification, some AMD will still be produced as there has been no capping and a topsoil and vegetation layer established. Development and trialling a passive treatment system was a logical solution. With the site in care and maintenance this was an opportunity to prove the concept and determine whether it could be scaled up once mining activity recommenced and as a possible option for post closure treatment.

Mussel Shell Reactor

A Mussel Shell Reactor (MSR) had been successfully trialled at other mining operations that have AMD associated with mining the Brunner Coal measures (e.g., Weber et al., 2015). In this instance, the challenge was to construct and build a system that would require minimal maintenance and inputs and would cope with the conditions presented at Denniston, particularly rainfall. The system also needed to produce sufficient excess alkalinity to neutralise the acidic water already present in Pit 3 and treat acidity produced by the Pit 3 highwalls.

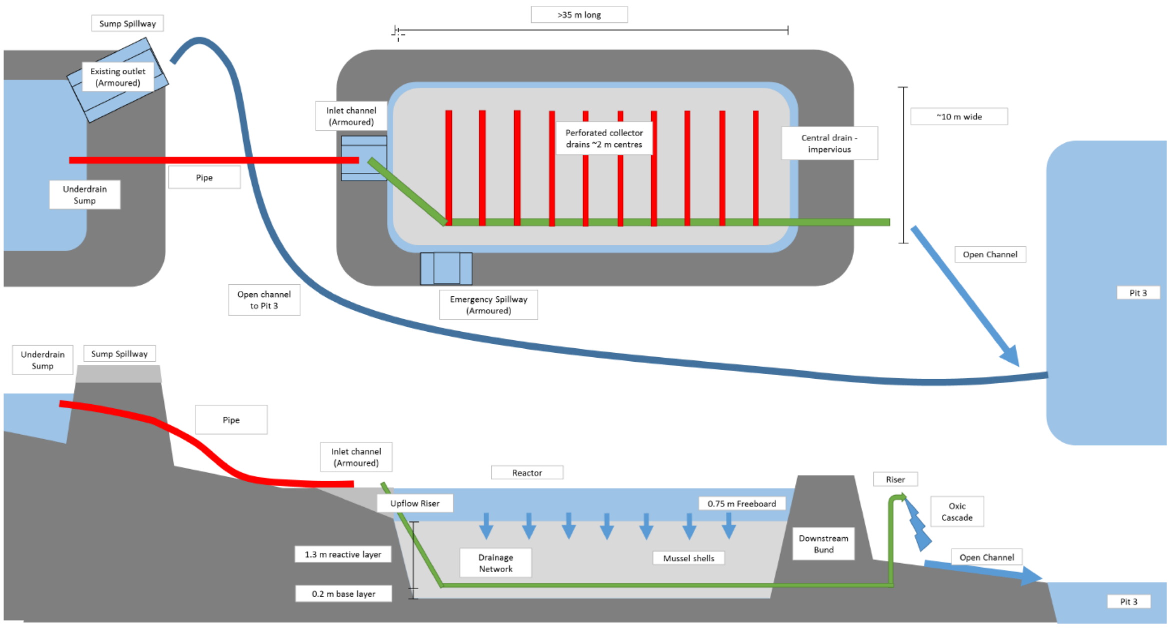

Figure 3. MSR Concept design

Construction

A schematic of the design is shown in Fig 3. The principles for construction were to construct the reactor at least cost and in a way that would require minimal ongoing input and or maintenance. This required minimising the sediment entering the bioreactor as this would result in clogging the shells, decreasing permeability, and preventing drainage of the AMD impacted waters through the bioreactor.

The ELF and underdrain leachate catchment bund were designed so that the majority of surface runoff was diverted away from the bioreactor, as this water did not need treatment. Flow recordings show that the flow out of the underdrain varies between 2 and 4 $Lsec^{-1}$ depending on rainfall. Water from the underdrain was collected and piped to the MSR. This minimised run-off inflow, erosion, and sedimentation.

Due to the availability of machinery and space, the MSR structure was built above ground with earth bunds lined with a geotextile fabric that would reduce erosion of the containment bunds. (Fig. 5).

The mussel shells are a waste product from the aquaculture industry. They were weathered, and semi-crushed. Weathered material does not smell or emit an odour like fresh material and is also less likely to attract vermin to the site. (Fig. 4)

Figure 4. Crushed Mussel Shells

The collection pipes were laid according to the design specifications (Fig. 3). Establishing an appropriate height for the outflow riser was the most difficult aspect. The height had to take account of the hydrostatic pressure from the water percolating through the shells and enable a suitable cover of water over the shells, but not so much that resulted in an overflow of the system, which would mean the water would not be treated. Trial and error, patience and wet boots, was the practical solution to getting the riser at the correct height. More freeboard would have enable greater flexibility in riser height but the MSR was constructed without survey.

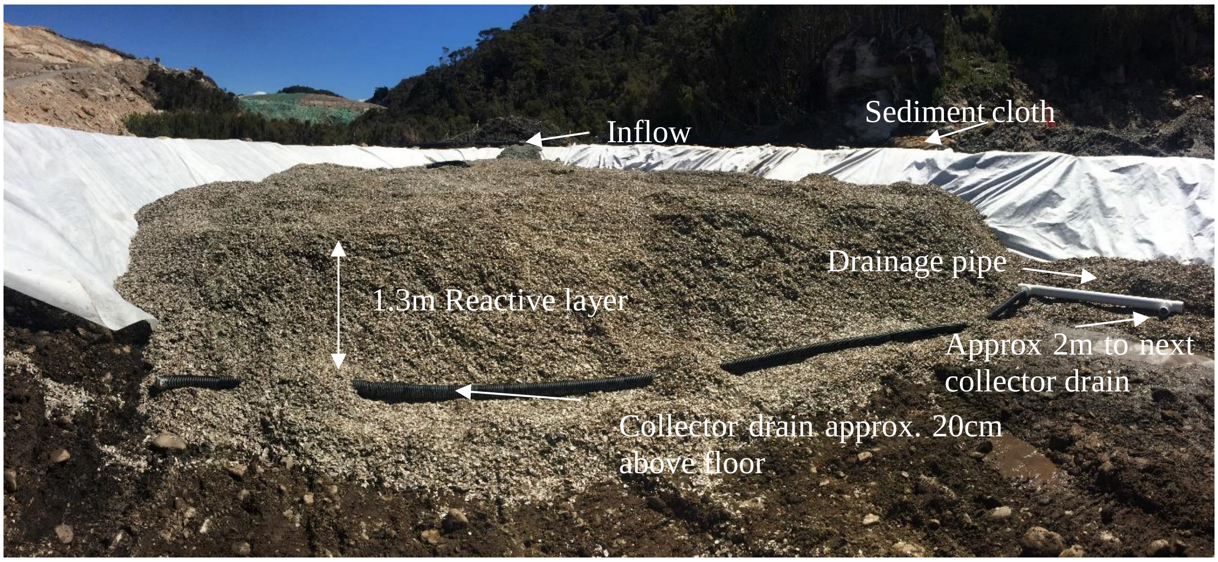

Figure 5. MSR profile during construction

Costs

The estimated total construction costs were around $50K this includes purchase and trucking of approximately 500 m^3 of mussel shells to site from Havelock (approximately 300 km) and machine costs for construction.

Water Quality Monitoring Results

The water quality monitoring results are self-evident. Over the last 12 months, water at the leachate collection point has a median pH of 3.4 and since the MRS has commenced operation in early December, the water leaving the reactor has had a median pH 7.9. Pit 3 pH shows a steady increase in pH as the excess alkalinity from the MSR has neutralised the acidity within the pit lake together with additional dilution by rainfall. Data now shows there is a small residual excess alkalinity leaving Pit 3, depending on the excess alkalinity from Pit 3, we may start to see an increase in pH further downstream from the pit as the water flows towards Lake Brazil.

Acid and metals also show a similar trend as the AMD impacted waters pass through the MSR treatment system and then down through Lake Brazil, and into Mill Creek and the receiving water of Cascade Creek (Fig. 7). As expected, dissolved Al and Fe in Pit 3 shows a delayed decline that is linked to a decrease in acidity and a subsequent increase in pH. The Pit 3 acidity remains lower than the Lake Brazil acidity, which is probably a result of other site influences from run-off from the ROM, a small adit in the barren Valley, as well as natural runoff across exposed rock and wetlands, none of which is captured by the MSR. Acidity and dissolvedmetal concentrations at the Mill Creek site are significantly lower, which is most likely due to additional clean water run-off and further downstream dilution. The Cascade Creek receiving environment remains consistently poorer quality than any of the discharges.

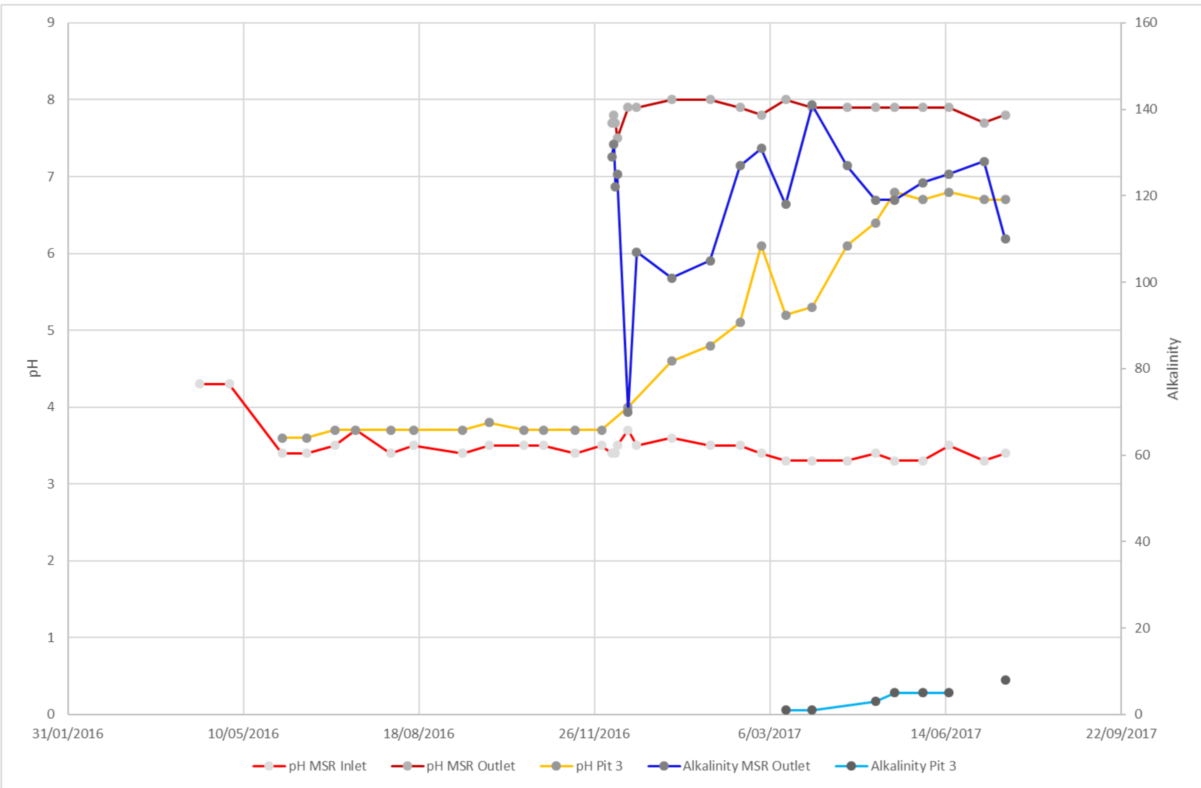

Figure 6. pH and Alkalinity MSR and Pit 3

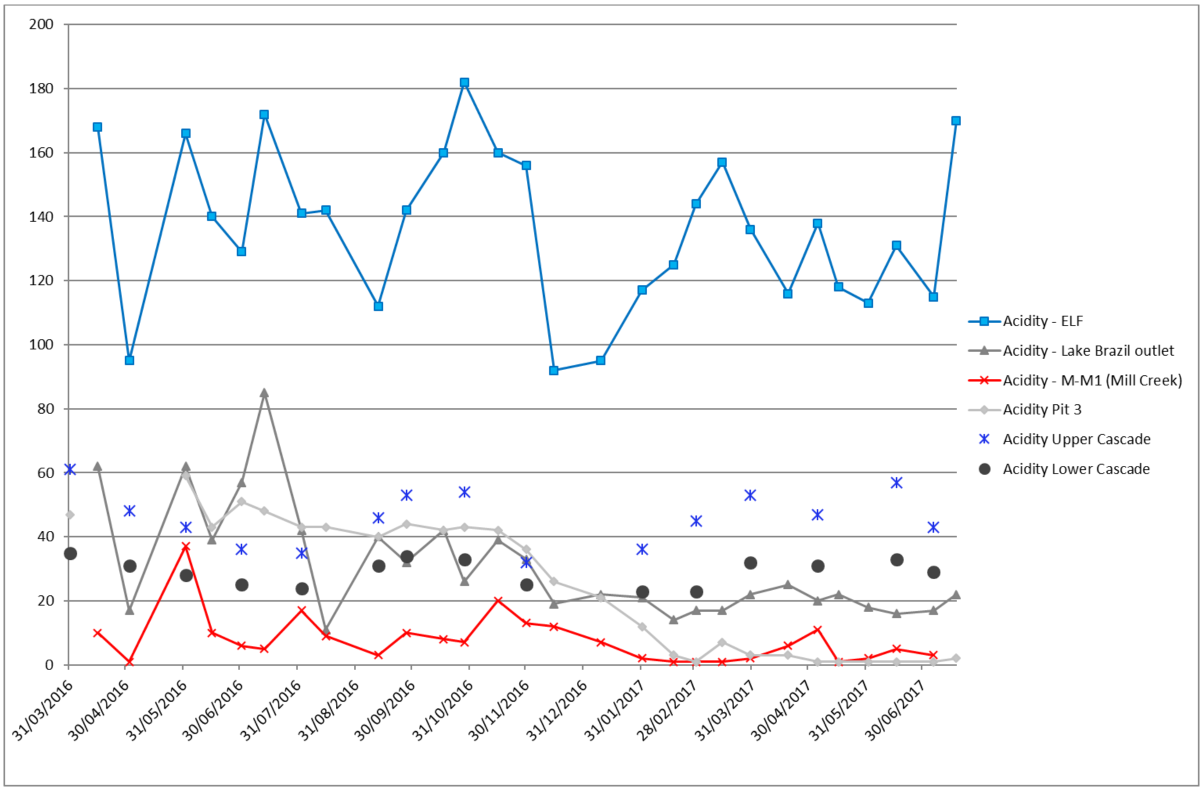

Figure 7. Acidity tracked through the site from the ELF to Cascade Creek

Discussion

Design and installation of a mussel shell reactor to treat AMD at the Escarpment Mine site has proven in the short term to be a pragmatic and cost effective solution for managing acid mine drainage, particularly during care and maintenance. The low construction and maintenance costs and output results to date show that this system is a useful tool to have available for AMD management.

The life of the reactor remains unproven, but modelling suggests that based on acid load and flow, the shells could last 10-13 years. Regular monitoring, and inspection will be required to determine if this is accurate.

Fortnightly water sampling will continue until a point where alkalinity leaving Pit 3 is relatively constant. There should then be an opportunity to reduce the frequency of monitoring. Regular inspections will continue to ensure that the pipelines and bank stability are satisfactory.

Beyond these limited requirements, there is limited anticipated input required while in care and maintenance.

Based on the results and experience with construction, opportunities are available to scale up this concept for treatment of larger acid loads. Scaling will remain reliant on good quality data for modelling a design to suit the site. The biggest risk is likely to be armouring and sedimentation within the MSR, which will require regular monitoring and inspection.

Acknowledgements

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References

Olds, W.E., Bird, B., Pearce, J.I., Sinclair, E., Orr, M., Weber, P.A., 2015. Geochemical Classification of Waste Rock using Process Flow Diagrams. *New Zealand Annual AusIMM Branch Conference*, Dunedin, 31 August – 2 September 2015, pp 307-318.

Weber, P., Weisener, C., Diloreto, Z., Pizey, M.H., 2015. Passive treatment of ARD using waste mussel shells – Part I: System development and geochemical processes. *10th International Conference on Acid Rock Drainage*, April 20-25, 2015, Santiago, Chile, pp 1204 -1213.