Comparison of diversion well substrates for the treatment of acid mine drainage, Bellvue Mine, West Coast, New Zealand

E. Forbes[1], D. Trumm[2], D. Bell[3] and J. Pope[4]

1 Department of Geological Science, University of Canterbury, New Zealand
emma.forbes@pg.canterbury.ac.nz
2 CRL Energy Ltd, PO Box 29 415, Christchurch, New Zealand, D.Trumm@crl.co.nz
3 Senior Lecturer in Engineering and Mining Geology, University of Canterbury, New Zealand, david.bell@canterbury.ac.nz
4 CRL Energy Ltd, PO Box 29 415, Christchurch, New Zealand, J.Pope@crl.co.nz

Abstract

Bellvue Mine, an abandoned coal mine north of Greymouth, West Coast, is discharging acidic run-off into Cannel Creek, resulting in low pH conditions and high dissolved metal concentrations. This has led to poor stream ecosystem health and low aquatic biodiversity. Diversion wells are a method of passive treatment of acid mine drainage. A typical well consists of a cylinder-shaped container filled with limestone aggregate, and a pipe centred down the well to allow water from an upstream dam to provide hydraulic head and entry to the system. Dissolution of the calcium carbonate raises the pH of the acidic drainage, adds alkalinity, and allows for precipitation of metal contaminants out of solution. Mussel shells are an alternative source of calcium carbonate and method of passive treatment: this is to be used in a mussel shell reactor at the Bellvue site later this year. Because the reactor is unable to treat acidic discharge during high flow events, a diversion well will allow for treatment of excess acidic discharge during high precipitation events. The use of a diversion well, and mussel shells as a diversion well substrate, has not previously been trialled in New Zealand. This research involves the installation of a diversion well at Bellvue Mine, and chemical analysis of treated waters, to determine the effectiveness of a diversion well using mussel shells in treating acid mine drainage in comparison to the more traditional diversion well using limestone.

Keywords: Acid mine drainage, passive treatment, diversion well, Bellvue Mine.

Introduction

Acid mine drainage is a significant environmental problem globally. Sulphide-bearing minerals, exposed as a result of metalliferous and coal mining, interact with oxygen and water to produce acidic run-off, a considerable pollutant of many surface water systems. A long history of coal mining on New Zealand's West Coast has resulted in the production of acid mine drainage, having a negative effect on the quality of fresh water streams.

Bellvue, an abandoned coal mine north of Greymouth, is discharging acidic run-off into Cannel Creek. Past studies have shown sections of the creek, downstream of the mine site, have pH levels as low as 3.55 (Trumm & Cavanagh, 2006). Acidic discharge is also causing high dissolved metal concentrations (West, 2014). As a result, stream water quality is poor, leading to low ecosystem health and a loss of aquatic biodiversity.

Passive treatment of acid mine drainage is a favourable method of treating contaminated waters at sites similar to Bellvue. These treatment systems are low maintenance, low cost and take advantage of the naturally occurring processes at the given site. A study carried out by West

(2014) involved improving knowledge of site geochemistry and trialling small scale passive treatment systems at Bellvue. However, a diversion well, a form of passive treatment, has not been trailed at the site. There is a lack of understanding as to how effective the operation of a diversion well will be at treating acid mine drainage at Bellvue over time.

The presented research aims to determine the efficiency of a diversion well using mussel shells for the treatment of acid mine drainage at Bellvue, in comparison to the more traditional diversion well using limestone.

Bellvue Mine study site

Bellvue Mine is approximately 12 km north of Greymouth, West Coast, situated on Cannel Creek (Fig. 1). Bellvue Mine operated over several decades beginning in 1927 until production ceased in 1970. The mine was opened as an extension to the larger James Mine, further northwest of Bellvue, along the same Brunner Coal seam. Extraction of coal has exposed minerals, specifically pyrite, allowing the formation of acid mine drainage, which flows into the nearby Cannel Creek. Bellvue Mine adit is located at the top of a 50 m cascade. Contaminated water pools at the mine adit as the mine entrance has collapsed over time, damming water behind it. Acid mine drainage flows down the cascade, over a flat, non-vegetated area and into Cannel Creek (Fig. 2).

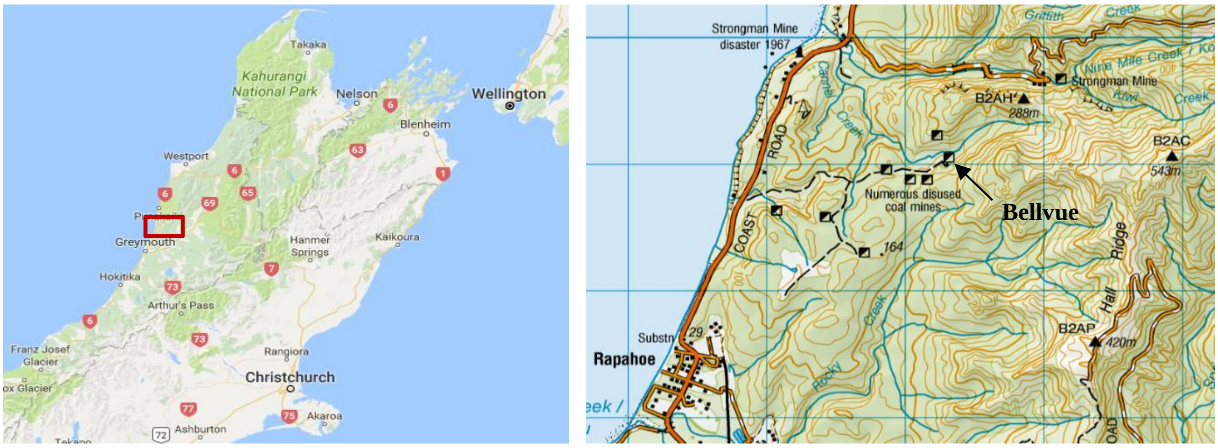

Figure 1. Red square indicating location of Bellvue Mine site, West Coast, New Zealand (modified from Land Information New Zealand, 2016).

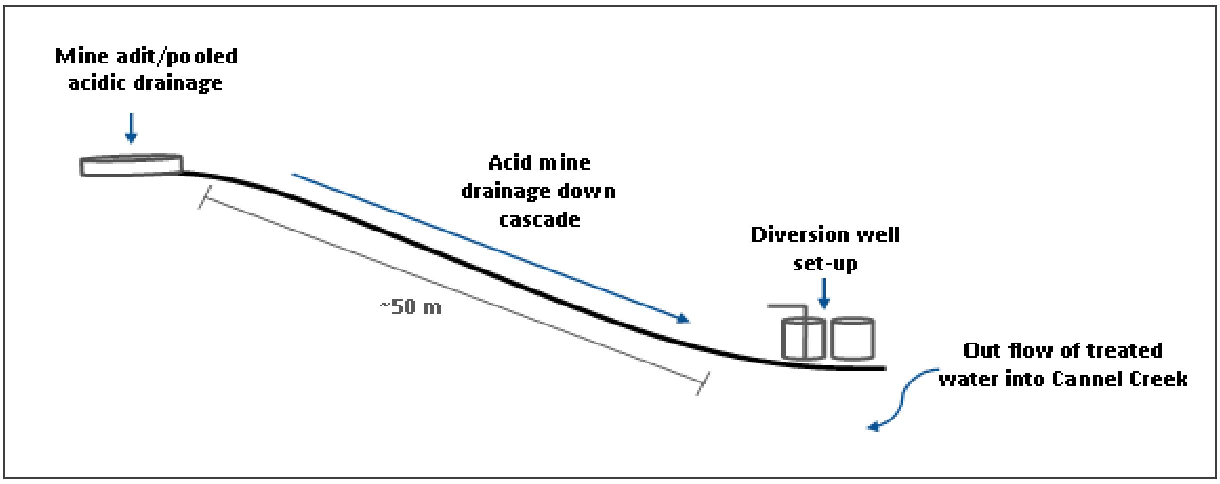

Figure 2. Schematic of Bellvue Mine site showing path of acid mine drainage (not to scale)

Local geology

Geology of the Greymouth region includes Pre-Cretaceous sedimentary deposition of the Greenland Group, overlain by Late Cretaceous to Early Quaternary sediments that make up the Paparoa and Brunner Coal Measures, followed by the Island Sandstone and Kaiata Mudstone Formations. Bellvue Mine lies within the Brunner Coal Measure (Nathan, 1978).

The Brunner Coal Measures unconformably overlie the Paparoa Coal Measures. This sequence is predominately composed of quartz-rich sandstones, conglomerates, carbonaceous mudstones and interbedded coal seams and has been dated Eocene in age (43 to 37 m.y) (Nathan, 1978).

Pyrite (FeS_2) in the Brunner Coal is primarily responsible for the formation of acidic run-off and high concentrations of iron at Bellvue. However, the exposure of surrounding lithologies as a result of mining, has led to abnormally high concentrations of Al, Mn, Zn and Ni in AMD discharge into Cannel Creek.

Diversion well function

Limestone diversion wells are a common form of passive treatment of acid mine drainage. Basic design and system function of a diversion well is described by Arnold (1991) and Schmidt and Sharpe (2002). A typical well consists of a circular casing, often sunk into the ground at a shallow level alongside a stream. Water is forced into the well by having an elevation difference that creates hydraulic head. This often involves damming water upstream. The water is flushed into the centre of the well through a pipe and exits the pipe near the bottom of the well. The water then flows upwards, fluidizing the limestone substrate. Calcium carbonate reacts with the contaminated water to raise the pH and increase alkalinity, thus allowing for the removal of metal contaminants. Treated water is then piped from the well back into the stream (Fig.3) (Arnold, 1991; Schmidt & Sharpe, 2002). A diversion well is usually 2/3 full of limestone, which needs to consist of greater than 85% of calcium carbonate for optimal results (Schmidt & Sharpe, 2002). This form of passive treatment is effective in that it treats acid mine drainage quickly, without long residence time, it does not require large amounts of space to install and is of low cost. However, regular maintenance is required to replace limestone and to clear any vegetation debris that can block the well intake (Arnold, 1991; Schmidt & Sharpe, 2002).

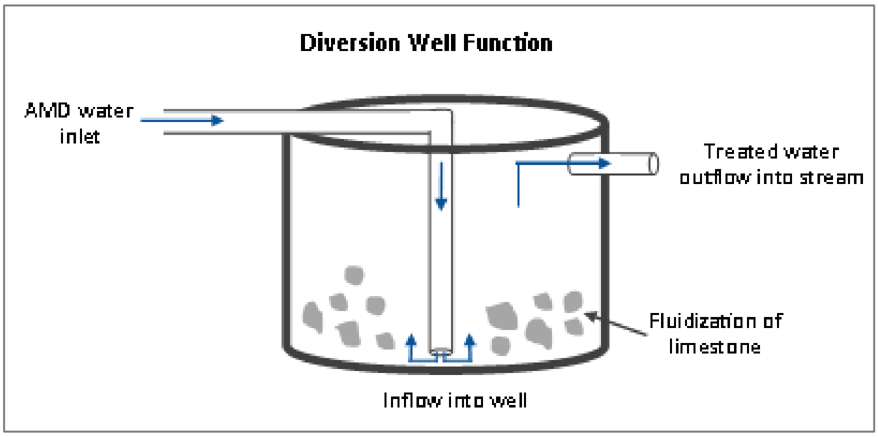

Figure 3. Schematic diagram of a diversion well design and function. Contaminated waters from an upstream dam flushed down central pipe into limestone substrate, allowing for neutralization of acidic water. Treated water is then flushed through an outlet pipe back into stream.

The initial installation of a diversion well at Bellvue involved setting up a barrel (0.8 m high x 0.4 m diameter) to use as a well (Fig. 4). Acidic mine water is siphoned directly from the pooled mine waters at the mine adit and enters the well down a central 50 mm inlet pipe. The inlet pipe sits on the bottom of the well and is perforated near the bottom with 10 mm holes, equalling the cross-sectional area of the inlet pipe. A perforated inlet pipe allows better dispersal of water throughout the well and therefore, more effective fluidization of the substrate. The well is one half full of substrate (both limestone and mussel shells trialled separately). Water is then flushed into the substrate where neutralization reactions start to take place. A 50 mm outlet pipe at the top of the well pipes the water from the well into a settling pond (1000 L IBC). The settling pond allows for increases in residence time of water in the system, where the finer substrate flushed out of the well will have more time to dissolve and produce alkalinity. Treated water then leaves the settling pond at the base and is channelled into Cannel Creek.

Figure 4. A. Image of diversion well with inlet piping AMD and an outlet allowing flow into settling pond. B. Image of IBC used as a settling pond. Water from well piped into top of settling pond, treated water outflow at base into Cannel Creek. C. Image of perforated 50 mm inlet pipe into diversion well.

Limestone and mussel shell substrates where trailed in the system. 50 L of 0 – 5 mm limestone was added to the well. The system was turned on to allow water flow. Water quality parameters (pH, electric conductivity and dissolved oxygen) and chemical sampling of inlet and treated outlet water was carried out (total metals, dissolved metals and sulphate samples taken from settling pond outlet water) at 15-minute intervals over 30-minutes. The limestone was then emptied from the well and replaced with 50 L of 4.5 – 12 mm mussel shells. Water quality parameters and chemical sampling was then repeated.

Preliminary results

Water quality and chemical analysis results show comparison between limestone and mussel shell substrates and the changes in water chemistry over a 30-mintue period. Initial chemical analysis and water quality results are shown in table 1 below.

Table 1. Chemical analysis and water quality parameters of treated acid mine drainage allowing comparison of limestone to mussel shell substrates. * Indicates the results for the dissolved fraction is greater than the total fraction, but within analytical variation of the methods.

	Total Metals (g/m^3)					**Dissolved Metals (g/m^3)**					**Water quality parameters**			
	Fe	**Al**	**Zn**	**Mn**	**Ni**	**Fe**	**Al**	**Zn**	**Mn**	**Ni**	**Sulphate (g/m^3)**	**pH**	**EC (µS/cm)**	**DO (%)**
Inlet AMD	84	39	0.33	0.72	0.130	83	40*	0.34*	0.82*	0.137*	740	2.71	1100	37.4
Limestone Initial (0 minutes)	43	14.1	0.23	0.78	0.121*	22	0.168	0.198	0.81*	0.122*	1,970	5.81	976	68.2
Limestone After 15 minutes	56	32	0.27	0.69	0.119	53	32	0.27	0.76*	0.121*	700	3.04	1047	55.1
Limestone After 30 minutes	56	33	0.27	0.69	0.121	55	33	0.27	0.76*	0.125*	710	2.89	1122	52.7
Mussel Shells Initial	62	34	0.27	0.68	0.123	61	35*	0.28*	0.75*	0.121	690	2.91	1065	32.7
Mussel Shells After 15 minutes	61	34	0.28	0.67	0.120	61	35*	0.28	0.76*	0.126*	700	2.83	1144	49.1
Mussel Shells After 30 minutes	62	34	0.27	0.68	0.121	60	36*	0.27	0.77*	0.127*	690	2.80	1162	48.7

The limestone did fluidize well in the diversion well. A lot of the finer grains were flushed into the settling pond. However, this current set-up did not allow for these fines to remain in the system and were therefore, flushed out into Cannel Creek. The initial chemistry showed immediate improvements in water quality; metal concentrations and electrical conductivity decreased, the sulphate concentration, pH and dissolved oxygen increased. However, as fine material continued to leave the settling pond, less fine material was left available in the system for rapid neutralisation reactions to occur. Subsequently, dissolved metal concentrations and water quality parameters showed decreasing improvement over the 30-minute period.

The mussel shells did not fluidize. Very little fine material was leaving the diversion well and flowing into the settling pond. As a result, dissolved metal concentrations and water quality parameters showed little improvement.

As a preliminary set-up of the diversion well system at Bellvue, several aspects need to be improved over time to increase the efficiency of operation. The residence time needs to be increased to allow neutralisation reactions to occur for longer periods of time. For the mussel shells to be effective, a finer grain size is likely necessary to achieve optimal fluidization results and therefore, improvements in water chemistry. This research project is ongoing and aims to achieve a fully functional diversion well system that can remain long-term at the site as a semi-passive treatment of acid mine drainage.

Acknowledgements

This research was financed by OceanaGold and the Ministry for Business, Innovation and Employment, Contract CRLE1403. Access to the mine site was provided by MBD Contracting and Solid Energy New Zealand.

References

Arnold, D.E. (1991). *Diversion wells- A low cost approach to treatment of acid mine drainage*. Proceedings of 12th Annual West Virginia surface mine drainage task force symposium, WV Mining and Reclamation Association, Charleston, WV, USA, pp 39-50.

Land Information New Zealand. (2016). Topo250 Map 17 Greymouth. Retrieved from http://www.linz.govt.nz/land/maps/linz-topographic-maps/

Nathan, S. (1978). Sheet S44 Greymouth (1st ed). Geological Map of New Zealand 1:63 360. Map (1 sheet) and notes (36 p.). N.Z. Department of Scientific and Industrial Research, Wellington.

Schmidt, K. & Sharpe, W. (2002). Passive treatment methods for acid water in Pennsylvania. Penn State College of Agricultural Sciences, Agricultural Research and Cooperative Extension. Retrieved from http://extension.psu.edu/publications/uh157

Trumm, D. & Cavanagh, J.E. (2006). Investigation of remediation of acid-mine-impacted waters at Cannel Creek. Land Care Research Report: LC0506/169, prepared for West Coast Regional Council.

West, R. (2014). Trialling small-scale passive systems for treatment of acid mine drainage: A case study from Bellvue Mine, West Coast, New Zealand (Master’s thesis, University of Canterbury, Christchurch, New Zealand). Retrieved from https://ir.canterbury.ac.nz/handle/10092/10907