Te Kuha Opencast Mine - Geochemistry Review

5 August 2016

Department of Conservation
Te Papa Atawhai

O'Kane Consultants




Integrated Mine Waste Management and Closure Services
Specialists in Geochemistry and Unsaturated Zone Hydrology

Te Kuha Opencast Mine - Geochemistry Review

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EXECUTIVE SUMMARY

This report by O'Kane Consultants (NZ) Limited (OKC) provides a review of the geochemical risks associated with the proposed Te Kuha Coal Mine for the Department of Conservation (DOC). The purpose is to provide DOC with suitable information in regards to geochemistry to assess potential risks and inform decision makers about such risks associated with any subsequent Access Arrangement with the mine applicant (Rangitira Developments Limited).

Key Findings:

A number of issues have been identified by OKC that require further work or clarifications by the applicant. It is possible that some of these issues have been clarified in other reports that were not available for this review, or will be completed in reports being prepared by CRL Energy Limited. The key issues identified by this review include:

<u>Baseline Conditions</u>

- Elevated concentrations of metals (*e.g.*, Al and Cu) are evident in baseline stream water quality data and these data need to be considered for the establishment of water quality conditions.
- Aluminium concentrations are high, but may be in a non-toxic form, bound to dissolved organic carbon. Further work is required to understand any relationship as this could affect any water quality limits and objectives.
- Cu, Pb, and Zn are naturally enriched in groundwater in the area.
- Recommendations for further work are provided in Section 3.4 of this report.

<u>Waste Rock Classification</u>

- Based on the ABA data provided there is the potential for AMD impacted drainage from waste rock and possibly the coal associated with the proposed Te Kuha project. This suggests that an AMD Management Plan is appropriate. This plan should be adaptive in nature and it is reasonable that it could be provided as part of an annual work plan (AWP).
- Recommendations for further work in regards to acid base accounting are provided in Section 4.1.5 of this report.
- Column leach testing provides a rapid methodology to assess the water quality characteristics of a waste rock sample. It provides a good signature of the water quality and contaminants of concern. However, generally AMIRA-type column leach tests or field column leach tests (such as the type used for Te Kuha) often have much higher water:rock ratio's than would occur within a waste rock dump. Consideration of this effect needs to be acknowledged when applying such trial data to expected water quality. Further discussion of this matter is provided in Section 4.2.9 of this report.

- Elevated concentrations of nitrogen from nitrogen-based explosives should be considered in the water quality model.

- Recommendations for further work are provided in Section 4.2.10 of this report.

Overburden Management

- A clear mining schedule is needed, which should be linked to the volumes of waste rock (and geochemical types of waste rock) that will be placed in each dump such that NAF, PCM, and BCM can be separated and re-handled accordingly. The development of the waste rock dump design and schedule should be linked to the preliminary block model of the *in situ* waste rock. This should be updated as more geochemical and geological data become available through an adaptive management process. CRL Energy Limited (2015) note that a plan of the temporary waste rock dumps should be completed, which presumably relates to such matters.

- Little data or quantification of oxygen ingress rates or net percolation rates have been provided. These parameters provide an indication of ongoing sulfide oxidation and an expectation of the contaminant load reporting to the receiving environment. Further clarification of these rates is required.

- Recommendations for further work are provided in Section 5.2.2 of this report.

Prevention, Minimisation, Control

- There is limited discussion on methods to prevent, minimise and control the release of contaminants of concern (COC) such as designing the dump to minimise the release of COCs. It is noted that a report is in progress by CRL Energy Limited on the WRD design. This report should be reviewed.

- CRL Energy Limited (2016) state that the use of leachate chemistry in the GoldSim model is conservative and provides results that are similar to the range of values for mine drainage chemistry found at other mines where circum-neutral pH is present where the Pope *et al.* (2010) reference is quoted.

    - Further supporting argument is required to confirm that these analogies are reasonable, although such a comment seems fair and reasonable when compared to the dataset used.

- It is not clear how basal flows from the WRDs have been managed in the model. Such flow rates should be determined from numerical modelling (SPA modelling) or similar. It is likely these seeps from WRD's will have a relatively constant base flow and will be elevated in contaminants of concern, which will therefore have more pronounced effects during dry periods. These data (flow, quality, load) should be developed into a GoldSim site water model to consider effects on the receiving environment.

- Mine influenced water quality, based on three scenario's is presented in the CRL Energy Limited (2016) report (Table 9 of that report). OKC assumes these are reasonable scenarios for surface flows on the mine site, yet are probably optimistic in regards to basal drainage from the WRD. Further work is required to confirm water qualities from basal WRD seeps and the effects on the site-wide water balance model.

- Data presented as outputs from the water balance model suggest some metals (*e.g.,* Zn) may be elevated in the downstream receiving environment due to the mining activity.

- Recommendations for further work are provided in Section 6.4.3 of this report.

<u>Monitoring and Treatment</u>

- No monitoring programme (water quality parameters, frequency, and location) was available for review.

- No information was presented to discuss the treatment of COCs, although it was acknowledged that such contaminants may be elevated in site discharge waters. Further work is required in regards to treatment options and it is recommended this be considered using an adaptive management process and that conservative water quality from WRD basal seeps be used in any model

<u>Closure</u>

- Little data were available in regards to closure of the site and how the longer term effects of AMD will affect water quality or what if any treatment options will be required.
- It is recommended that an adaptive management process could be established for the project particularly for aspects that are uncertain or likely to change.

TABLE OF CONTENTS

LIST OF FIGURES

1 REVIEW BACKGROUND

1.1 Introduction

Rangitira Developments Limited (the Applicant) have requested an Access Arrangement with the Department of Conservation (DOC) for 12 hectares associated with a larger 109 hectare open cast coal mine, referred to as the Te Kuha Coal Mine having an estimated coal resource of ~ 4 million tonnes. DOC have indicated that for the purposes of the geochemistry review it could be difficult to separate out effects spatially so it is requested that the overall effects of the project be considered.

The review is based on the following documents supplied by DOC to OKC:

- 14-41213 Te Kuha Water Management – 26August2014JPope – submitted 2-9-14 (PDF) Te Kuha Concept Mine Probabilistic Drainage Model – West and Camp Ck (PDF). No appendices to this report were available;
- Te Kuha Mine Planning V7 3Sep15 Part 1 (PDF);
- Te Kuha Mine Planning V7 3Sep15 Part 2 (PDF); and,
- MP 41289 Aquatic Review – Streamlined 2014 – 21 Nov 14 (PDF).

It is requested by DOC that the key objectives of this geochemical review be:

- Review the sampling and surveys undertaken to date and overall methodology, ensuring that the approach is best practice and fit for purpose;
- Review the conclusions being made from the sampling and surveys and comment on whether they are both reasonable and robust;
- Review the water quality management and mitigation approaches being mooted to manage potential effects and comment on whether they are both reasonable and robust; and,
- Make suggestions/recommendations if OKC believe there may be better or more effective methods/approaches that could be implemented.

It is understood that a copy of the OKC peer review will be provided to the applicant for reference and further dialogue/discussion. OKC may be required to provide input in regards to geochemistry conditions associated with any Access Arrangement Contract.

OKC has not visited the site and this report is based on a desk-top assessment using the above supplied data.

1.2 Context

OKC will consider, based on the data provided, the ability to manage any adverse geochemical effects of the project, particularly those associated with Acid and Metalliferous Drainage (AMD). In this regard a review will be provided based on the hierarchical approach to the prediction, prevention, minimisation, control, and treatment of AMD at the proposed mine such that appropriate closure of the site is achieved at the end of mining activities. This will include a review of six key AMD management steps:

- **Prediction** of AMD, which is critical to understanding the potential and longevity of acid and metalliferous drainage and enables the development of an AMD strategy. Prediction is facilitated by geochemical analysis and interpretations and the production of a geological-geochemical model of the *in situ* waste rock that characterises and classifies the overburden according to its AMD potential. This model in turn is used to develop the waste block model from which the waste mining schedule is generated for the life of mine. This waste mining schedule facilitates effective mine planning such as the distribution and volume of AMD producing overburden and acid neutralising overburden and effective waste dump design for management of reactive waste.

- The **prevention** of AMD is achieved by preventing the interaction of the principal constituents of the AMD production process, namely sulfide minerals such as pyrite, with oxygen and water.

- Where prevention is not possible, the objective is to **minimise** the oxidation of sulfide minerals and flushing of stored acidic salts that can result in the formation of AMD.

- Any remaining AMD will be controlled to prevent the release of untreated AMD influenced water to the receiving environment. An important component of understanding whether **control strategies** are effective is monitoring of water quality and quantities, enabling calculation of contaminant loads.

- In the event of AMD migration from the waste rock there is a requirement for the **treatment** of AMD influenced water prior to discharge to the receiving environment.

- A key component for any AMD strategy is **planning for closure** to minimise legacy issues associated with in-perpetuity uncontrolled AMD.

These six AMD management steps were used to guide the geochemical review process for the Te Kuha Project and recommendations are based on these management steps. The Key Objectives will be considered for each of the six AMD management steps.

2 PROJECT BACKGROUND

2.1 Background

Streamlined Environmental Limited (2014) states the Te Kuha Limited Partnership requires access to land administered by the Department of Conservation (DOC), for the purpose of constructing and operating an open cast coal mine and associated infrastructure and that a separate application is required for an easement concession for the construction and operation of a haul road.

CRL Energy Limited (2014) state that Te Kuha Limited Partnership is the owner of Rangitira Developments Limited, which holds Mining Permit 41-289. Te Kuha Limited Partnership is a limited partnership with Stevenson Group Limited (SML) and Wi Pere Holdings Limited Partnership and SML have been appointed as the project coordinator and proposed mine operator (refer to CRL Energy Limited, 2016).

Streamlined Environmental Limited (2014) note that the access is for a period of 16 years associated with the mine life and an additional aftercare period of 10 years to cover all stages of the operation, including rehabilitation and closure of the mine. Stevenson Mining Limited (2015) indicate that the duration of the mine plan is 15 years with rehabilitation lasting until year 18. The Te Kuha project is located 12 kilometres south-east of Westport (Figure 2.1).

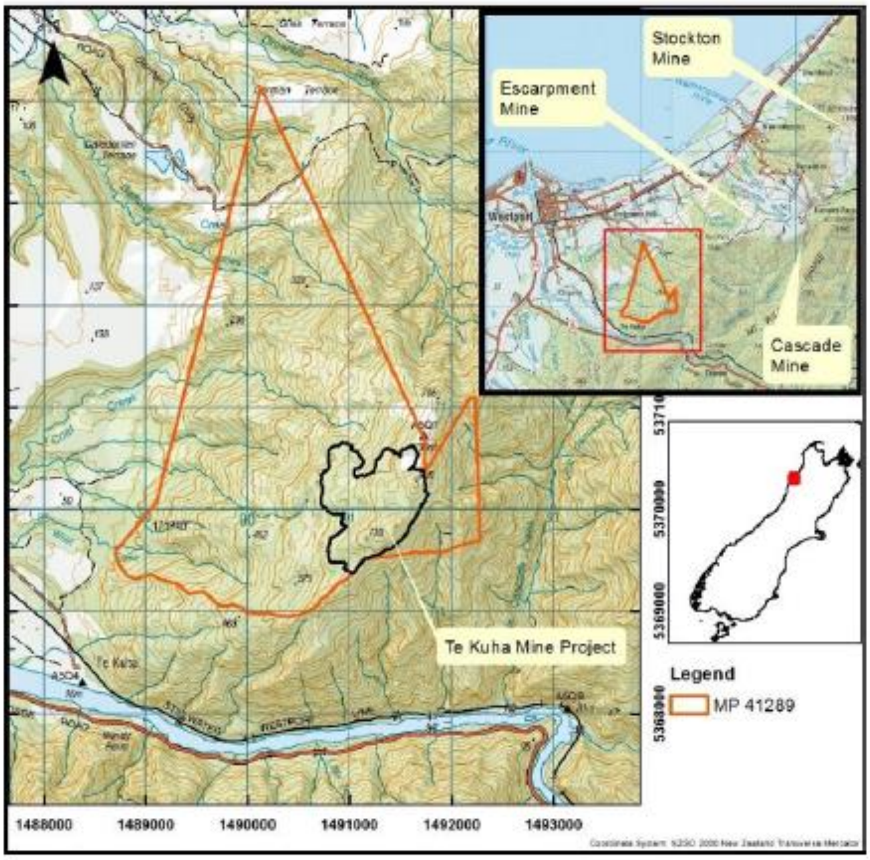

Figure 2.1: Te Kuha Proposed Mine Project Location

Source: CRL Energy Limited (2014)

CRL Energy Limited (2014) state that the Te Kuha deposit and the area that will be disturbed by mine operations lies within the tributaries of West Creek and Coal Creek on the western side of the ridge line. To the east, the upper parts of the Little Cascade Creek and the un-named tributaries to the Buller River also occur in the footprint of the proposed mine disturbance. The proposed mine footprint is 109 ha, with an additional 9 km of access road. A processing plant is proposed at Te Kuha near the Buller River and would be located on private land.

2.2 Mining Process

Two mine pits are planned as part of the project, which will target coals within the Brunner Coal Measures (BCM) and the Paparoa Coal Measures (PCM); in some instances these coal measures overlap, and where this occurs, the Brunner Pit will be mined first (Stevenson Mining Limited, 2015). The mine plan involves mining the coal in a series of mining strips (Figure 2.2). This method of mining will enable progressive rehabilitation of the mine site.

Two ex-pit waste rock dumps are proposed being 20.7 ha (Main Lower Dump) and 4.5 ha (Small Upper Dump) that will be used from year 5 onwards (Stevenson Mining Limited, 2015). Eventually both these dumps are amalgamated as they are joined and blended into the pit back fill material (Stevenson Mining Limited, 2015). It is proposed that 40% of the waste rock within these dumps will be returned to the pit as backfill

Based on the current mine plan, 15,205,614 tonnes of overburden will be disturbed over a 15 year mining life with additional waste rock management from years 16 - 18 associated with mine site rehabilitation (Stevenson Mining Limited, 2015). It is proposed that overburden will be re-handled (approximately 40% of the ex-pit waste rock) and will be returned to the pit where possible.

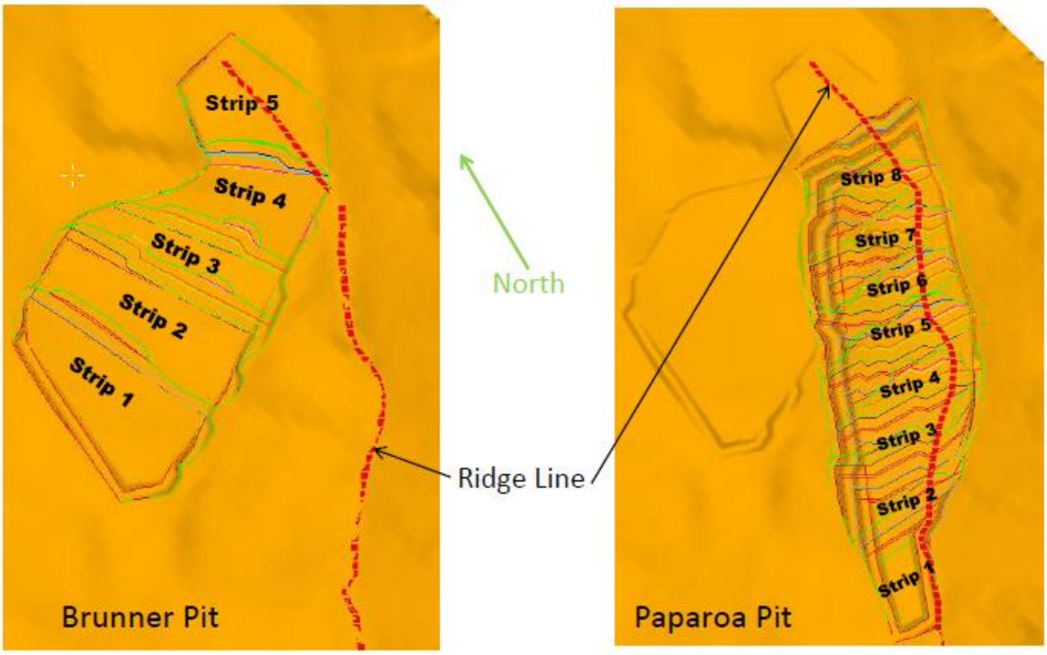

Figure 2.2: Proposed Mine Plan for the Te Kuha Mine

Source: Stevenson Mining Limited (2015)

3 BASELINE WATER QUALITY

3.1 Introduction

The current mining area has no previous mining activity and streams can be considered undisturbed from such activities. For the purposes of this review a dataset provided by Pope *et al.* (2010) was used to determine contaminants of concern associated with trace metals from coal measures of the West Coast. Pope *et al.* (2010) state that the concentration of trace elements in drainages from mines in the Brunner Coal Measures is enriched compared to background, especially in As, Cd, Co, Cr, Cu, Mn, Ni, and Zn. OKC note that based on the Pope *et al.* (2010) dataset, as compared to ANZECC (2000) guidelines for 95% protection trigger value, that a number of sites can also be elevated in Pb. These metals were used to assess baseline water quality for the project together with Fe, Al, and sulfate, being other typical constituents elevated in drainage waters from mines within the Brunner Coal Measures.

ANZECC (2000) trigger values (95%), where available, are used as an indication of any elevated contaminants of concern. No hardness modification is undertaken as the waters are classified as soft (< 60 mg/L $CaCO_3$ equivalent hardness) and Table A3 of the ANZECC guidelines indicate that the trigger value (TV) should be used.

3.2 Surface Water

3.2.1 Quality

CRL Energy Limited (2014) note that water quality in the upland streams is similar to water quality that drains Brunner Coal Measures in other places; pH is commonly low (~pH 4 – 5.5); there is little or no alkalinity; the concentrations of dissolved metals including Fe and Al is commonly high (0.1 – 0.5 mg/L); and trace element concentrations such as Mn, Ni, and Zn can be enriched compared to catchments that do not drain BCM. CRL Energy Limited (2016) reported aluminium ranges from 0.105 to 0.189 mg/L.

Streamlined Environmental Limited (2014) note that within the Te Kuha Project area pH ranged from acidic to near-neutral, with more acidic streams in the mountain sites and West Creek and that elevated metal concentrations (especially aluminium) were typical of waterbodies surveyed.

OKC note that elevated aluminium is common in brown water streams due to the low pH and aluminium being bound to organic acids present in the water (humic and fulvic acids). Further work should be done to determine any correlation with dissolved organic carbon and aluminium. The test to determine the dissolved non-purgeable organic carbon (DNPOC) would help quantify such relationships, if any. Elevated aluminium bound to organic acids is non-toxic to aquatic organisms. Any derivation of baseline conditions for aluminium should also consider aluminium speciation as this may affect any proposed consent limits for this metal.

CRL Energy (2014) provide data on the water quality of upland sites and lowland sites. This includes major components and trace elements (Tables 4,5,6,7 of that report). The report refers to a number of appendices. These were not available for this review. Key data relevant to this review are as follows:

Upstream Sites – Major Components

- A zero ("0") appears in Table 4 on a number of occasions. It is not clear what this means. If test result was below the Limit of Reporting (LOR) then the LOR should be presented and noted that this is the LOR;
- pH ranged from 4.1 to 6.5 with 80% of analysis between 4.5 and 5.2;
- Acidity ranging from 0 to 111 mg $CaCO_3$/L. OKC notes that this is not coincident with elevated EC or sulfate, which suggests organic acidity. CRL Energy (2014) note that these acidities did not correlate well with calculated acidity based on Fe, Al, and pH, which also suggests organic acidity (humic and fulvic acids). DNPOC testing should be undertaken to evaluate such organic acidity;
- Alkalinity is low and below 2.7 mg $CaCO_3$/L equivalent and thus indicates very little capacity to buffer any acidity introduced into the catchment by mining activities; and,
- Sulfate is low (typically 1 – 2 mg/L).

Downstream Sites – Major Components

- A zero ("0") appears in Table 5 on a number of occasions. It is not clear what this means. If it was below the LOR then the LOR should be presented and it should be noted this is the LOR;
- pH ranged from 6.0 – 7.6 being higher than the upstream sites;
- Acidity ranging from 1.8 – 8 mg $CaCO_3$/L;
- Alkalinity ranges from 3.4 – 18.8 mg $CaCO_3$/L equivalent, which is higher than upstream sites; and,
- Sulfate is slightly higher than upstream sites ranging from 1- 30 mg/L.

All Sites – Trace Elements

CRL reports reviewed note that 31 trace metals were analysed in water samples collected from upland and lowland streams. A general discussion is provided on these elements. OKC makes the following comments on the data and accompanying discussion:

- On numerous occasions a "0" appears in tables 6 and 7. It is not clear what this means. If it was below the LOR then the LOR should be presented. If this 0 is not the LOR then consideration should be given to the sample population size and its appropriateness.

- The CRL Energy Report indicates that Sb, Bi, Mo, Se, Ag, Tl, Ti, and V were below detection in all analyses completed. Detection limits have not been provided and it is unclear whether these limits of reporting (LOR) were higher than ANZECC guidelines. The LOR's should be provided.

- Data are available for contaminants of concern as identified from the Pope *et al.* (2010) study except for Cd, which is discussed in the text but no data are provided in Tables 6 and 7 of that report. Cd data should be provided.

- Cu is, in four instances, greater than the ANZECC (2000) 95% protection trigger value of 0.0014 mg/L threshold. This should be considered for establishing baseline conditions.

Average upland water quality data for streams within the project were summarised by CRL Energy Limited (2016) and are represented below in Table 3.1. From the data provided it demonstrates that water quality is not currently impacted by the effects of sulfide oxidation as evidenced by low sulfate, although pH is low and alkalinity is low meaning there is little ability to buffer acidity inputs. OKC note that data for metals such as Cd are not provided.

CRL Energy Limited (2016) note that the upland stream response to rainfall is rapid and demonstrates that during a rainfall event almost all rainfall is shed as runoff with slightly elevated creek flow for one to two days following rainfall events.

Table 3.1: Average upland water quality data for streams within the project area

Analyte	Units	ANZECC (95% TV)	Coal Creek	Landslide Creek	Camp Creek	West Creek
pH	S.U.		5.6	4.6	4.6	4.7
HCO_3^-	mg $CaCO_3$/L		2.9	1.3	1.7	1.6
Cl	mg/L		4.9	4.6	5	5.3
SO_4	mg/L		1	1.7	1.8	3.3
Ca	mg/L		0.27	0.2	0.23	0.15
Mg	mg/L		0.5	0.37	0.43	0.39
K	mg/L		0.23	0.28	0.18	0.16
Na	mg/L		3	3	3.1	3.3
Al	mg/L		0.105	0.189	0.189	0.180
As	mg/L	0.013	0.001	0.001	0.001	0.001
Fe	mg/L		0.27	0.01	0.17	0.4
Mn	mg/L	1.9	0.0113	0.0028	0.0022	0.0016
Ni	mg/L	0.011	0.0005	0.0005	0.0005	0.0005
Zn	mg/L	0.008	0.0031	0.0019	0.0024	0.0018

Source: CRL Energy Limited (2016); Table 4.

3.3 Groundwater

CRL Energy Limited (2014, 2016) note that two groundwater systems are present; an extensive deep permanent system, mostly occurring below coal; and, a shallow ephemeral system that is rainfall fed, discontinuous in time and space, perched and feeds the highest levels in stream beds and tarns.

CRL Energy Limited (2014) state that groundwater chemistry data from the samples collected to date mostly falls within the variability of surface water chemistry, indicating that groundwater processes are the dominant controls on water chemistry at Te Kuha at base flow conditions

CRL Energy (2014) provide data on the water quality of groundwater. This includes major components and trace elements (Tables 8 and 9 of that report). Key data relevant to this review are:

Groundwater – Major Components and Trace Metals

- pH ranged from 5.4 – 7.2;
- Alkalinity ranged from 3.2 – 49 mg $CaCO_3$/L;
- Acidity ranged from 3.4 – 28 mg $CaCO_3$/L;
- Sulfate was low ranging from 0.7 – 1.2 mg/L;
- Based on the calculated hardness waters would be considered soft (< 60 mg $CaCO_3$/L);
- Data are available for contaminants of concern as identified from the Pope *et al.* (2010) study except for Cd, which is discussed in the text but no data are provided in Tables 8 and 9 of that report. Cd data should be provided;
- Cu is, in four instances, greater than the ANZECC (2000) 95% protection trigger value of 0.0014 mg/L threshold;
- Pb is, in three instances greater than the ANZECC (2000) 95% protection trigger value of 0.0034 mg/L threshold; and,
- Zn, in all instances is greater than the ANZECC (2000) 95% protection trigger value of 0.008 mg/L threshold.

CRL Energy Limited (2014) note that groundwater depths measured to date are all beneath coal except TK5 and TK10, which are close to the ridge line towards the north of the deposit. It is assumed the groundwater quality data supplied for groundwater is from depth, beneath the coal.

CRL Energy Limited (2014) note that during dry periods many of the upland catchment streams are likely to have very low flows or remain dry and therefore high intensity rainfall events are the main water management challenges at Te Kuha from a volume perspective.

3.4 Discussion and Recommendations

A number of samples have been collected to provide an indication of baseline water quality for the site both in regards to surface waters and groundwater. In general, from the data provided, the streams in the area appear to have good water quality. More baseline data would be advantageous, especially as some contaminants of concern are elevated. A robust baseline dataset resolves any future issues that could arise around the initial quality of the waters at site.

Based on an abundant dataset provided by previous researchers it is expected waters impacted by any drainage from acid-forming materials could contain a variety of contaminants including Fe, Al, sulfate, acidity, elevated EC and low pH. A dataset provided by Pope *et al*. (2010) explains what contaminants of concern could occur from Paparoa and Brunner coal measures. Trace metals generally of concern for West Coast Coal Measures include As, Co, Cd, Cr, Cu, Mn, Ni, Pb, and Zn.

Results from testing indicate that:

- pH can be low at times, possibly due to organic acidity. Further investigations into organic acidity would be beneficial for understanding baseline conditions;
- Al is elevated, possibly due to the formation of dissolved Al-organic complexes. DNPOC measurements should be undertaken to understand such relationships if this is considered important;
- Cu is elevated currently in stream waters being greater than ANZECC (2000) 95% protection trigger values;
- Cu, Pb, and Zn are elevated in groundwater being greater than ANZECC (2000) 95% protection trigger values;
- Data for Cd is missing and should be provided for surface waters and groundwater;
- Any monitoring programme for metals and trace elements in the water should include pH, Fe, Al, As, Co, Cd, Cr, Cu, Mn, Ni, Pb, and Zn. Once there is confidence in trends and water quality the monitoring programme could be reduced to fewer parameters;
- Additional consideration should be given to sulfate and whether the effects of elevated sulfate would impact the downstream receiving environment (*e.g.,* is the lower reaches of the stream used for stock water); and,
- The baseline data can be used to develop consent conditions for water quality. This should be done in consultation with stream ecologists.

4 WASTE ROCK CHARACTERISATION

Waste rock characterisation is a key step in understanding whether there is likely to be poor water quality associated with geochemical reactions once overburden waste rock is exposed to atmospheric oxygen and water. There are numerous industry standard methodologies, although in Australasia, an industry standard document is the AMIRA (2002) ARD Test Handbook.

OKC note that the requirements for the AMD management plan is subject to their being potential for AMD or the release of other contaminants of concern from the coal and/or waste rock. If there is the potential, then the requirements for an AMD Management Plan is appropriate. Such a plan should be adaptive in nature and be provided as part of an annual work plan (AWP).

4.1 Acid Base Accounting

4.1.1 Introduction

A key aspect of waste rock characterisation is acid base accounting (ABA) where the net acid production potential (NAPP) is determined by the amount of acid neutralisation capacity (ANC) in the rock and the maximum potential acidity (MPA) of the rock:

NAPP = MPA – ANC (all units in kg H_2SO_4/t equivalent)

A negative NAPP indicates that the sample has a net neutralising capacity and can be considered non-acid forming (NAF) and a positive NAPP indicates that the sample has a net acid generating capacity and can be considered potentially acid forming (PAF). MPA based on sulfide sulfur is often a better approach for un-oxidised rock as this provides a more reasonable estimate of acid potential by ignoring non-sulfide forms of sulfur (although if acid-forming sulfate minerals are present these need to be accounted for). Other test methodologies are available such as the Net Acid Generation (NAG) test, although the NAPP calculation is considered a better tool for coal measures due to the formation of organic acidity in the NAG test. Further details of ABA methodologies are available in the published literature (*e.g.,* AMIRA, 2002).

CRL Energy Limited (2014) note that acid base accounting was completed by standard methods, being the AMIRA methodologies, which is appropriate.

4.1.2 Sampling Frequency

An AMD characterisation programme is generally implemented prior to mining to obtain necessary data for regulatory approvals in the initial instance, and then involves an ongoing testing programme to confirm the waste rock model and the current initial geological/geochemical interpretation for the site. The MEND guidelines of Price (1997) considers sample numbers versus tonnes of waste rock disturbed (Figure 4.1).

CRL Energy Limited (2014) state that 46 ABA tests have been undertaken, whereas the MEND guidelines would suggest ~100 would be more appropriate for a project of this size (~15 M tonnes).

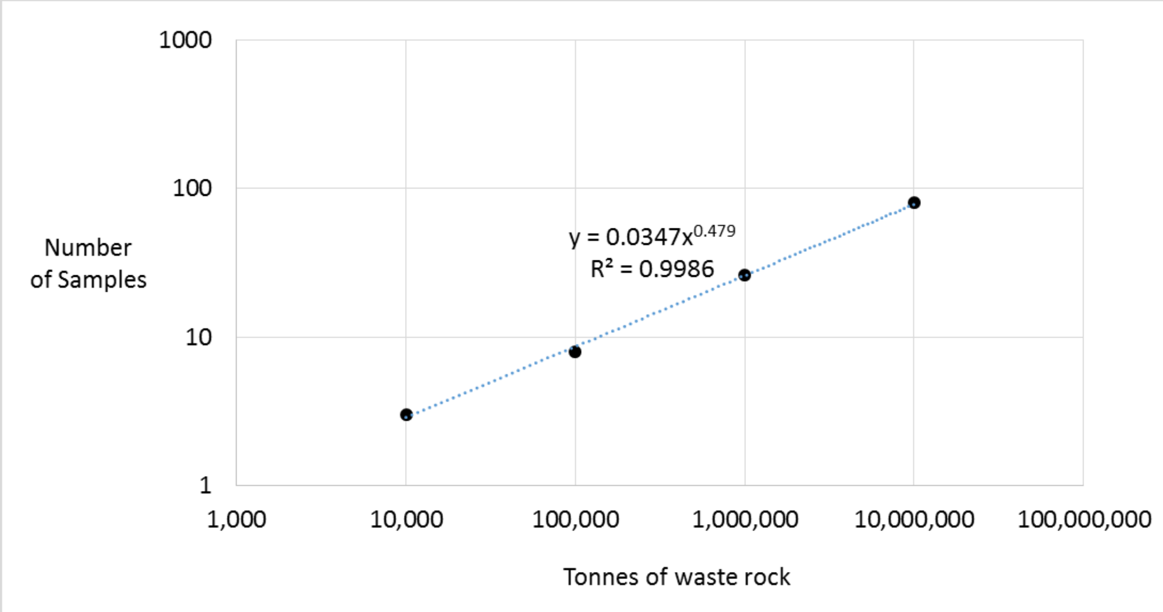

Figure 4.1: Price (1997) minimum number of samples for preliminary acid base accounting

Further ABA testing will be required as part of ongoing project development and during mine operations. However, it is reasonable to expect testing and sampling processes can be developed as part of an adaptive management plan for AMD.

CRL (2014) state that ABA samples collected to date are well enough distributed throughout the deposit to give confidence that the balance of acid to non-acid forming rocks have been identified. The provision of a model showing the distribution of these samples would be beneficial to confirm this assumption. Samples should be representative of:

- Both the BCM and PCM;
- The lithological variations in the BCM and PCM;
- The roof and floor rocks to the main coal seams; and,
- The coal, particularly if there are stockpiles or 50:50 stockpiles that will remain in place for extended periods of time.

4.1.3 Sample Population

A total of 41 samples are presented in Table 10 of the CRL Energy Limited (2014) report, although the same report notes there were 46 samples tested by ABA methodologies. It was noted on page 26 of the report there is an Appendix 4, although this was not provided, and perhaps the data are contained there.

ABA data were reviewed and there appears to be reasonable analysis of both the BCM and PCM. However:

- Five samples referred to as sulfide samples were presented, although no discussion was given to these, or where they came from;
- Four shallow weathered samples were tested. No discussion was provided on these samples;
- No ABA data have been presented for coal. Often coal may be stockpiled for extended periods of time; if it is elevated in sulfides these stockpiles can contribute to AMD impacted water. The Stevenson Mining Limited (2015) PowerPoint file indicates coal sulfur can be up to 1.22 wt% S. Testing should be undertaken to confirm ABA characteristics.
- No duplicates or QA/QC data were provided to support the robustness of laboratory methodologies and results.

4.1.4 ABA Data

It was noted by CRL Energy Limited (2014) that sulfur speciation was not undertaken and hence the use of total sulfur is conservative for acid base accounting. Such an approach is generally reasonable, although this can result in additional samples being classified as uncertain in regards to acid generating behaviour.

In general, compared to other sites in the region (*e.g.,* Stockton Mine, Escarpment Mine), the sulfur content for BCM is low at Te Kuha, on average equivalent to a MPA of 4 kg H_2SO_4/t, which means the risks of significant AMD impacted drainage from the proposed Te Kuha mine site are less. Lower risk should be acknowledged in any adaptive management process.

Data provided by CRL Energy Limited (2014) indicate parts of the PCM at the Te Kuha Project are PAF with an average MPA of 3 kg H_2SO_4/t, although the average ANC is 14 kg H_2SO_4/t. This means that AMD management processes need to be applied to both the BCM and PCM.

Data presented indicate that NAG acidity is often different to NAPP. No discussion is provided on these differences. It would be beneficial to see such data plotted against each other to understand any correlations.

CRL Energy Limited (2014) state "*negative ANC values are present in the laboratory report from the BCM samples perhaps indicating that there are secondary acidic salts present. However, paste pH values remain high*". These negative ANC values have not been presented in Table 10 of the CRL Energy Limited (2014) report for review, however such data (excluding the potential for laboratory error) would suggest acidic salts are present. As noted by CRL Energy Limited, paste pH data are circum-neutral, which suggests that the risk from acidic salts may be minor. Further analysis is required. The formation of acidic salts and other oxidation products have implications for AMD management in that oxidation of the rock is not necessary for poor water quality.

The classification of a number of NAF samples is considered marginal. It is common practice to assume more ANC is required than MPA for a non-acid forming WRD as the WRD will typically export alkalinity that then is no longer available for neutralisation of acidity associated with sulfide oxidation.

A number of samples are classified as uncertain based on NAPP versus NAG classification (CRL Energy Limited (2014) Report; Figure 155). As previously encountered at other operations a better approach is to develop a site specific systematic process flow classification, which will reduce the number of samples being classified as uncertain in regards to being non-acid forming or acid forming (*e.g.,* such an approach was used at the Escarpment Coal Mine; Olds *et al.,* 2015).

CRL Energy (2014) note that the re-handling of waste rock during final rehabilitation at the Te Kuha deposit could release acidity. Re-handling of waste rock containing stored oxidation products may be an issue if it is part of the upper groundwater zone and enables rapid mobilisation of stored oxidation products to waterways. ABA testing should be undertaken to confirm the stored acidity and methods developed to minimise formation and release of contaminates of concern.

4.1.5 ABA Recommendations and Further Work

The following recommendations are presented:

- Based on ABA data provided there is the potential for AMD impacted drainage from waste rock and possibly the coal associated with the proposed Te Kuha project. This suggests that an AMD Management Plan is appropriate. This plan should be adaptive in nature and it is reasonable that it could be provided as part of an annual work plan (AWP).

- A model should be provided that shows the samples are representative of the deposit, including lithologies, floor and roof rock, and coal.

- Undertake sulfur speciation testing to understand sulfur forms including organic, sulfide, and sulfate forms. A large number of analyses are not required, but sufficient to understand the general proportions. This will help with classification of uncertain samples (based on NAPP versus NAG pH) and reduce model conservatism.

- Provide ABA data relating to negative ANC values and additional supporting data as required to confirm whether the acidic salts are a function of laboratory processes or sample ageing and the significance of such results.

- Ongoing ABA accounting as part of the mine development process and any subsequent mining operations, which should provide a suitable number of samples and data for refinement of the waste rock model and mine scheduling.

- Development of a QA/QC process for ABA laboratory testing.

- Development of a waste rock geochemical classification scheme for the project, which is linked to the waste rock model to determine the tonnes of NAF, low-acid forming PAF, and high-acid forming PAF waste rock. The classification scheme should minimise the number of samples being classified as uncertain.

- The waste rock model should be developed from existing data to provide a best estimate of the tonnes of waste rock present in the current mine plan, which should be used for mine scheduling.

- A plan should be developed to manage any stored oxidation products present in the waste rock before it is re-handled back to the pit. CRL Energy Limited (2015) note that a geochemical study will completed prior to re-handling and that new management options might be required. These management options should be reviewed. Such options could be considered under an adaptive management strategy based on these geochemical studies.

4.2 Field Column Leach Testing

4.2.1 Introduction: Field Column Leach Testing

CRL Energy Limited (2104) ran five field column leach tests using 23 kg of waste rock (< 10 mm) in buckets established over a 200L drum at the base of the hill between the Te Kuha Project and Westport. These trials were undertaken to predict leachate chemistry at the proposed Te Kuha Mine during mining operations.

The trials included three rock types from the BCM and two rock types from the PCM. ABA data for these trials are provided in Table 4.1. Results indicate that the BCM columns are PAF based on NAPP and NAG and the PCM columns are NAF based on NAPP and NAG.

Table 4.1: ABA data for the CRL Field Columns

Column	Description	MPA	ANC	NAPP	NAG	NAG pH	Paste pH
		kg H_2SO_4/t	*kg H_2SO_4/t*	*kg H_2SO_4/t*	*kg H_2SO_4/t*	*S.U.*	*S.U.*
1	Sandstone BCM	0.3	0	0.3	11.8	4.8	7.1
2	Mudstone BCM	1.5	0	1.5	5.5	5.5	5.6
3	Mudstone BCM	4.9	0	4.9	47	2.9	5.1
4	Fine grained PCM	6.1	18.2	-12.1	0	7.1	6.4
5	Coarse grained PCM	3.7	15.5	-11.8	0	8	7.4

Source: CRL Energy (2014)

As shown in Table 4.1, the BCM rocks tested have no measurable ANC and a paste pH values < 5.5, which is lower than any ABA data presented in Table 10 of the CRL Energy Report (2014). Paste pH values < pH 5.5 suggest the presence of stored acidic oxidation products.

ANC data should be provided for these columns, presumably there is a LOR for ANC. If negative ANC data were recorded these should be presented as such acidity would report during the initial flushes of the waste rock in the field column trials (which was masked by HCl).

CRL Energy Limited (2014) indicate that only Column 3 rocks would be classified as PAF whereas Column 1 and Column 2 contain rocks that would be classified as uncertain. Although columns 1 and 2 have low NAPP values they are still considered PAF by ABA methodologies.

PCM columns have ANC:MPA ratios of ~3-4:1 indicating good capacity to neutralise acidity.

4.2.2 Field Column Leach Testing Results

Complete datasets are not available for the field column leach test and would have been beneficial for the purposes of this review, however, general summary data have been provided in Table 12 of the CRL Energy Limited (2014) report.

Initial field column leach test data results were compromised by inadequate rinsing of the field column leach test apparatus after acid washing using HCl, which affected at least the first two data points from the five field columns. Initial flush results are important data for column leach tests, which may have quantified stored oxidation products and acidity. First flush data can be used as an indicator of poor water quality from waste rock and can be used to model short term water quality. First flush data can be used as a conservative scenario for longer term water quality to generate boundaries for longer term adaptive management options.

CRL Energy Limited (2014) explains how the hydrogen ion acid generated was calculated based on chlorine present in the leachate and the resulting pH expected (Table 4.2). OKC undertook such calculations and obtained similar results.

Table 4.2: Chlorine concentration converted to pH

Parameter	Value	Units
Measure Chlorine in leachate	180	mg/L
Measure Chlorine in leachate	0.18	g/L
Measure Chlorine in leachate [Cl]	0.005077574	mol/L
Equivalent H+ ions [Cl] =[H+]	0.005077574	mol H
[H+] concerted to pH	2.29	pH

Data sourced from page 49 of the CRL Energy Limited (2014) report

The review of the CRL report for the column leach data was limited in that the Appendix 5, presumably containing the data, was not supplied for the purposes of this review. Furthermore:

- Data in the supplied graphs are often expressed in units of kg/tonne. Without the volume of leachate it is difficult to determine concentrations. It is preferable that such data also be supplied on a concentration basis (*e.g.,* mg/L) as these data can then be directly applied to water quality standards.

- No information is provided to validate the accuracy of the data presented; *e.g.,* laboratory QA/QC.
- Data relating to potential contaminants of concern as identified from the work of Pope *et al.* (2010) are not available for review. Data relating to As, Cd, Co, Cr, Cu, Mn, Ni, Pb, and Zn should be presented and discussed.

4.2.3 Column 1 – BCM - PAF

CRL Energy Limited (2014) indicate that acidity as measured was low due to low Fe and Al in solution and that acidity was essentially driven by pH, which seems reasonable given the low sulfur content and potential MPA. The pH of the leachate increases with time; Fe and Al decrease with time.

It is indicated that Zn is the most elevated trace element having measured concentrations in leachate of 0.049 – 0.56 mg/L. Such Zn discharge rates are greater than ANZECC (2000) 95% protection trigger value of 0.008 mg/L. Zn and Ni remain reasonably constant with time.

It is indicated that Cu is high in the first sample being 0.01 mg/L, which is greater than ANZECC (2000) 95% protection trigger value of 0.0014 mg/L.

4.2.4 Column 2 – BCM PAF

After the first flush there is a decrease in Fe and Al and acidity. Sulfate decreases with time. CRL Energy Limited (2014) indicate that pH is generally between 4.3 and 5.4, and is generally increasing. MPA is generally low for this sample.

Trace elements generally decrease with time. Zn is elevated at 0.01 – 0.4 mg/L, which is greater than ANZECC (2000) 95% protection trigger value of 0.008 mg/L. Cu is elevated initially at 0.014 mg/L, which is greater than ANZECC (2000) 95% protection trigger value of 0.0014 mg/L.

4.2.5 Column 3 – BCM PAF

The pH of leachate is between 4 and 4.3. CRL Energy Limited (2014) notes that acidity is derived from pH and Al and not Fe. This is reasonable based on pH where Al would be mobilised (< pH 5).

Sulfate is higher than in the other BCM PAF samples, which agrees with slightly higher MPA data and thus sulfate content.

Zn is high at 0.15 – 1.33 mg/L, which is greater than the ANZECC (2000) 95% protection trigger value of 0.008 mg/L. Other metals such as Cu, Pb, and Ni have concentrations greater than 0.01 mg/L, which are elevated compared to ANZECC (2000) guidelines.

4.2.6 Column 4 – PCM NAF

Data indicate that pH increases with time, although the trend is obscured by the HCl acidity affecting the initial two washes.

Sulfate is high decreasing from 54 to 10 mg/L.

Zn is high ranging from 0.006 – 0.25 mg/L, which is greater than ANZECC (2000) 95% protection trigger value of 0.008 mg/L. Cu and Ni are greater than 0.01 mg/L which are elevated compared to ANZECC (2000) guidelines.

4.2.7 Column 5 – PCM NAF

Data indicate that pH increases with time, although the trend is obscured by the HCl acidity affecting the initial two washes.

Sulfate is the most abundant anion (CRL Energy Limited, 2014).

Zn is high ranging from 0.05 – 0.5 mg/L, which is greater than ANZECC (2000) 95% protection trigger value of 0.008 mg/L. Cu, Ni, and Pb are greater than 0.01 mg/L which are elevated compared to ANZECC (2000) guidelines.

4.2.8 Field Column Summary

CRL Energy Limited (2014) indicate that in general the leachate water quality is comparable to the natural drainages from the upland stream sites with similar pH ranges and similar anions and cations. CRL Energy Limited (2014) summary notes the following:

1. With the exception of elevated Al and Zn concentrations, the water quality in leachate is likely to cause only minor environmental impacts if it were discharged directly to the receiving environment compared to all other mines in the Brunner Coal Measures.

    - OKC note that the comparison to other mines is fair, however, the Te Kuha site is currently not affected by mining activities and the data suggest that trace metals can be elevated (as compared to ANZECC (2000) trigger values). Further consideration is warranted.

    - Confirmation that WRD water quality (discharging as basal seepage) is comparable to field column leach testing is required. This is particularly important for such rocks where water quality of net percolating waters may become concentrated and is unimpeded by secondary mineral solubility constraints.

2. CRL Energy Limited (2014) acknowledges that if contaminants of concern are present in leachate that could cause substantial environmental impact, then alternative waste rock handling processes might be implemented to improve water quality.

- From the data provided it appears that contaminants of concern are likely in drainage waters from waste rock;

- OKC understands that such a report is in progress as referenced in the CRL Energy Limited (2016) report and will require review; and,

- In addition to waste rock management there may be the need for water treatment and this should be considered as part of an adaptive management plan.

4.2.9 Discussion - Column Leach Testing

Column leach testing provides a rapid methodology to assess the water quality characteristics of a waste rock sample. It provides a good signature of the water quality and contaminants of concern. However, generally AMIRA-type column leach tests or field leach tests (such as the ones used for Te Kuha) have much higher water:rock ratio's than would occur within a waste rock dump. Consideration of this effect needs to be acknowledged when applying such trial data to expected water quality.

Significant quantities of oxidation products are flushed from the trial columns (laboratory and field) containing waste rock with a high capacity to generate acidity. Such data can be used to determine the intrinsic oxidation rate (IOR) of a sample. In a waste rock dump, with lower quantities of water, these oxidation products are not flushed immediately and due to solubility constraints are often stored as secondary oxidation products. Thus, for high capacity acid forming samples, the IOR measured by columns does not equal the contaminant load reporting from the waste rock dump. AMD practitioners thus apply a scaling rule (*e.g.,* reducing column leaching rates typically by an order of magnitude) to account for this difference. In general, this scaling back has little effect, and the forecast remains poor quality acidic AMD impacted waters.

However, for non-acid forming waste rock or low–acid forming waste rock there are less effects associated with solubility constraints as often they are not achieved. Net percolation of waters can continue to dissolve minor amounts of oxidation products as mineral saturations have not been achieved. Thus, net percolation of waters through a waste rock dump interact with much greater volumes of waste rock than would be available in a column leach test. The result is the ongoing concentration of dissolved contaminants until either the water discharges from the waste rock dump or solubility constraints are reached and precipitation of secondary oxidation products occur. This means that column leach tests of non-acid forming or low-acid forming waste rocks can underestimate the water quality discharging from the waste rock dump as basal seepage.

No comment has been provided as to the effects of the water:rock ratio. Further investigations and considerations are warranted.

4.2.10 Further Work

- It would be appropriate to represent the column leach test data and highlight contaminants of concern in regards to any agreed water quality conditions for the site, which will need to consider that some contaminants of concern are elevated naturally. Perhaps a metals Ecotoxicity Quotient (MEQ) approach could be undertaken (Weber and Olds, in prep).

- In OKC's experience data reduction is beneficial for quickly assessing contaminants of concern. It is recommended that column data be presented in full and compared to water quality guidelines or agreed water quality consent conditions using a simple colour coding scheme for rapid visual assessment.

- Columns releasing alkalinity are essentially losing ANC such that with time the ANC:MPA ratio becomes less. Eventually this can result in NAF rock becoming PAF rock. Plotting of alkalinity trends for the PCM columns would provide guidance on such matters. Consideration of alkalinity loses, which affects ANC, should be included in any waste rock geochemical classification.

- Opportunistic use of any alkalinity draining from the WRD should also be considered, perhaps as part of an adaptive management process.

- Some of the key contaminants of concern elevated in the drainage from the field columns are associated with pyrite oxidation, where they are likely to be contained as inclusions within the pyrite (*e.g.,* Ni, Zn, and Cu). Confirmation of this would provide evidence for methods to manage such contaminants (*e.g.,* oxygen exclusion; encapsulation), which could be done, perhaps, by plotting sulfate versus each contaminant of concern. It is noted that CRL Energy Limited (2016) states that relationships between sulfur and Ni and Zn are weak. A greater dataset might be beneficial.

- The effects of elevated contaminants of concern, greater than the concentrations being measured in the column leach tests, needs to be considered and these results should be used as conservative estimates of WRD basal seepage water quality. Methods to consider this are numerous and could include:

    - The use of lower water:rock ratio's in the field column trials, being comparable to that expected of the Waste Rock Dumps;

    - Recycling of column leachate effluent to become the influent over a number of iterations;

    - Desk-top analysis where the water quality data are 'concentrated up' by decreasing the amount of solution to be comparable to that expected in the WRDs.

    - Consideration of the longevity of such water and any changes once the waste rock is buried in the WRD (and geochemical conditions change).

4.3 Other Geochemical Effects

4.3.1 Nitrogen

CRL Energy Limited (2016) considered the effects of nitrate and nitrite in the site water model. It is assumed these data do not consider any additional load from the use of N-based explosives. It is unclear if explosives will be used. Further comment on this matter is required and any potential effect on the downstream receiving environment considered.

4.3.2 Boron

Boron can be elevated in drainage from coal mines, although the dataset of Pope *et al.,* (2010) suggests it may not be a problem for West Coast sites. Comment is required on this matter.

5 OVERBURDEN

5.1 Introduction

It is generally expected that the key contaminant loads from opencast mining operations such as Te Kuha are from waste rock dumps (WRDs). This is associated with exposing significant acid-forming waste rock surface area to oxygen and water. Hence, appropriate management steps are required.

CRL Energy Limited (2014) acknowledges that if contaminants of concern are present in leachate that could cause substantial environmental impact, then alternative waste rock handling processes might be implemented to improve water quality.

From the data provided it appears that contaminants of concern are likely in drainage waters from waste rock and thus a plan for how the WRD will be constructed is warranted. OKC understands that such a report is in progress as referenced in the CRL Energy Limited (2016) report, and will require review.

5.2 WRD Construction Process

5.2.1 Discussion

Stevenson Mining Limited (2015) note that there are two ex-pit dumps (Figure 5.1):

- The Main Lower Dump, which holds the majority of ex-pit waste rock; and,
- The Small Upper Dump, which is required from Year 5 of the project

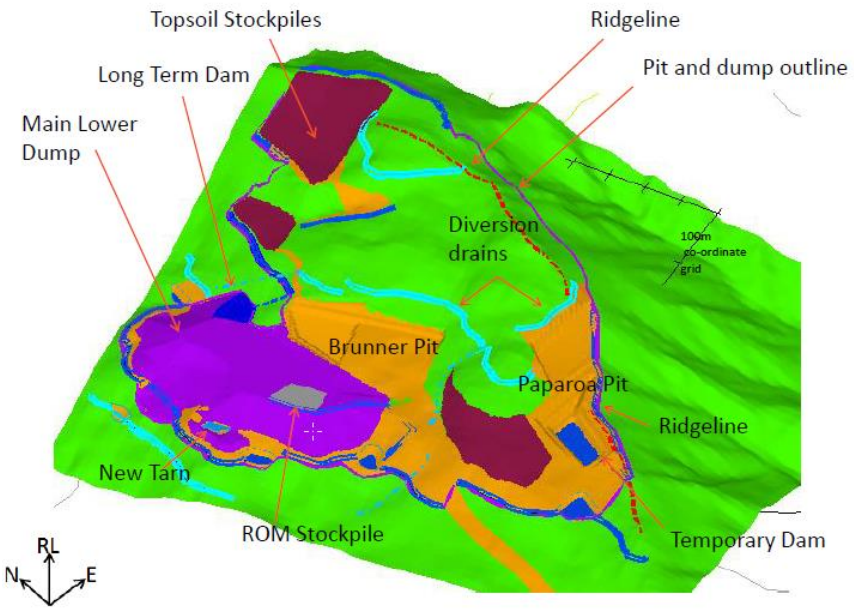

Figure 5.1: Proposed infrastructure for the Te Kuha Coal Mine – Year 1

Source: Stevenson Mining Limited (2015).

Stevenson Mining Limited (2015) indicate that the PCM waste rock (non-acid forming) will be used to line the Main Lower WRD and that both dumps will be built from the bottom up with progressive rehabilitation and that 40% of the progressively rehabilitated area will be re-handled to fill the final void. CRL Energy Limited (2014) state that re-handling of this waste rock could cause the release of acid that is otherwise stabilised within the temporary WRD and poses a risk.

CRL Energy Limited (2014) note that the PCM can be used to minimise the oxidation and generation of acidity in the BCM by capping the BCM with PCM. It is proposed that 3-5 m of NAF PCM be used as a capping layer to prevent root penetration. It is proposed that the excess alkalinity generated from the PCM will be available to interact with acidity, presumably in the underlying BCM. This can be considered an alkaline cover and opportunistically uses the additional PCM alkalinity as recommended in Section 4.2.10.

CRL Energy Limited (2014) note that compaction of the NAF PCM cover layer or the construction of a low permeability layer is not required as the alkalinity from the NAF PCM layer needs to infiltrate downwards. However, it is recommended by CRL Energy Limited (2014) that compaction of the cover layer be undertaken to encourage runoff.

It is proposed that the WRD be constructed in ~5 m lifts to prevent grainsize segregation and chimney effects that encourage oxygen ingress (CRL Energy Limited, 2014). Such an approach is logical although further information is required as to whether paddock dumping (or lifts ~2m in height) would be appropriate as had been undertaken at the Escarpment Coal Mine.

5.2.2 Recommendations and Further Work

In general it would be beneficial to review the report being prepared by CRL Energy Limited on the methodology for constructing the WRDs. For example the following information would be beneficial:

- A clear mining schedule is needed, which should be linked to the volumes of each geochemical type of waste rock that will be placed in each dump such that NAF PCM and BCM can be separated and re-handled appropriately. The development of the waste rock dump design and schedule should be linked to the preliminary waste rock block model. This should be updated as more geochemical and geological data become available through an adaptive management process. CRL Energy Limited (2015) note that a plan of the temporary waste rock dumps should be completed, which presumably relates to such matters. This needs to be reviewed.

- Explanation is required on how the Main Lower WRD will be lined with NAF PCM and for what purpose.

- Clarification is required as to the process of progressive rehabilitation followed by subsequent re-handling of this material. It seems onerous to undertake rehabilitation activities and then dig it up.

- Traffic management and QA/QC processes will need to be developed to ensure the correct placement of waste rock within the ex-pit WRDs and the backfill.

Little data or quantification of oxygen ingress rates or net percolation rates have been provided. These parameters provide an indication of ongoing sulfide oxidation and an expectation of the contaminant load reporting to the receiving environment. Specifically the following should be provided:

- Oxygen flux into the ex-pit WRDs and the backfill. These data can be used to determine the long-term contaminant loads being formed within each structure. Oxygen flux should be presented in g/m^2/yr or similar such that acidity and contaminant loads can be calculated for each structure and a mass balance ABA process can be undertaken for the WRD based on ANC and alkalinity loss. Furthermore:
    - The depth of oxygen ingress should be determined for this site and comment given on advection and diffusion mechanisms for oxygen.
- Derivation of net percolation (NP) reporting as basal seepage from the WRD, which should consider soil-plant-atmospheric (SPA) modelling or similar (*e.g.,* VADOSE/W) to understand changes in NP based on cover installation and rehabilitation efforts. Any draindown periods following compaction (to shed rainfall and runoff) should also be considered. Quantifying NP is critical to:
    - Confirm flow rates for each WRD and thus provide estimates of water quality during operation and longer term.
    - Introduce derived flow rates into the GoldSim probabilistic water quality model and use these data to determine risks associated with the potential for poor water quality during operation and longer term.
- Specifications are required for aspects of the WRD construction, for instance compaction of the NAF PCM layer to shed runoff. QA/QC methodologies and further explanation are required.
- Explanation of how any stored oxidation products in the re-handle waste rock will be managed is required
- No data are provided on the thickness of soil to be spread over the WRDs.

No data are provided on the water quality expected from the coal stockpiles and what will happen to contaminated coal, often considered 50:50 (coal:rock). It is noted coal sulfur content can be up to 1.22 wt% (Stevenson Mining Limited, 2015).

6 PREVENTION, MINIMISATION, CONTROL

6.1 Introduction

Prevention, minimisation, and control of poor quality waters associated with mining operations is a key step in reducing the severity of any impact associated with geochemical reactions in the waste rock:

- The **prevention** of AMD is achieved by preventing the interaction of the principal constituents of the AMD production process, namely sulfide minerals such as pyrite, with oxygen and water.
- Where prevention is not possible, the objective is to **minimise** the oxidation of sulfide minerals and the formation of AMD.
- Any remaining AMD will be controlled to prevent the release of untreated AMD influenced water to the receiving environment. An important component of understanding whether **control strategies** are effective is monitoring of water quality and quantity, enabling calculation of contaminant loads.

6.2 Discussion – Prevention and Minimisation

Methods are proposed to reduce oxygen ingress into the WRD using short lift heights (~ 5 m), which will contribute to lowering sulfide oxidation rates compared to using lift heights > 5m. Methods are provided to reduce net percolation into the WRD by compacting the NAF BCM to shed run-off

CRL Energy Limited (2016) state that acid forming rocks will be managed and oxidation (acid formation) will be prevented. It is reasonable to assume that such methodologies will be explained in the design methodology being prepared by CRL Energy for the WRD, but further review will be required.

The use of NAF PCM covers is also planned as part of the design of the WRDs to control oxidation in the BCM. The cover system design will need review.

Clean water diversion drains are proposed to separate mine-impacted waters from clean water sources. It is assumed that where possible, all upslope water will be diverted away from WRD's such that the flow rate through the base of the WRD is reduced, removing a transport mechanism for oxidation products. This needs to be explained in the WRD design methodology report.

6.3 Control

6.3.1 General

Streamlined Environmental Limited (2014) state that the Integrated Water Management Plan for the site (dated 26 August 2014) indicates that water management planning is based on containment of maximum daily runoff from a one in two year flood event from disturbed areas and that larger events will freely discharge to the environment. Further details are required on such matters and the expected impact of these discharges on the receiving environment.

CRL Energy Limited (2016) state that one year following rehabilitation surface runoff water will be discharged directly to the environment, with appropriate monitoring. No data are provided to confirm that this water quality will be suitable for discharge. Further investigations are necessary.

6.3.2 WRD Basal Drainage

A key component of AMD control is to ensure basal drainage from the WRD is controlled and delivered to locations for management if the need arises. To have diffuse flow from a WRD severely limits the ability to capture and treat this water if required and makes adaptive management more difficult and costly.

It is noted that CRL Energy are compiling a conceptual waste rock management plan for Te Kuha and it is recommended that designs be developed for the management of basal flows. These designs will require review.

6.3.3 Coal Stockpiles

Control of drainage from any coal stockpiles needs to be considered.

6.4 Site Water Model

6.4.1 Introduction

A water model for the Te Kuha Site was developed by CRL Energy Limited (2016). This was developed using GoldSim and was constructed to provide projections for water chemistry and water quantity that should be treated primarily for suspended sediment prior to leaving site.

Key model assumptions include:

- An immediate runoff of 90% of rainfall with a 10% contribution to base flow;
- No loss of rainfall to deep groundwater recharge;
- Upland stream water chemistry has been presented (Table 3.1);
- Mine impacted water chemistry was based on field column leach data and this is mixed in the treatment sump prior to discharge, which includes other (diluting) site waters. A number of mine impacted water chemistry scenarios are run (discussed below in Section 6.4.2).

6.4.2 *WRD Leachate Water Quality*

The field column leachate data from 28 months of testing was used to define three scenarios for mine impacted water chemistry for the site (CRL Energy Limited (2016):

Scenario 1:

CRL Energy Limited (2016) state that leachate data from the first year of operation of the field columns was averaged to provide a worst case scenario for mine drainage chemistry. The scenario assumes that all surface water on site has similar reaction with waste rock to that which occurs in the field column leach test. It is noted by CRL Energy Limited (2016) limited that column leach test-type drainage are only likely to be present at a small proportion of the site. It is proposed by CRL Energy Limited (2016) that Scenario 1 likely reflects mine impacted waters at site during low flows and provides an upper limit for dissolved contaminants.

- OKC assumes this scenario excludes the first two data points, which were contaminated by HCl. Clarification is required on this matter.
- It is not clear whether the averaging included data from all five columns. Clarification is required and justification for whatever approach was adopted.
- OKC note that the application of this water type to surficial waste rock is reasonable, as the volume of water to rock is probably comparable and represents a high flushing environment.
- OKC note that it is probably not applicable to WRD basal leachate (see Section 4.2.9) and that expected WRD basal seepage chemistry and flows need to be determined.

Scenario 2:

For Scenario 2 the water quality for mine impacted waters is from the average water quality data over the entire period of field column leach testing, which reduces the impacts of initially elevated dissolved contaminants of concern. CRL Energy Limited (2015) note that this reflects the progressive leaching of waste rock that has been deposited for extended periods.

- OKC note that the application of this water type to surficial waste rock is reasonable, as the volume of water to rock is probably comparable and represents a high flushing environment.
- OKC note that it is probably not applicable to WRD basal leachate (see Section 4.2.9) and that expected WRD basal seepage chemistry and flows need to be determined.

Scenario 3

In Scenario 3 the water quality determined in Scenario 2 is diluted by 0.8 due to mixing with upland stream water un-impacted by mining activities. CRL Energy Limited (2016) explains this represents mine impacted water quality during rainfall events.

- No explanation is provided for the reasoning of using 0.8. Clarification is required.
- OKC note that the application of this water type to surficial waste rock is reasonable, as the volume of water to rock is probably comparable and represents a high flushing environment.
- OKC note that it is probably not applicable to WRD basal leachate (see Section 4.2.9) and that expected WRD basal seepage chemistry and flows need to be determined.

6.4.3 Discussion and Recommendations

- CRL Energy Limited (2016) state that the use of leachate chemistry in the GoldSim model is conservative and provides results that are similar to the range of values for mine drainage chemistry found at other mines where circum-neutral pH is present where the Pope *et al.* (2010) reference is quoted.
    - Further supporting argument is required to confirm that these analogies are reasonable, although such a comment seems fair compared to the dataset presented.
- It is unclear where basal seeps from the WRD's will report and how seeps will be managed. It is likely this is explained in other documents.
- It is not clear how basal flows from the WRDs have been managed in the model. Such flow rates should be determined from numerical modelling (SPA modelling) or similar. It is likely these seeps from WRD's will have a relatively constant base flow and will be elevated in contaminants of concern, which will therefore have more pronounced effects during dry periods. Such data (flow, quality, and load) should be developed into a GoldSim site water model to consider these effects on the receiving environment.
- It is likely that if the WRD's are built to exclude oxygen ingress there will be a shift from poor water quality to better water quality with time, although there will be a stage of poor water quality again once the waste rock is re-handled and backfilled to the pit.
- Mine influenced water quality, based on three scenario's is presented in the CRL Energy Limited (2016) report (Table 9 of that report). OKC would assume these are reasonable scenarios for surface flows on the mine site, yet are probably optimistic in regards to basal drainage from the WRD. Further work is required to confirm water qualities from basal WRD seeps and the effects on the site water model.

- CRL indicates that Fe concentrations are likely to be low in site leachate waters based on data from the field column leach tests. However, the field column leach tests were conducted under oxidising conditions. It is proposed that the waste rock dumps at Te Kuha will be built in ~5m lifts to minimise grainsize segregation and chimney effects which will minimise oxygen ingress and thus parts of the WRD will be low in oxygen and Fe^{2+} could thus remain in solution. Consideration of this is required for operational and longer-term water management.

- CRL Energy Limited (2016) indicate that Ni, Zn, and Mn remain dissolved and are likely to remain dissolved through neutralisation to pH~7. Such matters require consideration for both operation management and management after closure in the longer term. Modelled Zn concentrations based on Scenario 1 are presented below in Figure 6.1 and are greater than potential discharge limit of 0.1 mg/L Zn (CRL Energy Limited, 2016).

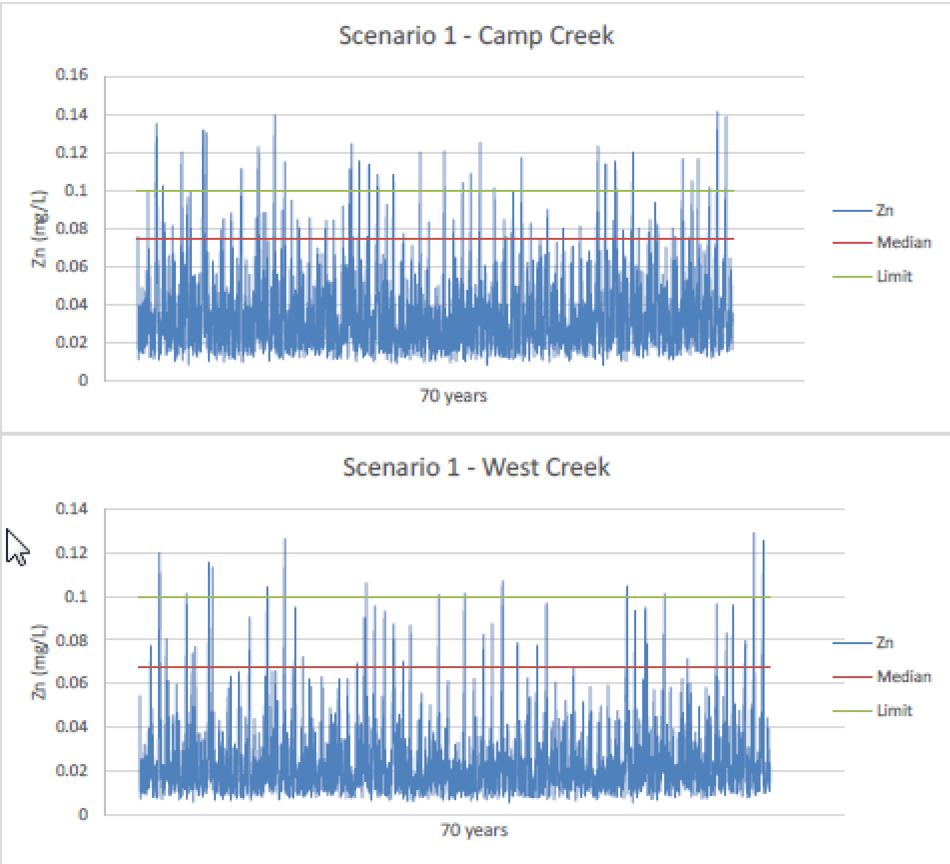

Figure 22: Predicted variation in Zn at proposed compliance points (West & Camp Ck) after discharge of treated water using Scenario 1

Figure 6.1: Scenario 1 Zn water quality predictions for proposed compliance points for West Creek and Camp Creek

Source: CRL Energy Limited (2016) Figure 22.

7 MONITORING AND TREATMENT

7.1 Monitoring

A number of contaminants of concern have been assessed by CRL Energy Limited for baseline water quality and for leachate from field column leach tests. This provides a good screening level assessment. Data provided by Pope *et al.* (2010) indicated that in general contaminants of concern for West Coast Coal mines are: As, Cd, Co, Cr, Cu, Mn, Ni, Pb, and Zn together with the usual major contaminants being Fe, Al, acidity, and sulfate. Such data sets can be used to determine the key contaminants of concern for the project, which can be used for developing Resource Consent guidelines.

A robust water quality baseline should be developed prior to mining starting.

Often, as a requirement of Resource Consent conditions all parameters must be monitored to ensure compliance. This can be costly and time consuming. It is more reasonable to consider alternatives such as trigger values before certain parameters require monitoring. For instance, if the pH > 5.5 and waters were well oxygenated it would generally be unnecessary to monitor for Al and Fe (*e.g.,* Weber and Olds, in prep). This approach should be a discussion between the regulator and the applicant.

7.2 Treatment

7.2.1 Introduction

In OKC's experience, the mining of coal and overburden containing pyrite will generate poor water quality. Even if the acidity is neutralised by carbonate minerals present in the rock, contaminants of concern can remain in solution. For instance, it is proposed that the WRDs will be constructed at Te Kuha to exclude oxygen and thus redox sensitive species such as Fe will remain in solution and be present in seep waters from WRD's. Consideration of such matters is required.

Further discussion and analysis is required in regards to the treatment of contaminants of concern. The option of water treatment, and the form of water treatment, should be considered as part of an adaptive management process reflecting the magnitude of possible acid loads generated at the site.

7.2.2 Operational Water Treatment

CRL Energy Ltd (2016) state that during mining operations all site water will be directed to the west through water treatment and into tributaries of West Creek and Coal Creek. A concept treatment location is proposed on plans provided by CRL Energy Limited (2016) and this report also indicates that a contingency will be put in place to neutralise acid in the event of AMD formation. Further details of contingencies should be presented and it was noted that the work was in preparation.

Pit lake water quality is likely to be different for the PCM Pit versus the BCM Pit. Further data, including discharge flow rates and therefore loads, should be provided on the pit lake water quality.

7.2.3 Closure

Data needs to be presented for long term water quality from the WRDs with time being the long term source of contaminants. If treatment is required at closure, or if there is the possibility of treatment at closure then this should be discussed.

8 CLOSURE

8.1 Summary

Minimal detail is provided on closure of the site after mining activities other than progressive rehabilitation *etc.* It is indicated that after 1 year water from rehabilitated areas will be discharged directly to streams. This needs to be discussed in more detail, with contingencies considered to deal with unexpected poor water quality.

A closure plan is required. It is acknowledged this should be based on adaptive management principles as many aspects of the project could change. From an AMD management perspective this plan should address water quality, contaminant loads, and methodologies to manage any effects.

8.2 Adaptive Management

It is reasonable to expect that a number of issues associated with the potential for poor water quality and waters impacted by AMD can be addressed through an adaptive management plan approach. The applicability of an adaptive management strategy is predicated on the level of risk and the ability to respond quickly should the matter arise. Understanding the potential risk is thus a key step in the development of an adaptive management plan.

Stevenson Mining Limited (2015) note that the mine plan is a conceptual design as it is based on a relatively low level of exploration data and further work is recommended in order to develop a bankable mine design and schedule.

Adaptive management processes will be important for:

- Waste rock block modelling, changes to the mine schedule and WRD design;
- Water management and water treatment; and,
- Closure of the site.

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