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Acid Mine Drainage in New Zealand

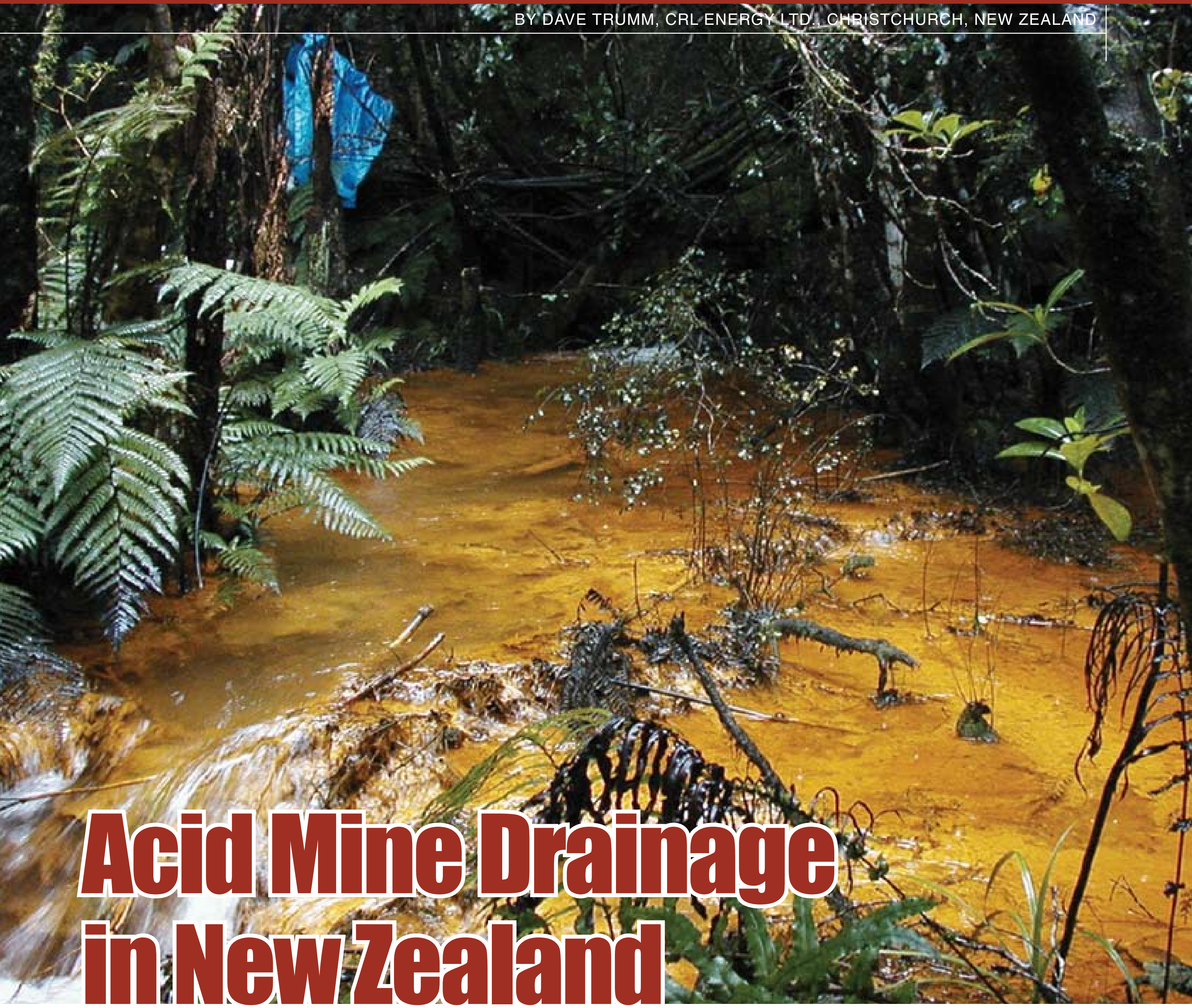

Figure 3. AMD at the abandoned BlackBall mine near Greymouth. Flow rates vary between 30 and 100 L/s.

Introduction

Acid mine drainage (AMD) associated with coal mining has been a difficult problem to solve in much of the world. Although research and application of remediation systems has been ongoing for over 40 years in the eastern USA (Ziemkiewicz et al. 2003; Sengupta 1994), other places in the world have not been so lucky. This can be for various reasons, including: little money available for research and remediation, minimal or no regulations for AMD discharge to river systems, or possibly no recognition that it is even a problem. AMD has become a serious problem in New Zealand over the last few decades, and efforts to curb the pollution have begun. This article provides a brief background on the extent and importance of coal mining in New Zealand and a short review of research and remediation efforts which have aimed to solve the AMD problem downunder.

Extent of Coal Mining in New Zealand

New Zealand agriculture, cement, timber, and general industrial processing all rely on coal to power their plants. Coal use for electricity generation has always been relatively low, however, in recent years with low levels of water in hydroelectric lakes, coal has been increasingly used to meet growing energy requirements. Permitting for a new coal-fired power plant has recently begun for the West Coast on the South Island. Although coal use is prominent in New Zealand, the majority of the high quality coking coal is exported to steel mills in Japan.

In New Zealand, coal is mined using two basic extraction methods: surface mining (open cast) and underground mining (hydromining and bord and pillar methods). Most of the historic mining was underground, while most of the current mining today is by open cast techniques.

Most of the economic coal resources of New Zealand are restricted to the northern and western regions of both the North Island and the South Island. The seven coal regions of the country are: Northland, Waikato, Taranaki, Nelson, West Coast, Canterbury, Otago, and Southland (Figure 1). Large lignite resources occur in Central Otago and Eastern Southland, whereas sub-bituminous coal is located in the Waikato Coal Region, the Taranaki Coal Region, and in Western Southland. Bituminous coals are located primarily in the West Coast Region. Quality values for typical bituminous coal are: 13,000 Btu/lb, 58 percent carbon, 7 percent moisture, 0.8 percent to 4 percent ash, and 0.2 percent to 1.6 percent sulfur. For sub-bituminous coal, typical values are: 9,300 Btu/lb, 38 percent carbon, 23 percent moisture, 2 percent to 11 percent ash, and 0.1 percent to 3 percent sulfur (Barry et al. 1994).

The Waikato Region in the North Island and the West Coast Region in the South Island are the biggest suppliers of coal and the majority of the high-quality bituminous coal comes from the Buller Coalfield in the West Coast Region (Figure 1). Within the Buller Coalfield, the Denniston and Stockton areas have been the most extensively mined using both underground and open cast methods. The Stockton Plateau contains the location of the biggest coal mine in New Zealand (Stockton No. 2). The mines on this plateau are currently operated by Solid Energy New Zealand Limited (SENZ). Approximately 40 million tons of coal was mined in New Zealand in 2005, with 60 percent being exported and the rest going to domestic uses for heating (10 percent), manufacturing and other industrial domestic uses (30 percent).

Figure 2. Typical West Coast topography.

Occurrence of AMD

As would be expected, the majority of AMD coincides with the major coal-producing region in New Zealand, the West Coast of the South Island. Within this region, however, lithologic variation and mining techniques influence the occurrence and chemistry of AMD (Pope, Newman and Craw 2006).

Coal dominantly occurs on the West Coast within the Brunner Coal Measures (mostly to the north) and the Paparoa Coal Measures (mostly to the south). Differences in depositional environments and diagenetic processes between these two formations result in a generally greater occurrence of AMD from the Brunner Coal Measures. The Paparoa Coal Measures were deposited in a fluvial to lacustrine environment, where rapid accumulation of sediments preserved co-deposited carbonate rocks, whereas the Brunner Coal Measures were deposited in an estuarine environment, in which reworking of sediments was unfavorable for the preservation of carbonate- bearing rocks (Pope, Newman and Craw 2006). Post deposition, the Paparoa Coal was enriched with carbonate minerals, whereas the Brunner Coal was enriched with pyrite from overlying marine sediments. Therefore, the absence of carbonate rocks and enrichment with pyrite results in a greater occurrence of AMD from the Brunner Coal Measures.

AMD from open cast mines hosted in the Brunner Coal Measures typically has a higher aluminum to iron ratio than AMD from underground mines (Pope, Newman and Craw 2006). The Al:Fe ratio is typically greater than two in open cast mines and less than four in underground mines. It is hypothesized that the reaction between H2SO4 (produced by pyrite

Figure 4. AMD at the abandoned Sullivan Mine north of Westport. Flow rate averages about 30 L/s and is considered a low-flow site.

oxidation) and aluminum-bearing silicate minerals in the coal measures – such as clays and feldspars – proceed more rapidly and to a greater extent in open cast mines because coal measure sediments are more disturbed in mine pits compared to underground mines.

Difference between AMD in New Zealand and Eastern USA

There are two major differences between the dominant AMD-producing region in the USA (Pennsylvania and West Virginia) and New Zealand, which affect the AMD: topography and climate. The topography along the West Coast rises steeply from sea level to over 700 meters (2,300 feet), and is mostly cloaked in thick, protected, native rainforest (Figure 2). Mining sites are usually situated in the higher reaches and are often very remote. The dominant westerly winds off the Tasman Sea results in a high-rainfall climate with very low temperature seasonality. Rainfall on the Stockton Plateau is, approximately, 7 meters (275 inches) per year.

This topography and climate results in AMD with very high flow rates, sometimes coupled with rainfall events, in locations with very limited space for remediation (Figures 3, 4, 5, 6). The isolation of mining sites, along with the low population on the West Coast, results in an AMD legacy that is largely hidden from public view and does not impact on the clean-green image of New Zealand. It is estimated, however, that approximately 125 kilometers of streams are adversely affected by AMD (James 2003; Figure 7).

State of Assessment and Remediation of AMD

AMD in New Zealand has been studied for many years. Most of these studies either focus on the geochemistry of AMD or the effects of the AMD on the aquatic ecosystem, and the majority of the research is conducted by academics from various universities in New Zealand. A few non-governmental research organizations, such as CRL Energy Limited, also conduct AMD research. Some of the more significant publications on these subjects are Winterbourn (1998), Lindsay, Kingsbury, and Pizey (2003), Harding and Boothryd (2004), Hughes et al. (2004), Harding (2005), and Pope, Newman and Craw (2006).

In contrast to assessment of AMD, very little remediation has been accomplished in New Zealand. The majority of attempts have consisted of small-scale pilot studies. An early reference to AMD treatment is an active treatment system that was constructed at the Golden Cross Mine site to treat AMD with moderate pH levels (about 5) but high concentrations of iron and manganese (Goldstone and MacGillivray 2002). The treatment consisted of aeration followed by addition of calcium oxide to raise the pH and promote removal of iron and manganese. A bioreactor was also constructed at the site, but results to date show that the system was not adequate for removal of manganese. Internal reports have been produced for SENZ regarding installation and performance of an anoxic limestone drain (ALD) that was installed at the Bennydale Mine site, but no external publications on the success of this system are known. Periodic dosing

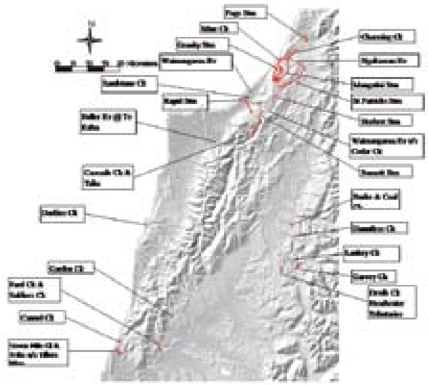

Figure 7. Map of known streams impacted by AMD in the West Coast Region.

of low-flow, moderate pH AMD (pH 4) with calcium oxide has been reported at the Malvern Hills Coal Mine (Bell and Seale, 2004). Small-scale trials of an ALD and limestone dosing system are currently underway at the Stockton Mine site.

Aside from the above-referenced work, other remediation attempts include several pilot studies and one full-scale system by the author. Small-scale remediation systems consisting of an ALD, vertical flow wetland (VFW), and an open limestone channel (OLC) were constructed at the abandoned Sullivan Mine (Figure 4) with the goal of determining an optimum remediation strategy for full-scale implementation (Trumm, Black and Gordon, 2003; Trumm et al. 2003; Trumm, et al. 2005). The results of this work indicated that a VFW may be the best solution for the Sullivan Mine, however construction of the full-scale system has not yet begun. Laboratory experiments were conducted suggesting that a limestone leaching bed may be successful in treating AMD from the abandoned Blackball Mine near Greymouth (Figure 3; Trumm and Gordon, 2004). Another small-scale VFW was constructed at the Pike River Coal Mine adit and operated successfully for six months (Trumm, Watts and Gunn, 2005; Trumm, Watts, and Gunn, 2006). A full-scale VFW was constructed at the site in July 2006, however no publications have yet been produced on the success of the system. Finally, small-scale systems consisting of a limestone leaching bed (LLB), a VFW, an OLC, and a diversion well were constructed at the Herbert AMD site at the Stockton Mine in 2006. Both the VFW and the LLB performed well and a full-scale LLB is currently being constructed at the site.

Why is there so Little AMD Remediation in New Zealand?

There are several reasons. There is no remediation fund specifically for AMD. Therefore, any efforts toward remediation are funded completely by the mining companies. Although New Zealand has a strong clean-green image overseas and has a strong green movement (the Green Party actually form part of the current government), regulations for AMD treatment and prevention are vague and enforcement is lacking.

Environmental regulations are driven primarily by the Resource Management Act 1991 (RMA; New Zealand Government, 1991) which does not specifically refer to AMD. Rather, the RMA states that contaminants cannot be discharged to the environment unless the local regional environmental authority (a regional council) has granted consent or unless the discharge is considered a permitted activity under the regional plan of the regional council. Mines existing prior to publication of the RMA have been allowed to continue to discharge AMD under their previous discharge agreement (if there was any in the first place). The regional council for the dominant AMD-producing area in New Zealand, the West Coast Regional Council (WCRC) has been in negotiations with mines existing prior to the RMA to help set limits for AMD. The process has encountered many difficulties as both the mining companies and the WCRC try to determine appropriate background levels for specific sites and appropriate and achievable targets.

For mines started after publication of the RMA, the WCRC typically sets discharge limits based on various water quality targets. These targets are sometimes site specific or are based on the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000). Inconsistent guidelines for setting discharge limits currently plague the industry and the WCRC. A research program is currently underway to help streamline this process (Black, Clemens and Trumm, 2004; Cavanagh et al. 2005). This program aims to incorporate a database of known AMD risk based on geology with threshold levels that affect the aquatic ecosystem and with known AMD treatment technologies. The database, along with the ecological work, will provide a tool that can be used by the mining industry and regulators to set appropriate resource consents for new mines.

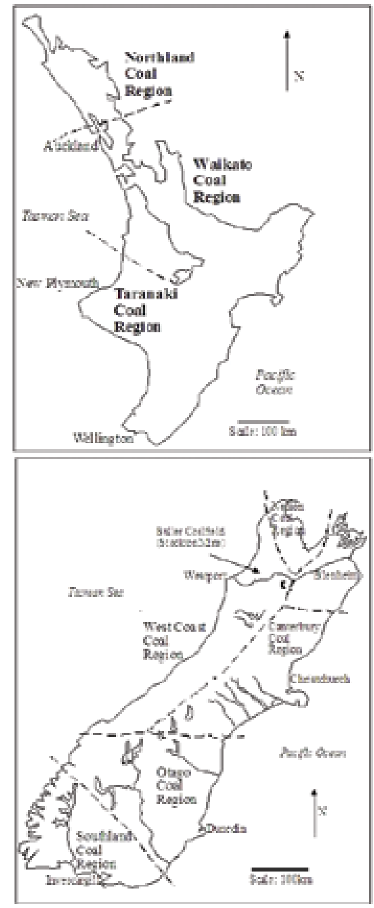

Figure 1. The coal regions of New Zealand.

Aside from the obvious difficulties with funding, regulations, and enforcement, there are other, perhaps more important reasons that the AMD situation in New Zealand has not improved much over the years. Coal mining is the backbone of the West Coast economy. Coal mining is the largest employer in the region and has been a respected industry for over 100 years. The effects of coal mining (such as AMD) are largely hidden from public view in a low-population region and the effects of AMD in local watersheds are not commonly recognized as a problem. The source of AMD is typically in steep terrain surrounded by protected native rainforests, which limits remediation options. Times, however, are changing. Current mining companies are volunteering to reduce impacts from active mine sites and the regional council is enforcing discharge limits for new mines. Abandoned mines with AMD will likely be the next target.

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