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MEMORANDUM 1

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Date:	19 March 2021
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Document Number:	J-NZ0130-002-M-Rev0
Document Title:	Canterbury Coal Mine Closure – Tara Mussel Shell Reactor Treatment System Design

INTRODUCTION

As part of a best practicable approach to the management of acid and metalliferous drainage (AMD), Bathurst Coal Limited (BCL) have undertaken considerable efforts to characterise materials and implement material management options to prevent oxidation and reduce contaminant loads from the site, including reducing historical legacy discharges and downstream effects. AMD affected waters have been controlled at site to specific discharge points and minor additional management and treatment of impacted waters are required to maintain compliance with resource consent conditions. This will be supported by performance monitoring and trigger action response plans (TARPs) that will be part of an adaptive management approach for mine closure.

The remnant AMD-impacted seep (CC02) discharging to Tara Gully is currently ~0.076 L/s and has relatively low acidity of ~60 mg/L and is elevated in zinc (Zn), manganese (Mn), iron (Fe), and boron (B). This memorandum details the treatment plan for this relatively minor seep via a mussel shell reactor (MSR). A MSR is a proven way to treat AMD seeps with a passive treatment system that involves low maintenance. MSR systems are successfully being used to treat AMD impacted waters at Escarpment and Stockton mines on the West Coast (Robertson et al., 2017; Weber et al., 2015).

Mine Waste Management Ltd (MWM) were engaged by BCL to complete a technical work scope that can be referenced in an assessment of environmental effects (AEE) for Canterbury Coal Mine (CCM) closure consents. The work scope relates to AMD management, water quality compliance, and adaptive management aspects of the closure AEE. This is the first (Memorandum 1) of four technical memorandum deliverables. The four deliverables discuss:

- Memorandum 1: The Tara mussel shell reactor treatment system design;
- Memorandum 2: The N02 Pit Pond water quality forecast;
- Memorandum 3: The water quality of combined CCM discharge from Tara Pond 1 and Tara MSR discharge; and
- Memorandum 4: Recommendations for post closure monitoring requirements and relinquishment criteria from an AMD management perspective.

SUMMARY

This memorandum presents the Tara MSR design and maintenance requirements. The Tara MSR will treat discharge from the CC02 underdrain post closure and may be required for a period of years to decades for combined CCM discharge at that location to meet CRC170541 water quality criteria. This memorandum establishes:

- The proposed Tara MSR is appropriately sized for effective treatment of CC02 discharges.
- The main Tara MSR maintenance activity will be periodic removal of sludge / spent mussel shell substrate and replacement with additional shells to continue treatment. Sludge removal on a 10 to 20 yearly basis is anticipated based on 'current' Fe loads discharging CC02.
- The Tara MSR is designed to remove CC02 Fe and Zn loads (with moderate Mn load reduction expected). On-site treatment trials indicate that MSR discharge is expected to meet CRC170541 water quality criteria for all parameters excluding B. The modelled Tara MSR effluent B concentration of 3.65 mg/L exceeds the 1.5 mg/L CRC170541 compliance limit (which is assessed as a 3-monthly rolling median). Achieving B compliance downstream of the Tara MSR discharge point (at CC02-tele) will therefore require dilution.

BACKGROUND

The proposed Tara MSR is being designed to treat discharge from the CC02 underdrain post closure. The structure currently drains historic underground workings (and the adjacent hill behind workings) and collects seepages through the Green Engineered Landform (ELF). The CC02 underdrain flows continuously and discharges into the ~300 m^3 Tara Pond 1. Surface flows from the Green ELF catchment are also directed to Tara Pond 1. CC02 / Tara Pond 1 water generally does not meet resource consent compliance limits at the compliance monitoring point (largely due to the elevated B, Mn, and Zn concentrations discharging from the CC02 underdrain) so cannot be discharged directly without additional management. The CC02 Fe concentrations are also moderately elevated but are within consent criteria. Figure 1 shows the CCM water investigation sites and proposed Tara MSR location (red star).

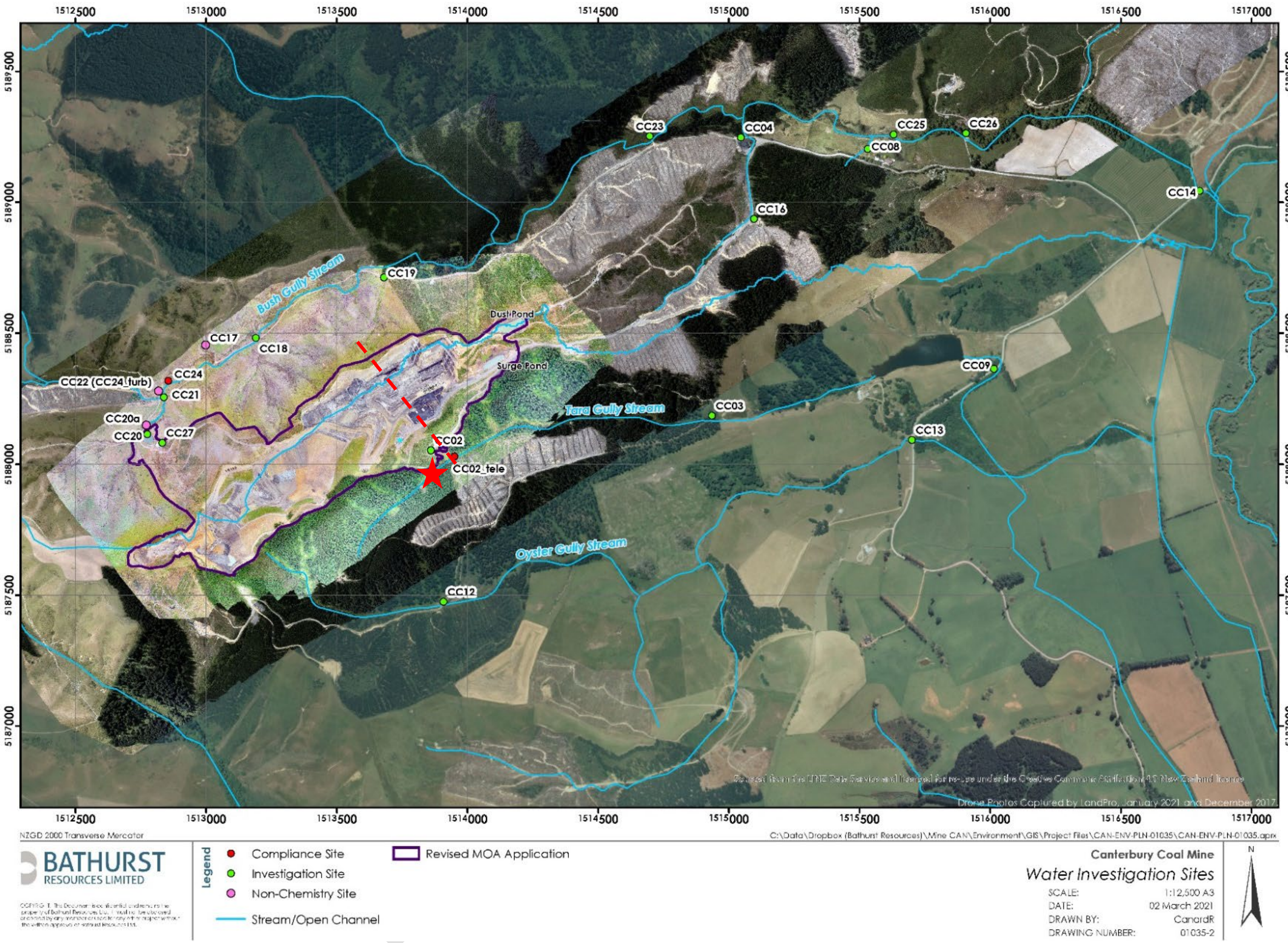

Figure 1. CCM water investigation sites. Approximate Tara MSR location shown as red star. Figure 7 cross section alignment shown as broken red line.

Tara Pond 1 (located adjacent to the CC02 dot in Figure 1) water is currently pumped up to the Surge Pond for treatment/mixing with other mine influenced waters prior to discharge. This process includes water treatment (through $Ca(OH)_2$ dosing to increase pH and remove contaminants such as Zn) and sedimentation to manage sediment loads associated with rain events. The Tara Pond 1 water level is managed by pump level switches to maintain surge capacity for total suspended solids (TSS) management during rain events.

Post closure BCL intend to collect and treat CC02 underdrain water using the Tara MSR prior to discharging to Tara Gully Stream. Underdrain water will be collected by a new pipeline inserted (and sealed) directly into the CC02 underdrain. This will prevent surface water flows (potentially elevated in sediment) entering the Tara MSR through the post closure period when revegetation is establishing. The Tara MSR will target treatment including:

- Removal of Fe (which is potentially in the ferrous (Fe^{2+}) speciation) by aeration (in standing water on the surface of the MSR), hydrolysis to form insoluble Fe precipitates, and filtration through the mussel shell media; and
- Removal of Mn and Zn through either co-precipitation/adsorption to Fe precipitates or direct precipitation to form insoluble Mn and Zn precipitates.

The Tara MSR design has been largely completed by BCL, including specification of reactor volume and mussel shell / substrate volume and the inlet / outlet piping configuration. BCL have undertaken a survey of the maximum practicable MSR footprint at the proposed site. The MSR site is located below CC02 / Tara Pond 1 (shown by red star in Figure 1 and in detail in Figure 2). The maximum potential MSR void has been estimated at ~24 m long (at the top), 5 m wide (at the top), and 1.5 m deep. The internal walls of the void will be battered for stability. Long sections and cross sections are shown in Figure 3 and Figure 4, respectively.

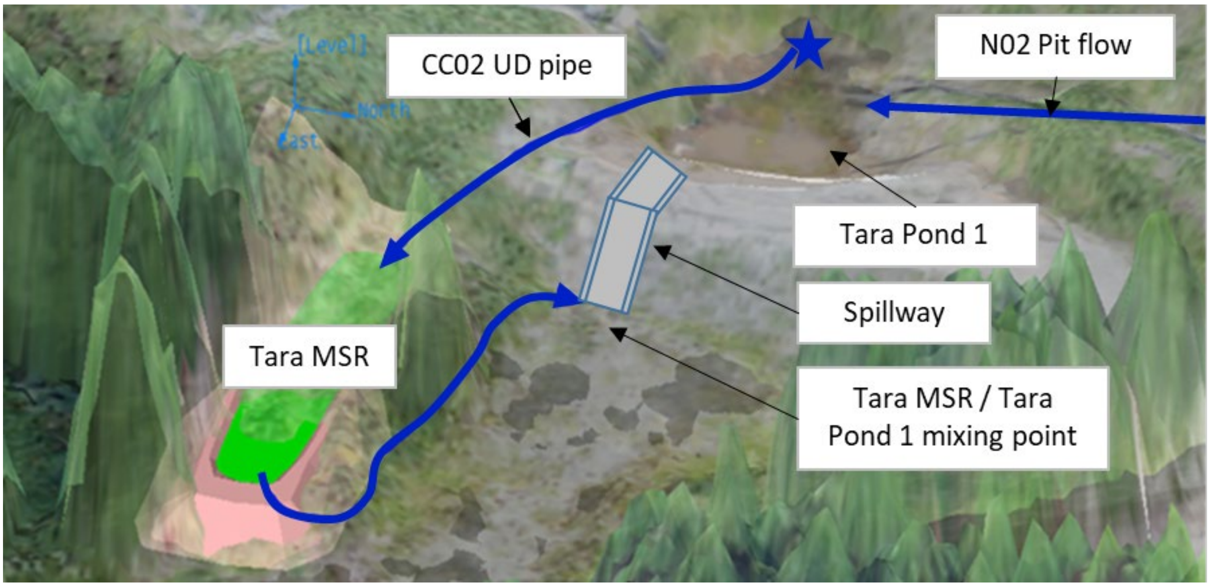

Figure 2. Tara site showing MSR to lower left. Current CC02 monitoring site shown at blue star.

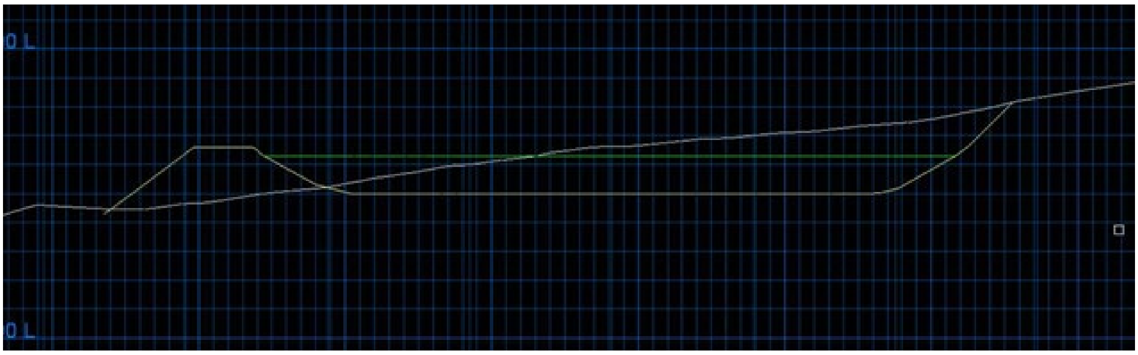

Figure 3. Tara MSR long section

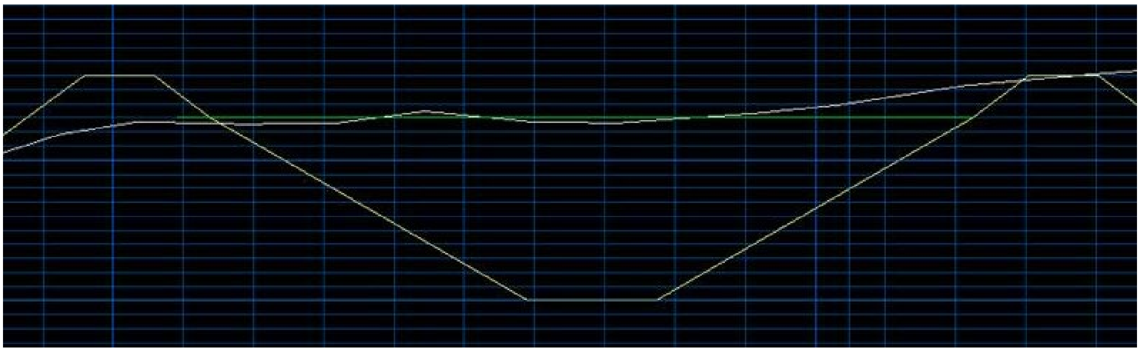

Figure 4. Tara MSR cross section

Through the design process BCL have determined the following:

- Backfill of the void with a 1 m deep layer of shells will result in a shell layer surface area of 94 m^2 at the top and a shell volume of 53 m^3 (NB: underdrain network will be installed at the base of the shell layer approximately 200 mm above the void base); and
- The water column depth above the shells of up to 0.5 m (including freeboard) to provide driving head and hold up to 58 m^3 of untreated water.

SCOPE OF WORKS

The work scope provided to MWM requested the following items be addressed using empirical data and measured trends:

- Provide estimate of frequency of cleanouts / refresh neutralising/filtering medium; and
- Provide estimated water quality (WQ) of outflow from the MSR after treatment; and

These aspects are discussed in the following sections.

TARA MSR MAINTENANCE REQUIREMENTS

The triggers for Tara MSR maintenance are expected to be:

- Sludge accumulation at or below the mussel shell layer surface, decreasing treatment capacity and resulting in untreated water spilling from the MSR; and
- Exhaustion of the mussel shell acidity neutralising capacity (ANC).

Figure 5 shows sludge accumulation through the trial 1,000 L Intermediate Bulk Container (IBC) MSR (operated in a downflow configuration) at Canterbury Coal Mine. Sludge has accumulated on the shell layer surface and through the mussel shell layer over the ~8 month period of the trial. The field sampler also noted there were areas with orange sludge accumulation in pockets as deep as 5-10 cm below the surface.

The composition of sludge accumulating in the trial MSR is expected to be a combination of:

- Iron oxy-hydroxide precipitates (orange sludge accumulation) that form as CC02 underdrain sourced Fe is captured on the mussel shell substrate; and
- Sediments transferred into the IBC MSR from Tara Pond 1. It should be noted that the sediment contribution to Tara MSR influent water is expected to be minimal as flows will be captured from inside the CC02 underdrain.

Figure 5. Trial IBC MSR sludge accumulation

Two sets of calculations estimating the effect of sludge accumulation on maintenance requirements have been undertaken. These calculations consider:

- Sludge layer accumulation increasing driving head requirements / decreasing treatment capacity; and
- Mussel shell substrate exhaustion due to shell ($CaCO_3$) dissolution for acidity (primarily Fe) neutralisation by hydrolysis.

Tara MSR design parameters

The frequency of maintenance activities (removal of sludge or exhausted MSR substrate) is a function of influent contaminant loads. The CC02 water quality and three-sample rolling average contaminant load monitoring data for key MSR design parameters are shown in Figure 6. Relevant observations from Figure 6 include:

- CC02 seepage flow rate decreased through late 2019 and early 2020. This coincides with mining into the CC02 underdrain seepage hydrogeologic catchment including removal of some historic workings and adjacent hillside that contributed to the seepage volumes. The reduction in CC02 flow rate is expected to be permanent as the final N02 Pit Pond water level will act as a sink, being below any remaining historic workings with no connectivity to the CC02 underdrain (Figure 7);
- The Fe concentration (and therefore calculated acidity) at CC02 decreased over the second half of 2020. A proportional decrease in other contaminant concentrations (e.g., Mn, Zn, and sulfate) was not observed. However, CC02 water hardness has increased by ~10% (from ~1,000 to ~1,100 mg $CaCO_3$/L) potentially indicating greater in-dump neutralisation of acidity (and therefore Fe retention); and
- The decrease in CC02 discharge flow rate has resulted in a decrease in contaminant load for all parameters shown in Figure 6. The magnitude of the load decrease varies for different parameters with some contaminant concentrations increasing significantly (e.g. Boron), which partially offset the load reduction due to flow decrease. However, the key MSR design parameter contaminant loads (Fe and acidity) showed a marked decrease through the 2020 dataset.

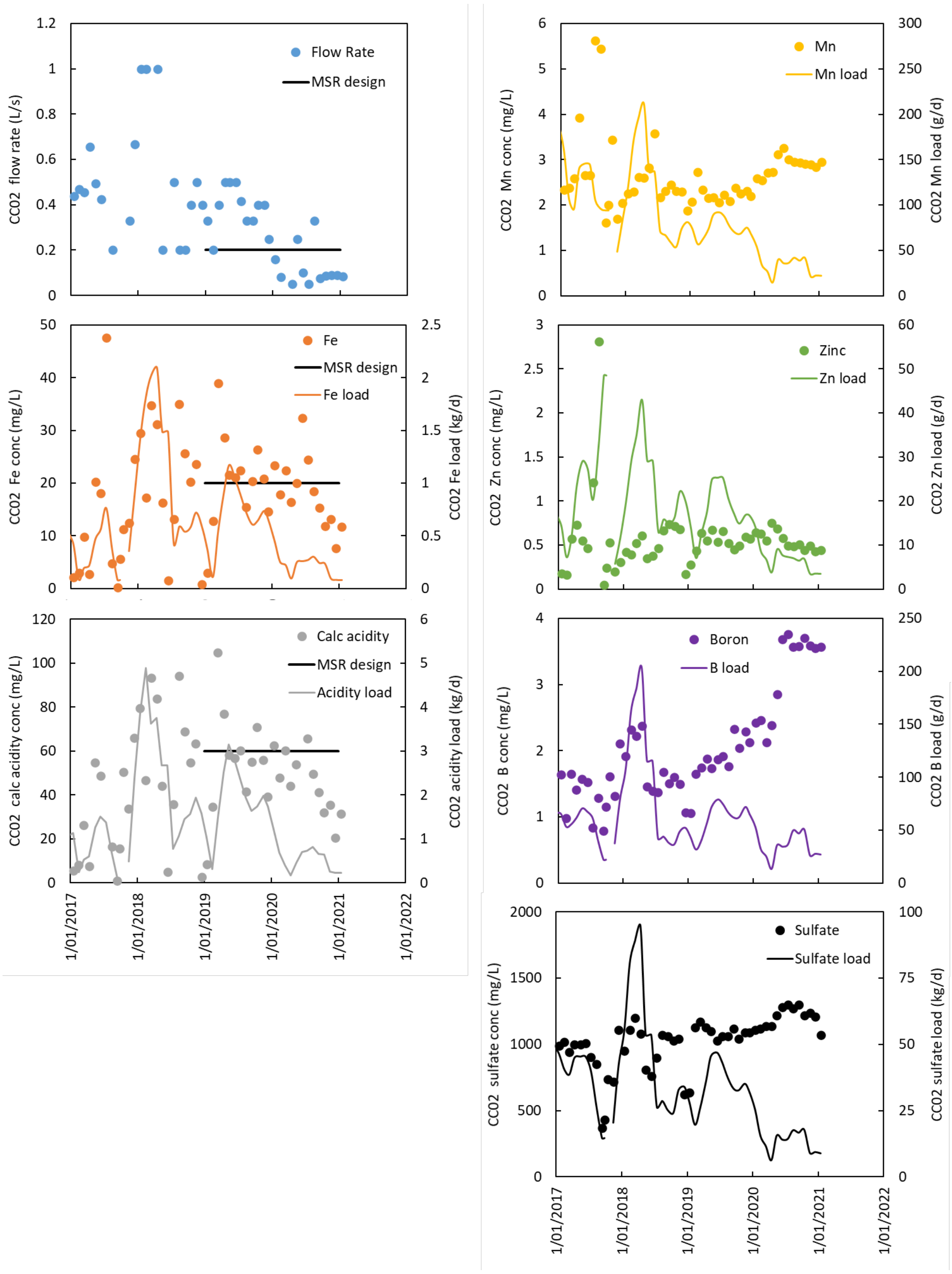

Figure 6. CC02 key contaminant concentrations, flow rates, loads, and the nominal 'MSR design' specification (lines) from Table 1

The reduction in CC02 flow rate through the second half of 2020 is expected to be permanent due to removal of the historic workings contribution to CC02 flow (shown in Figure 7) and lowering of the phreatic ground water surface within the Green ELF due to excavation of the N02 Pit. Post closure there may also be a drain down period where seepage rates further decrease as the landform surface fully stabilises (with overall lower permeability and reduced net percolation rates) after rehabilitation and revegetation. Ongoing performance monitoring will confirm this assumption.

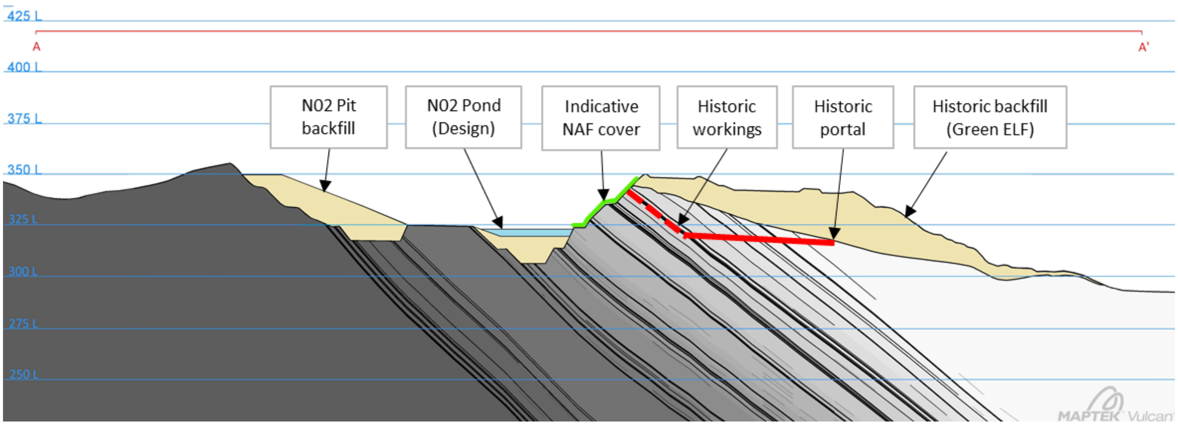

Figure 7. Cross section showing N02 Pit final landform (alignment shown in Figure 1)

The apparent reduction in Fe concentration through late 2020 is not mirrored by a reduction in sulfate (or other contaminant) concentration. For MSR design purposes, the Table 1 values were used (which are approximately equal to median CC02 values measured over the 2019/20 period), which have also been summarised in Figure 6 in the 'MSR design' series.

Table 1: CC02 MSR design parameters

Parameter	Unit	Value
Flow rate	(L/s)	0.2
Fe concentration	(mg/L)	20
Acidity concentration	(mg $CaCO_3$/L)	60
Alkalinity gain through MSR	(mg $CaCO_3$/L)	100*

** Nominal MSR discharge alkalinity conservatively based on previous CCM MSR discharge alkalinity measurements (ranging from 100 to 200 mg $CaCO_3$/L for the Office MSR1 and the Surge MSR2 discharge) and referencing Robertson et al. (2017)*

Comparison of MSR design parameters and measured data over the late 2020 period indicate that the selected MSR design parameters are conservative with design flow rates and Fe concentrations approximately double current measurements on site. This equates to design Fe and acidity loads that are higher than currently measured loads by approximately a factor of four. This is appropriate for MSR design conservatism, but a less frequent maintenance / desludging frequency will be presented in the 'Expected MSR Maintenance Requirements' section to reflect 2020 data trends.

Assessment: MSR treatment capacity

The decrease in MSR treatment capacity over time (between maintenance activities) has been assessed using three different potential failure modes:

- Formation of a sludge layer on top of the mussel shell substrate layer, causing an increase in driving head requirements to maintain treatment requirements;
- Exhaustion of the acid neutralising capacity of mussel shells; and
- Sludge accumulation within the pore spaces between mussel shells effectively preventing mobilisation of alkalinity from shells.

These mechanisms are discussed in the following three sections. The overall 'Expected MSR maintenance frequency' is then discussed in the following section (considering all three failure modes).

<u>Sludge layer accumulation and MSR driving head requirements</u>

The sludge layer accumulation rate has been estimated based on the design influent Fe load and the surface area of the mussel shell substrate layer (Table 2). The calculation process includes several references to parameters published by Barnes (2008), which presented the results of a vertical flow reactor trial treating an iron-rich mine discharge. This treatment process is similar to the Tara MSR process from a sludge layer accumulation perspective, assuming the sludge layer forms on the surface of the mussel shell layer. Sludge samples from the IBC MSR trial have been collected by BCL, which may provide a more representative dry sludge Fe content and in-situ sludge solids content (data pending). These calculations may therefore be updated when these data are available if the differences are material.

Table 2: Tara MSR sludge layer accumulation

Parameter	Unit	Value
Flow rate	(L/s)	0.2
Fe load	(g/d)	346
Fe load to dry sludge scale factor	(g dry sludge / g Fe load)	3.15*
Dry sludge accumulation	(g/d)	1,090
	(t/yr)	0.40
In-situ wet sludge solids content	% (w/w)	14.5**
In-situ bulk density	(t/m^3)	1.12***
In-situ wet sludge volume accumulation	(m^3/yr)	2.5
Sludge layer thickness (1-year)	(m)	0.026****

** Derived from Barnes (2008) showing a ~32% Fe content in a dry sludge product treating a Fe rich mine discharge using a vertical flow reactor, ** in-situ sludge solids content measured by Barnes (2008), *** in-situ bulk density derived assuming a dry sludge specific density of 3,710 kg/m^3 after Barnes (2008), **** sludge layer thickness equivalent to spreading the annual wet sludge volume across the 94 m^2 shell substrate surface.*

Darcy's law can be used to derive the head required to drive the design CC02 flow rate (0.2 L/s) across the ~0.026 m thick sludge layer. Darcy's law (when arranged to calculate driving head) states:

$$\Delta H = \frac{Q}{KA} L \qquad \text{(Equation 1)}$$

Where, K is permeability (m/s)

Q is flow rate (m^3/s)

ΔH is driving head (m)

L is sludge layer thickness (m)

A is surface area of gravel bed (m^2)

Barnes (2008) derived a sludge permeability of 7.2 x 10^{-7} m/s for an Fe rich sludge layer accumulating on the gravel surface of a vertical flow reactor. This is expected to be a reasonable analogue for the permeability of sludge accumulating on the Tara MSR mussel shell layer surface. Solving Equation 1 shows that a 0.08 m head would be required to drive the 0.2 L/s design flow across the Tara MSR sludge layer after one year of sludge accumulation. From this assessment (using design parameters) the Tara MSR would theoretically have sufficient freeboard (0.5 m) to treat CC02 underdrain discharges for up to 5 years prior to desludging. It is important to note that the 5-year period is based on conservative design parameters (Table 1), whereas the current flow rates and Fe loads would suggest maintenance is required every 10 - 20 years, which is a more reasonable estimate of desludging requirements.

<u>Substrate exhaustion and maintenance requirements</u>

The rate of MSR substrate exhaustion is proportional to the influent acidity load and alkalinity lost from the MSR. The rate of mussel shell substrate exhaustion is calculated in Table 3. These calculations show that the rate of mussel shell exhaustion is relatively low (due to the relatively low influent acidity concentration) and equates to exhaustion of the upper 0.014 m of shells per year.

Table 3: Tara MSR mussel shell substrate exhaustion

Design parameter	Unit	Value
Flow rate	(L/s)	0.2
Influent acidity concentration	(mg $CaCO_3$/L)	60
Effluent alkalinity concentration	(mg $CaCO_3$/L)	100*
Net alkalinity gain	(mg $CaCO_3$/L)	160
Net alkalinity consumption	(g $CaCO_3$/d)	2,765
	(t $CaCO_3$/yr)	1.01
Mussel shell effective ANC	(t ANC / t shells)	0.75**
Annual mussel shell consumption	(t/yr)	1.35
Mussel shell bulk density (dry)	(m^3/t)	0.99***
Annual shell volume consumption	(m^3/yr)	1.36
Annual substrate exhaustion depth	(m/yr)	0.014

** Nominal MSR discharge alkalinity taken from Robertson (2017), ** Calculated using data from Diloreto (2016) which showed a fresh mussel shell ANC of ~800 kg $CaCO_3$/t versus an exhausted mussel shell ANC of ~50 kg $CaCO_3$/t in the Fe sludge layer, *** Weber (2015).*

Compared to the estimated driving head maintenance frequency using design Fe loads (i.e., sludge accumulation over ~5 years leading to the maximum potential driving head of 0.5 m) the annual substrate exhaustion rate of 0.014 m/yr is relatively low. Substrate exhaustion over a ~5 year period would theoretically equate to exhaustion of the upper ~90 mm of shell ANC. Thus, mussel shell ANC exhaustion is unlikely to be a critical design parameter for the Tara MSR and is not considered further.

<u>Sludge accumulation within the MSR pore space</u>

A further check on MSR treatment capacity is to compare the in-situ wet sludge volume accumulation rate of 2.5 m^3/yr (from Table 1) to the mussel shell substrate porosity. This is a different failure mechanism to that assessed in the driving head section (i.e., sludge accumulation in the shell pore space rather than sludge accumulation as a layer above the mussel shell layer). As the pore space becomes filled the substrate will effectively be exhausted by preventing the mussel shell surfaces from mobilising alkalinity. McCauley (2011) reported a mussel shell porosity of 0.72 (i.e. ratio of 0.72 m^3 pore space per m^3 mussel shell substrate). As such, the wet sludge accumulation of 2.5 m^3/yr could fill the pore spaces of ~3.4 m^3 of mussel shell substrate. This would equate to filling the mussel shell pore space to a depth of 0.036 m below the shell surface across the 94 m^2 reactor area and is likely to be a more realistic indicator of effective substrate exhaustion rates. If filling of the pore space in the upper 200 mm of the mussel shell layer were adopted as the target for desludging, the exhaustion rate of 0.036 m/yr would trigger desludging after ~ 5 years assuming design Fe loads (a similar period to driving head desludging requirements).

Expected MSR maintenance frequency

A five-yearly MSR desludging and mussel shell replacement programme is anticipated for the Tara MSR, based on MSR design Fe and acidity loads. This is expected to be equivalent to both:

- An increase in driving head requirements to ~0.4 m (retaining ~0.1 m of the free board capacity) for treatment of the design 0.2 L/s flow; and
- Sludge accumulation through the upper ~0.2 m of the mussel shell substrate layer.

The 5-yearly desludging frequency is expected based on the design Fe and acidity loads, which are approximately four times higher than the loads observed through the year 2020.

It is therefore a reasonable assumption that MSR desludging will only be required on a 10 to 20 yearly basis if CC02 underdrain contaminant loads stabilise at the current levels. Successful Tara MSR operating data are required to validate this assumption as there are other potential failure modes (e.g., TSS loads in underdrain discharge, algal growth, vegetation growth, within the MSR, etc.) that have not been considered in this assessment. Performance monitoring will be important for the TARPS for any potential failure mode.

Over the long term the contaminant concentrations discharging from the CC02 underdrain are expected to decrease as sulfide mineral oxidation rates decrease and the quantity of stored oxidation products decrease. This will result in less frequent MSR desludging requirements.

<u>ESTIMATED MSR DISCHARGE WATER QUALITY</u>

BCL have been trialling the MSR treatment process specifically using CC02 underdrain water collecting in Tara Pond 1. This involves pumping water from Tara Pond 1 into an IBC partially filled with mussel shells. Influent and effluent water samples are collected periodically and analysed for water quality. These trial data have been reviewed to provide an estimate of MSR discharge water quality.

An initial review of data showed anomalies in the Day 1, 89, and 98 samples. For these samples, the effluent sulfate concentration (Figure 8) was significantly lower than the influent sulfate concentration. While sulfate retention within the MSR is possible (as insoluble sulfides) this was ruled out as other relatively conservative parameters (B, calcium (Ca), and magnesium (Mg)) showed similar concentration anomalies.

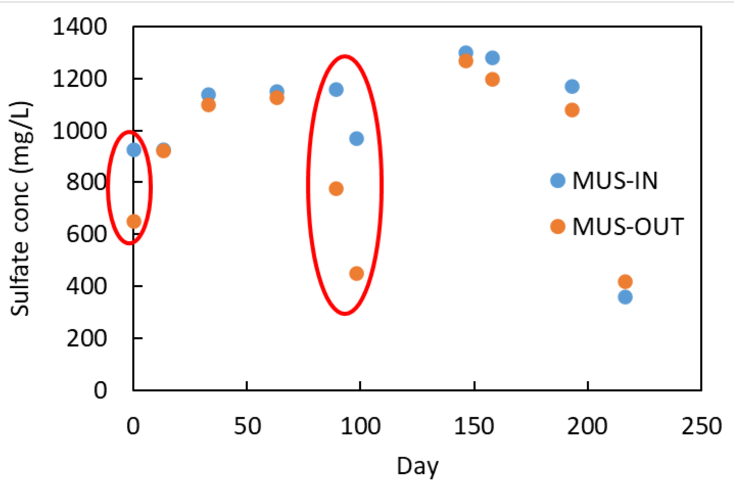

Figure 8. MSR trial sulfate data showing anomolous samples on days 1, 89, and 98

A summary of the remaining average influent and effluent contaminant concentration data (excluding days 1, 89, and 98) are presented in Table 4. These data show that contaminants can be separated into three groups based on behaviour through the trial MSR:

- High degree (>80%) of removal – acidity, Fe, Nickel (Ni), and Zn (NB: Aluminium (Al) would be included in this group if influent concentrations were higher);
- Moderate (~30%) degree of removal – Mn; and
- Low/negligible degree of removal – Sulfate, B.

The median CC02 contaminant concentration through the 2019/20 period is also shown in Table 4. This shows that median IBC influent contaminant concentrations are representative of the median CC02 contaminant concentrations. The exception is Fe concentration (and therefore calculated acidity concentration), which is relatively low in the median IBC influent. However, there is still a high degree (98%) of Fe removal.

The median contaminant removal is shown in Table 4 as a percentage of the influent concentration value. This includes a positive removal percentage for acidity, Fe, Ni, Zn, and Mn. A negative removal percentage is shown for Ca and total hardness, indicating an increase in these parameters through the treatment process. This reflects the Ca mobilisation due to mussel shell (primarily composed of $CaCO_3$) dissolution. ‘Negligible’ removal is shown for other parameters where appropriate.

Table 4: Onsite MSR trial reactor data

Parameter	Median CC02 (mg/L)*	Median IBC influent (mg/L)	Median IBC effluent (mg/L)	Median removal (%)	Tara MSR** effluent (mg/L)
pH (pH units)	6.4	6.6	7.3	n/a	7.3
Calc acidity	54.3	13.9	0.2	98	1.1
Sulfate (SO_4)	1,130	1047	1018	negligible	1,130
Al	0.005	0.021	0.004	negligible	0.005
Fe	20.4	5.1	0.06	98	0.40
Ni	0.089	0.078	0.013	83	0.015
Zn	0.55	0.44	0.051	88	0.065
B	2.3	2.50	2.40	negligible	3.65***
Ca	235	205	245	-25	302
Mg	115	105	102	negligible	115
Mn	2.6	2.6	1.9	33	1.7
Total Hardness	1,047	943	1031	-13	1,228
Turbidity	16	18	12	n/a	n/a
Sample count (n)	24	7	7	n/a	n/a

** Median CC02 water quality data over the 2019/20 period, ** Forecast Tara MSR effluent chemistry based on Median CC02 influent and median removal rates, *** Effluent B concentration based 90th percentile CC02 water quality data over the 2019/20 period.*

These median removal rates were applied to the median CC02 water quality to determine likely Tara MSR effluent concentrations. The exception was effluent B concentration, where a Tara MSR effluent B concentration of 3.65 mg/L was modelled to reflect the recent (June 2020 onwards) elevated concentration recorded at CC02. Figure 6 shows that this increase in B concentration coincides with decreasing CC02 underdrain flows and that the B load has actually decreased for the June 2020 onwards period. The Tara MSR effluent meets CRC170541 compliance limits (Table 5) for CC02-tele water quality for all parameters, excluding B. Compliance is achieved for Ni and Zn after hardness modification, with hardness modified trigger values shown in the bracketed values in Table 5.

Table 5: CRC170451 CC02-tele compliance limits downstream of main mine operations area and forecast Tara MSR effluent concentrations

Contaminant	Unit	Frequency	Compliance Limit	Tara MSR effluent
pH	(pH)	Monthly	6-9	7.3
Turbidity	(NTU)	Monthly	50 NTU	n/a
Boron	(mg/L)	Monthly	1.5*	**3.65**
Manganese	(mg/L)	Monthly	1.9	1.7
Nickel**	(mg/L)	Monthly	0.011 (0.258)**	0.015
Zinc**	(mg/L)	Monthly	0.008 (0.188)**	0.065
Iron	(mg/L)	Monthly (if pH is <4.5)	1	0.4
Aluminium	(mg/L)	Monthly (if pH is <5.5 or >7.5)	0.055	0.005
TSS	(mg/L)	Monthly	n/a	n/a

** Adopted in the 3rd February 2020 compliance monitoring report for CRC173823 – compliance assessed as a 3-monthly rolling median; ** Where the compliance limit (ANZECC 95% TV) is modified by the hardness algorithm: $TV(H/30)^{0.85}$ using a Tara MSR effluent hardness of 1,228 mg $CaCO_3$/L.*

The adopted Tara MSR effluent B concentration of 3.65 mg/L exceeds the 1.5 mg/L compliance limit (which is assessed as a 3-monthly rolling median). This was expected as B removal through MSR treatment systems has not been observed in on-site trials or at other operating MSR. Achieving B compliance downstream of the Tara MSR discharge point (at CC02-tele) will therefore require dilution.

The minimum calculated amount of clean water required for CC02 underdrain B dilution to meet CRC 170541 limits is shown in Figure 9. A diluting flow of 0.2 L/s would be sufficient for the majority of 2019/20 CC02 B samples to meet compliance limits. This includes the recent period where B concentrations of up to 3.75 mg/L have been reported coincident with relatively low CC02 underdrain flow rates of <0.1 L/s.

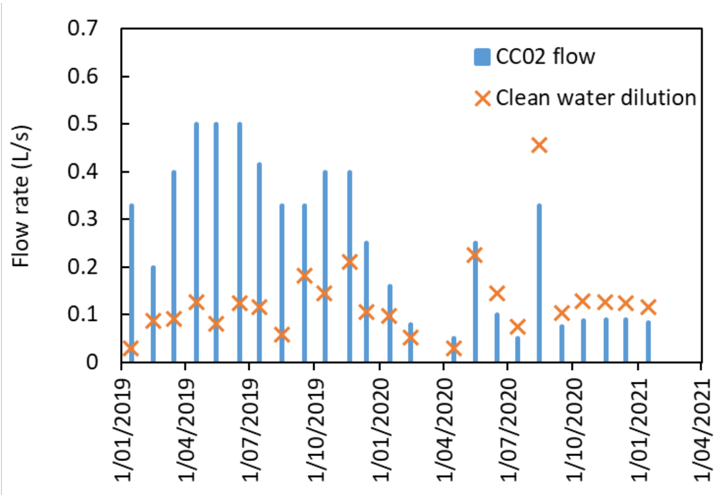

Figure 9. CC02 flow data and theoretical clean water dilution required for B compliance

The forecast Tara MSR effluent Mn concentration of 1.7 mg/L is less than the CC02-tele compliance limit. However, an IBC trial effluent Mn concentration of > 3 mg/L was reported in an individual sample, which is equivalent to no Mn removal through the IBC MSR. The clean water dilution rates required for Mn compliance at CC02-tele are equivalent to approximately half the dilution rates required for B compliance. Thus, conservatively assuming there is no Mn removal through the Tara MSR, Mn compliance would still be expected as a result of the B dilution step. Thus, it is important to note that Zn is the critical parameter for removal / treatment through the Tara MSR.

The contaminant concentration of the diluting body will define actual dilution flow requirements. Any additional B or Mn loads added by the dilution water body will increase the dilution volume required for CC02-tele compliance. The N02 Pit Pond is proposed as the diluting water body. It provides a large storage reservoir for decant discharge to maintain a relatively constant diluting flow at CC02-tele. The N02 Pit Pond water quality and corresponding volume requirements for Tara MSR dilution are discussed further in Memorandum 3 (MWM, 2021b).

RECOMMENDATIONS

To advance the Tara MSR component of closure preparations, MWM recommend:

- Constructing the Tara MSR as early as possible to provide some operating data prior to the site entering closure. This would require temporary use of water from the Malvern Hills Scheme to dilute Tara MSR discharge B concentrations to meet compliance. Early collection of Tara MSR performance monitoring data would validate sludge accumulation assumptions and implications on treatment performance and maintenance requirements.
- Develop conceptual MSR design and drawings showing layout of underdrain and pipe networks. BCL should also create a record of installation (i.e., photographs of key elements after installation); and
- Develop a MSR standard operating procedure (SOP) including performance monitoring programmes and maintenance / desludging triggers (i.e., TARPs).

ADAPTIVE MANAGMENENT

It is proposed that Adaptive Management will be used for mine closure activities at Canterbury Coal Mine where uncertainty exists for key AMD related risks, which have been identified by BCL through a risk review workshop. Adaptive management is a recognised management option under the Resource Management Act (RMA) (e.g., Leckie, 2017). Effective adaptive management is supported by understanding the nature and duration of possible events that could occur, monitoring these events, and then having options in place should there be variance from the expected condition. This requires:

- Understanding the risks;
- Monitoring (as early warning, i.e., performance monitoring);
- Variance planning; and
- Trigger Action Response Plans (TARPS).

For the proposed long term management of the AMD effects on CC02 underdrain water the following adaptive management is proposed.

1. Understand Risk
   a. The risks associated with AMD within the catchment and CC02 Underdrain are well understood with data available on quality and flow;
   b. Data confirms that passive treatment is a viable option for the management of key AMD effects (e.g., Fe, Zn);
   c. With recent, and significant changes in the catchment affecting water quality and flow rates, and decreasing contaminant loads there is uncertainty on longer term trends, although decreases in load and quality are expected; and
   d. Variance in loads is likely to affect treatment duration and management costs.
2. Conduct Performance Monitoring
   a. Continue monitoring of flow and quality to understand trends, including seasonal effects; and
   b. Review data at cessation of mine closure earthworks (after active closure period) to consider geochemical trends and any changes to the expected water quality trends / management requirements.
3. Plan
   a. Develop an adaptive management plan for passive treatment at the cessation of mine closure earthworks. This plan should include TARPS.

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