

APPENDIX N WATER TREATMENT REPORT

Water Treatment Report: MFS and ESE

Buller Plateaux Continuation Project

21 July 2026

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EXECUTIVE SUMMARY

Bathurst Resources Limited (BRL) is seeking to obtain authorisation through the Fast-track Approvals Act (FTAA) to progress development and mining of the coal resources across the wider Buller Plateaux. This project is referred to as the Buller Plateaux Continuation Project (BPCP). There are five key project sub-areas:

- Stockton mining area (Stockton)
- Mount Frederick South (MFS)
- Escarpment Extended (ESE)
- Upper Waimangaroa Haul Road (UWHR)
- Cypress mining area (Cypress)

Mine Waste Management Limited (MWM) has been engaged by BRL to provide guidance on water treatment for Mine Impacted Water (MIW) for the proposed BPCP that includes the effects of acid and metalliferous drainage (AMD) and total suspended solids (TSS). This report addresses water treatment at MFS and ESE. Water treatment at Stockton and Cypress is addressed by GHD (2026). Water treatment for the UWHR is addressed by BRL (2026e).

This Water Treatment Report addresses water treatment over the Construction, Operational, Active Closure, and Post Closure phases for MFS and ESE.

Objectives of this Report

The objectives of this report are to:

- Provide a summary of the interim water treatment requirements during the Construction Phase for MFS and ESE.
- Review the water treatment requirements (active and passive) during the Operational, Active Closure, and Post Closure phases when MIW will be released from ESE and MFS (after treatment).

Key Findings

Studies undertaken as part of the assessment of environmental effects for the BPCP for ESE and MFS highlight that management of MIW and the treatment of AMD and TSS are critical priorities. The following is required to achieve the proposed water quality limits (as determined by Hickey, 2026) for MFS and ESE:

- pH correction to achieve water quality limits at water quality compliance monitoring locations.
- Treatment of acidity.
- Treatment of TSS.

- Treatment of key potential constituents of concern (PCOC) that includes: iron (Fe), aluminium (Al), and trace metals that include cadmium (Cd), cobalt (Co), copper (Cu), manganese (Mn), nickel (Ni), and zinc (Zn).

Water Treatment Overview

During the Construction, Operational, and Active Closure phases, active treatment of MIW is required by a water treatment plant (WTP) at ESE and MFS, noting during the Construction Phase this will be a small portable water treatment system(s) that transitions to the permanent WTP during this phase. As engineered landforms (ELFs) are progressively rehabilitated during the Operational and Active Closure phases, and where acidity loads allow, the treatment of AMD impacted seepage will transition into numerous (n~20) passive treatment systems (PTS).

Mussell shell Bioreactors (MSRs) are proposed for the passive treatment of basal seepage from ELFs at the ESE and MFS sub-areas. MSRs will be installed progressively as mining operations in specific catchments are completed and land rehabilitated (some MSRs starting within a few years). The start of the Post Closure Phase commences once all ELF basal seepage is being treated passively.

For the purposes of this report there are four distinct project phases that are defined by the way MIW elevated in TSS and AMD are managed:

- Construction Phase: defined by the commencement of earthworks on site up until the permanent active WTPs and associated WTP ponds are commissioned. This will require routing of water and minor water management / treatment using a small portable water treatment plant(s) to neutralise acidity using either $\text{Ca}(\text{OH})_2$ (hydrated lime/calcium hydroxide¹) or NaOH (caustic); and the addition of flocculants as required to treat TSS. AMD sludge management is also required.
- Operational Phase: Water Management and active water treatment using calcium oxide (CaO), flocculants, and metal-chelating agents with AMD sludge being separated from treated discharge water by lamella clarifiers and mechanical sludge dewatering using pressure filtration (plate and frame filters (Process Flow, 2026a)) with AMD sludge disposal to ELFs. Some passive treatment commences for ELFs that are completed.
- Active Closure Phase: Active water treatment continues with a gradual transition to passive treatment of ELF basal seepage. AMD sludge disposal will either be onsite at an appropriate location, disposal at Stockton, or by other approved methods that may be developed over the Operational Phase of the BPCP.
- Post Closure Phase: defined by the decommissioning of the WTPs with water treatment being completed by gravity fed passive treatment systems. The proposed current technology being a MSR. AMD sludge disposal will either be onsite at an appropriate location, disposal at Stockton, or by other approved methods that may be developed over the Operational Phase of the BPCP. Back-up options include disposal to approved offsite landfills.

¹ Noting studies are underway into the use of MgO (BRL, 2025a) as a neutralising agent.

The management of water treatment sludge is a critical aspect of water treatment. This is discussed separately in MWM (2026d). Flow rates that will be treated during Operational, Active Closure, and Post Closure phases have been determined from the water and load balance models for ESE and MFS (MWM, 2026e,f).

Active Water Treatment

Active treatment is expected for a total of approximately 18 years at MFS and 30 years at ESE (noting this excludes the Construction Phase, prior to the WTP being commissioned (~2 years). The WTPs include the following treatment infrastructure and processes:

- WTP Surge Ponds (the “Stockpile Surge Pond” at MFS and the Ex-Pit Seal Pit at ESE) – receiving water from the run-off, seepage areas, and from pumping from the pit sumps.
- Powdered CaO silos and mixing tanks to generate a neutralising slurry for MIW water from the surge ponds.
- Pontoon mounted pumps to transfer water from the surge ponds to the acidity neutralisation tank.
- pH controlled CaO slurry dosing of AMD in the acidity neutralisation tank.
- Flocculant and metal-chelating agent dosing to CaO neutralised water prior to transfer to the Lamella Clarifiers.
- Separation of suspended and precipitated solids in the Lamella Clarifier with partial sludge return to the Lamella Clarifier in-flow (i.e., High Density Sludge (HDS) loop).
- Lamella Clarifier sludge is thickened with flocculant and pumped to a pressure filter for dewatering to create a “filter cake”. Dewatered filter cake is discharged to a bunker for loadout and trucking to disposal areas.
- Sulfuric acid (i.e., pH) trimming of the Lamella Clarifier thickener overflow (treated supernatant) where required to remove additional metals and meet pH compliance limits.
- Treated supernatant will report to a polishing pond after the pH correction before discharge to the receiving environment.
- Under high rainfall conditions the following may occur:
 - Bypass and direct discharge from pit sumps when river flows are >95th %ile and >90th %ile respectively.
 - Mine pit surge sumps and WTP surge ponds spill no more than 5% of the time on average.

This is discussed in more detail in the WLBM reports MWM (2026e,f).

Water treatability trials conducted by Process Flow (2026b) determined that neutralisation with calcium oxide (CaO), coagulation with Metalzorb FZ, and flocculation with Rheomax 1030 effectively reduces

TSS and dissolved metals in the supernatant, producing water quality consistent with ESE and MFS guideline values (Hickey, 2026).

WTP effluent discharge design standards are shown in Table E1 and are applied to WTP discharge at both ESE and MFS within the WLBM to understand effects on the receiving environment.

Table E1: WTP effluent discharge design standards.

PARAMETER ⁴	INFLUENT (mg/L) ³	TREATED EFFLUENT CONCENTRATION (mg/L)	TREATMENT EFFICIENCY (%)
Acidity	360	2.5	99.3
Alkalinity	0.5	5.5	-
Ca	62	Calculated ¹	-
Mg	19.2	Mg input water quality ²	-
Na	3.1	Na input water quality ²	-
K	7.1	K input water quality ²	-
SO ₄	570	SO ₄ input water quality ²	-
Al	44	0.074	99.8
Fe	9.5	0.01	99.9
Ni	0.197	0.0027	98.6
Mn	1.78	0.18	89.9
Cr	0.0045	0.0011	75.6
Cd	0.00088	0.000025	97.2
Co	0.081	0.001	98.8
Cu	0.0133	0.00025	98.1
Pb	0.00116	0.00005	95.7
Tl	0.0026	0.00117	55.0
Zn	1.04	0.0058	99.4
DOC	1	0.25	75.0
TSS	16	1.5	90.6
pH	3.2	6.4	-

¹ Calcium is calculated (as is done in the water and load balance models). The amount of Ca in the WTP effluent is a function of influent Ca concentration and the amount of CaO required to neutralise the influent acidity.

² These parameters are not affected by active treatment. Hence the inflowing concentration is the same as the effluent concentration.

³ Influent data collected from Manchester Street drain at Stockton Mine.

⁴ Arsenic (As) is not assessed as previous studies on the Barren Valley ELF (MWM, 2026a) indicate that it is below the limit of reporting (< 0.001 mg/L) and data from Stockton (provided in MWM 2026a), indicates that after treatment and removal of iron (Fe), As concentrations are typically < 0.005 mg/L as compared to the ANZG (2018) 95% trigger value of 0.013 mg/L.

AMD sludge management will comprise thickening and dewatering of sludge for final disposal. Further details on AMD sludge disposal are provided in MWM (2026d)

Passive Water Treatment

Studies indicate that ~20 passive treatment systems are required for the treatment of mine affected waters at MFS and ESE, with six PTSs being established at the ESE project sub-area and 14 PTSs being established at the MFS project sub-area (and another system will be required for the ESE Coal Storage and Infrastructure pads). Flow rates reporting to these facilities range from < 1 litres per second (L/s) up to ~120 L/s and acidity loads range from ~1 tonnes per year (t/yr) up to ~ 300 t/yr.

MSRs were selected as the preferred PTS technology based on:

- **Renewable Material:** The materials used in a MSR are derived from waste mussel shells, a by-product of the seafood industry, which supports a circular economy. Furthermore, the CO₂ within the shells, that are used for neutralisation of acidity, is renewable (i.e., not fossil CO₂).
- **Treatment Performance:** MSRs have shown to consistently remove PCOC such as acidity, Fe, and Al, and to a slightly lesser extent, trace metals such as Ni and Zn under both acidic and alkaline conditions. Secondary MSR treatment (polishing pond) have been proposed for further removal of residual trace metals and secondary contaminants as required. Site-specific operational field trials will be completed in the first 1-3 years of the Operational Phase of the BPCP to validate previous laboratory studies that the designs of these MSR polishing ponds are suitable to achieve closure water quality objectives in the targeted timeframe.
- **Sludge Management:** AMD sludge (predominantly Fe and Al) is generated from the treatment of acidic AMD impacted waters. Downflow MSRs are an efficient process to remove Fe and Al, acting as a vertical flow reactor as well as a neutralising PTS with pH correction such that AMD sludge forms at the surface of the MSR. This sludge can effectively be removed as part of routine maintenance as demonstrated at existing operating MSRs. Higher acidity loads (i.e., higher dissolved Fe and Al loads) can be managed by increased maintenance frequencies once treatment performance decreases. When active treatment is still occurring after ELFs have been rehabilitated (i.e., Active Closure Phase), AMD sludge disposal will either be onsite at an appropriate location (e.g., AMD sludge disposal cells at ESE Coal Pad), disposal at Stockton, or by other approved methods that may be developed over the Operational Phase of the BPCP. In the Post Closure Phase similar locations will be used. A back-up option includes disposal to offsite landfills.

Noting: Other options for AMD sludge management will be evaluated during the Operational Phase. If studies indicate that the method can provide geochemical stability, containment integrity, and cost-effective handling to align with closure objectives then this may be implemented at a later date (with additional regulatory approval as required).

- **Maintenance:** For maintenance of the MSRs (e.g., desludging) the system or part of the system needs to be taken off-line. This could involve dosing of bypass water with CaO or NaOH, designing MSRs to incorporate bays such that individual bays can be bypassed and drained for desludging while others remain operating. MSR Polishing ponds could also be constructed deeper to accommodate all sludge generation or be desludged periodically, if required. Further details are provided in the AMD WMP (BRL, 2026b).
- **Spatial Requirements:** MSRs can be sized for the expected flow (where ~100 m² of MSR surface area with a minimum depth of 1.5 m is needed for 1 L/s) provided sufficient surface area is available. For ESE and MFS, MSR surface area requirements have been factored into mine plans based on net percolation rates of 40% into ELFs after closure (MWM, 2026i), which drives treatment requirements. Additional space is provided for the MSR polishing ponds. Space for maintenance activities (e.g., desludging, vehicle access, etc is also required).

- **Demonstrated Experience and Longevity:** BRL has successfully implemented MSRs, with systems operating effectively for nearly a decade while showing low maintenance requirements.

While MSRs are the proposed passive treatment technology for the BPCP, other passive treatment options may be viable and have not been excluded from future consideration. Passive treatment technologies are advancing rapidly, e.g., enhanced passive treatment systems (Christenson et al., 2018)) and/or the use of a series of biogeochemical processes (i.e., a treatment train) to treat AMD characteristics (Nairn et al., 2023) may have application to the BPCP in the future.

Early construction of the MSR in the first 1-3 years of the Operational Phase will enable site-specific testing and validation through performance monitoring to demonstrate the system's effectiveness early in the project's implementation.

MSR treatment systems will include:

- Sediment management systems to mitigate any residual TSS and prevent the PTS from being overwhelmed with sediment (i.e., diversion of surface flow away from the MSR).
- Mussel shells to neutralise acidity (carbonate neutralisation) and precipitate Fe- and Al-hydroxides, a key component of acidity, and remove metals by adsorption / co-precipitation.
- Anaerobic treatment to remove nitrate, reduce sulfate concentrations, and precipitate metals as sulfides.
- A polishing pond to remove secondary contaminants generated in the anaerobic treatment stage (e.g., sulfide (HS^-), ammoniacal nitrogen, and low dissolved oxygen) as well as treat residual Fe, Ni, and Zn by oxidation and adsorption.
- Sludge management, which is discussed further in MWM (2026d).

MSR treatment efficiencies for different PCOC are shown in Table E2. The work to derive these efficiencies are provided in MWM (2026c). The process is well understood and documented at several operations (Stockton Mine, Canterbury Coal Mine, Echo Coal Mine).

Table E2: MSR treatment efficiencies.

PARAMETER	TREATMENT EFFICIENCIES (%)
SO ₄	10.4
Al	99.7
Fe	80 ¹
Ni	40.2
Mn	58.6
Cd	1.89
Co	82.8
Cu	96.6
Pb	85.8
Zn	63.7

1. A nominal efficiency of 80% is used rather than the measured 99.7% to account for the ELF being sub-oxic and some Fe(II) passing through the MSR untreated.
2. PCOC such as As, Cr, and TI were not evaluated given low concentrations in influent. Further details are provided in MWM (2026a).

MSR effluent flows into a polishing pond for aerobic treatment. This promotes Fe(OH)₃ formation supporting further Ni and Zn removal (by adsorption / co-precipitation) and oxidation of secondary contaminants. The polishing pond removal efficiencies for Ni and Zn are shown in Table E3. The removal efficiencies for Ni and Zn are shown in Table E3 as determined by MWM (2026c).

Table E3: MSR polishing pond treatment of MSR Stage 1 treated effluent

PARAMETER	TREATMENT EFFICIENCIES (%)
Fe	99.0
Zn	59.0
Ni	12.5

Studies indicate the pH of MSR effluent can be ~pH 8 (MWM, 2026c). This may require pH correction or mixing/dilution with surface flows so that water quality is compliant with proposed water quality pH limits at downstream compliance monitoring locations (Hickey, 2026). pH correction may use ferric chloride (FeCl₃), which will also support the removal of trace metals such as Zn and Ni if Fe concentrations in the MSR effluent are lower than expected. Ferric chloride dosing would involve a small dosing system (e.g., a 1,000L IBC connected to a small battery-operated dosing pump).

Supporting Studies

The following supporting studies and related reports are relied on for this Water Treatment Report:

- WLBM for MFS and ESE (MWM, 2026e,f)
- Erosion and Sediment Control Plan for Land Disturbance Activities (BRL, 2026e)
- Process Flow WTP design reports (Process Flow 2026a,b).
- Passive Treatment Design Toolkit (MWM, 2026c).
- AMD Sludge Report (MWM, 2026d).

These reports are discussed in this document. The technical content summarised in this report is used to support the development of the BPCP AMD Water Management Plan for ESE, MFS, and UWHR (BRL, 2026b).

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1 INTRODUCTION

Bathurst Resources Limited (BRL) is seeking to obtain authorisation through the Fast-track Approvals Act (FTAA) to progress development and mining of the coal resources across the wider Buller Plateaux. This project is referred to as the Buller Plateaux Continuation Project (BPCP). There are five key project sub-areas:

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- Escarpment Extended (ESE)
- Upper Waimangaroa Haul Road (UWHR)
- Cypress mining area (Cypress)

Mine Waste Management Limited (MWM) has been engaged by BRL to provide guidance on water treatment for Mine Impacted Water (MIW) for the proposed BPCP that includes the effects of acid and metalliferous drainage (AMD) and total suspended solids (TSS). This report addresses water treatment at MFS and ESE. Water treatment at Stockton and Cypress is discussed by GHD (2026). Water treatment for the UWHR is discussed by BRL (2026a).

This Water Treatment Report addresses water treatment over the Construction, Operational, Active Closure, and Post Closure phases for MFS and ESE.

The management of water treatment sludge is a critical aspect of the BPCP and is discussed separately in MWM (2026d).

BRL, (through BT Mining Limited), and its predecessor Solid Energy New Zealand Limited, have been treating MIW and managing AMD sludge at the Stockton Mine for almost 20 years. Significant technical expertise, experience, and skill in terms of managing AMD and MIW have developed over this timeframe. Further details on treatment at Stockton are available (e.g., Elder et al., 2011; GHD, 2026).

1.1 Project Site and Schedule Overview

Indicative BPCP timelines are reflected in Figure 1. The transition from active treatment to passive treatment is expected to occur over 5-20 years, following closure and final rehabilitation of engineered landforms (ELFs). The location of the MFS and ESE project sub-areas, in the context of the BPCP, is presented in Figure 2.

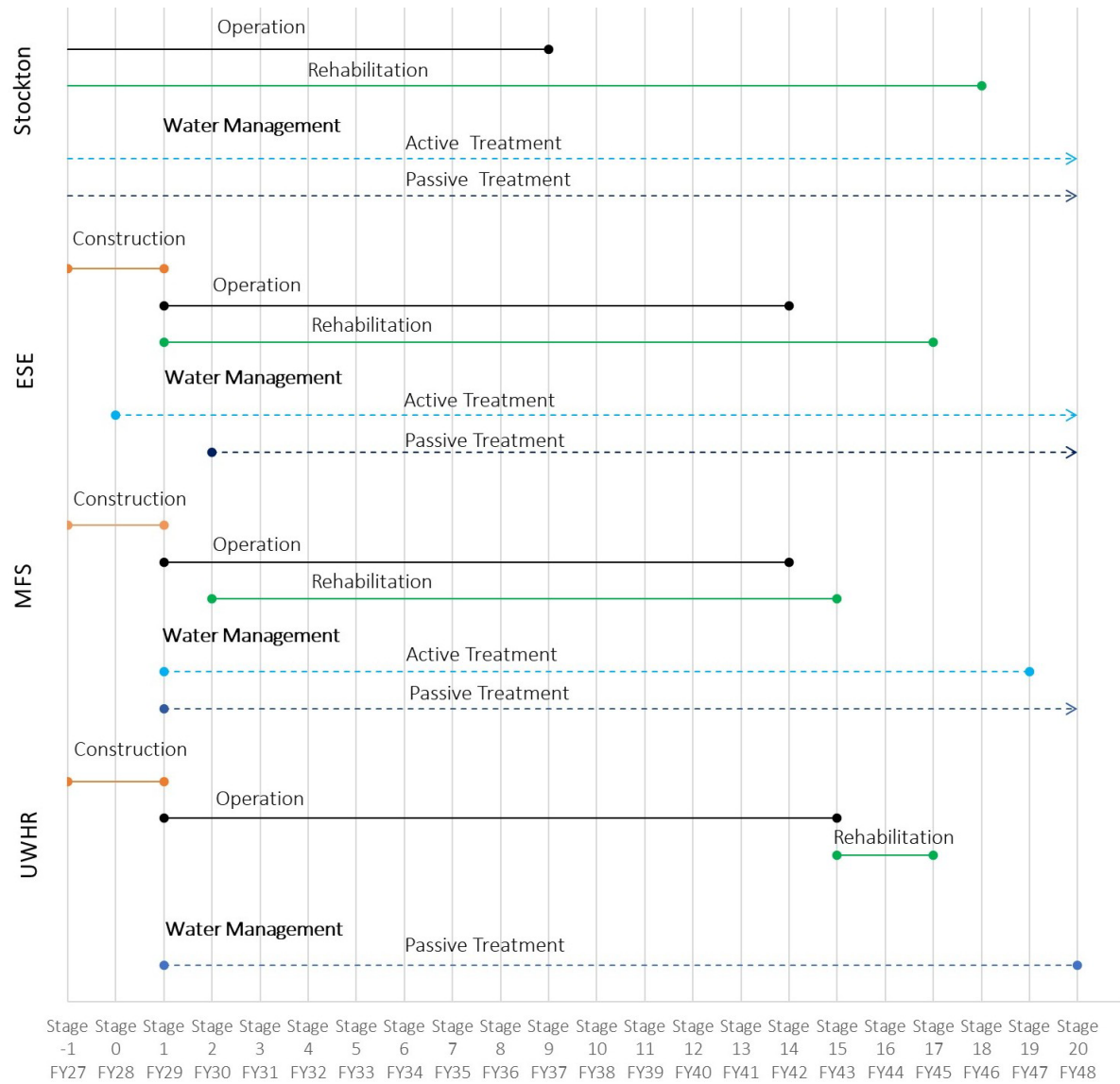
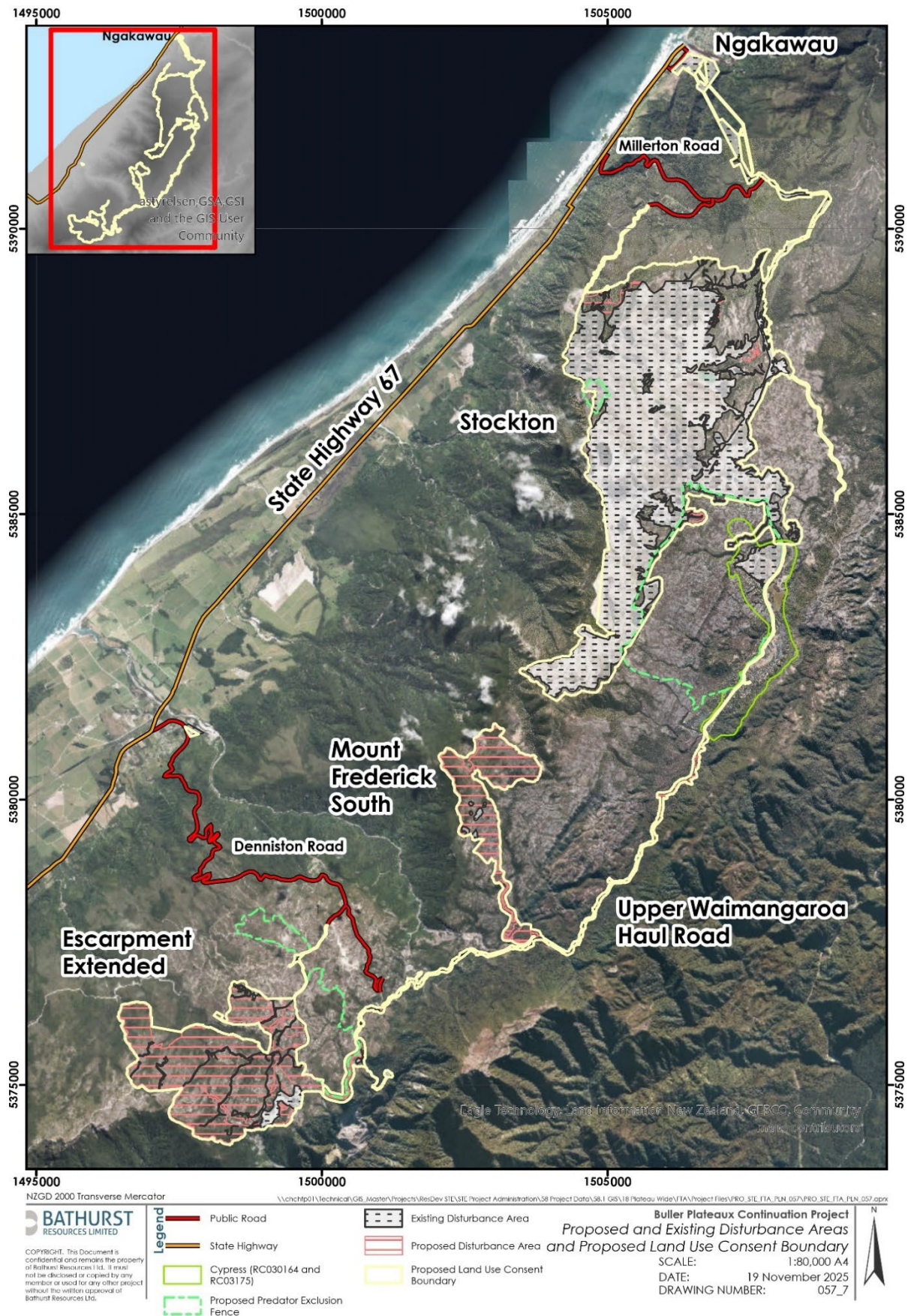


Figure 1: BPCP timelines (by stage and by indicative year).



1.2 BPCP Water Treatment Requirements

1.2.1 Summary

Studies undertaken as part of the assessment of environmental effects for the BPCP for ESE and MFS highlight that management of MIW and the treatment of AMD and TSS are critical priorities (BRL, 2026c).

The water and load balance models (WLBMs) developed by MWM (2026e,f) and other studies indicate that the BPCP needs to focus on the management and treatment of AMD and TSS that will contain potential constituents of concern (PCOC).

Treatment requirements for TSS and AMD will differ depending on the activity phase of operations including:

- Construction Phase: defined by the commencement of earthworks on site up until the active WTPs and associated WTP ponds are commissioned. This will require routing of water and minor water management / treatment using a small portable water treatment plant(s) to neutralise acidity using either $\text{Ca}(\text{OH})_2$ (hydrated lime/calcium hydroxide²) or NaOH (caustic); and the addition of flocculants as required to treat TSS. AMD sludge management is also required.
- Operational Phase: Water Management and active water treatment using CaO, flocculants, and metal-chelating agents with AMD sludge being separated from treated discharge water by lamella clarifiers and mechanical sludge dewatering using pressure filtration (plate and frame filters (Process Flow, 2026a)) with AMD sludge disposal to ELF. Some passive treatment commences for ELF that are completed.
- Active Closure Phase: Active water treatment continues with a gradual transition to passive treatment of ELF basal seepage. AMD sludge disposal will either be onsite at an appropriate location, disposal at Stockton, or by other approved methods that may be developed over the Operational Phase of the BPCP.
- Post Closure Phase: defined by the decommissioning of the WTPs with water treatment being completed by gravity fed passive treatment systems. The proposed current technology being a MSR. AMD sludge disposal will either be onsite at an appropriate location, disposal at Stockton, or by other approved methods that may be developed over the Operational Phase of the BPCP. Back-up options include disposal to approved offsite landfills.

The management of water treatment sludge is a critical aspect of water treatment. This is discussed separately in MWM (2026d). Flow rates that will be treated during Operational, Active Closure, and Post Closure phases have been determined from the WLBMs for ESE and MFS (MWM, 2026e,f)

1.2.2 MFS Mine Phases

Mining at MFS is planned to begin in 2029 and is planned to cease at the end of 2042, with rehabilitation activities complete by 2043. The Active Closure Phase is modelled to cease in 2046 with a transition to

² Noting studies are underway into the use of MgO (BRL, 2025a) as a neutralising agent.

passive treatment. Table 1 provides a summary of the mine phases for MFS and water treatment activities.

Table 1: MFS mine phases and water treatment activities.

MINE PHASE	YEARS (INCLUSIVE)	ACTIVITIES
Construction Phase	2027-2028	Portable water treatment plants.
Operations Phase	2029-2042	Active mining and production, active WTP in operation.
Active Closure Phase	2043-2046	Active mining has ceased. Completion of rehabilitation has been undertaken. Active treatment and associated infrastructure remain operational until ELF seepage water quality is deemed suitable for treatment through use of MSRs. MSR passive treatment systems become active at different times for each ELF.
Post-Closure Phase	2047-2128	MSRs provide complete treatment of the site water discharges.

1.2.3 ESE Mine Stages

Mining at ESE is planned to begin in 2028 and is planned to cease at the end of 2040, with rehabilitation activities complete by 2043. The Active Closure Phase is modelled to cease in 2057 with a transition to passive treatment. Table 2 provides a summary of the mine phases for ESE and water treatment activities.

Table 2: ESE mine phases and water treatment activities.

MINE PHASE	YEARS (INCLUSIVE)	ACTIVITIES
Construction Phase	2027	Portable water treatment plants.
Operations Phase	2028-2040	Active mining and active treatment at the WTP. Progressive rehabilitation and operation of limited number of MSRs.
Active Closure Phase	2041-2057	Active mining has ceased. Construction of post-closure infrastructure and completion of rehabilitation. WTP continues with limited operation of MSRs.
Post-closure Phase	2058-2143	Rehabilitation complete. Active treatment ceases and all ELF seepage treated with MSR.

1.3 Water Classification

This section summarises the types of water that will be encountered and/or will be created by the BPCP. Classification of waters will help support a better understanding of water management, both internally and externally.

Table 3: BPCP Water Classification

WATER CLASS	WATER TYPE	DESCRIPTION OF WATER TYPE	MANAGEMENT REQUIREMENTS	MONITORING
1	CLEAN WATER	Unimpacted water which is diverted around disturbed areas associated with mine workings.	No treatment is proposed for these waters with the expectation that they are not affected by AMD and TSS caused by BPCP activities. Addresses a key principle of water management – avoid clean water run-on to project areas.	Confirm water is suitable for discharge (untreated).
2	AMD IMPACTED WATER	Low pH, elevated sulfate and PCOC such as Al, Fe, and trace metals.	Water treatment being either active or passive, depending on flow rate, water quality, and mine phase.	Confirm treated water is suitable for discharge.
3	LEGACY AMD IMPACTED WATERS	AMD from historic workings.	BRL will look at control and treatment of these waters where practicable (e.g., initial pit at ESE intercepts large area of underground workings that will be directed from pit sumps for treatment) leading to betterment of surrounding waterways. Underground workings are completely mined out within the BPCP pit areas thus removing this legacy load.	Monitoring will be undertaken to understand betterment of waterways (ESNZ, 2026).
4	TSS IMPACTED WATER	Water that has a high sediment load due to erosion of unconsolidated surfaces through rainfall and surface water flows.	Water treatment being either active or passive, depending on flow rate, water quality, and mine phase. Passive treatment includes sediment ponds, check dams, floc blocks (further details in BRL, 2026e)	Confirm treated water is suitable for discharge.
5	REHABILITATED ELF SURFACE WATER	Once ELF surfaces are stabilised (after revegetation and rehabilitation) surface run off waters will be discharged to the surrounding streams without treatment.	No treatment is proposed for these waters after 2 years with the expectation (as advised by BRL based on experience at Stockton) that they are not affected by AMD or TSS. This requires a non-acid forming cover system to minimise AMD effects. It is assumed with grass hydroseeding that surfaces are stabilised in 2 years with subsequent low TSS, suitable for discharge.	Confirm water is suitable for discharge (untreated).
6	MINE IMPACTED WATERS (MIW)	Includes both AMD and TSS impacted waters that will be directed to active and passive treatment systems.	Water treatment is either active or passive, depending on flow rate, water quality, and mine phase.	Confirm water is suitable for discharge (treated).
7	TREATED WATER	Waters which have undergone active and passive water treatment prior to	Waters are discharged to the receiving environment	Performance and compliance monitoring to confirm that active and

WATER CLASS	WATER TYPE	DESCRIPTION OF WATER TYPE	MANAGEMENT REQUIREMENTS	MONITORING
		discharge to the receiving environment		passive treatment meets design specifications and water quality limits (e.g., Hickey, 2026)
8	BYPASS WATER	High flow event that exceeds maximum design capacity of pits and/or water treatment facilities (e.g., Pit Sumps and WTP Surge Ponds), resulting in untreated MIW discharge to the surrounding waterways noting that some TSS will be removed by sedimentation within pit sumps.	Discharge structures will be required.	Performance and compliance monitoring
9	CLOSURE WATERBODIES – WATER MANAGEMENT	Closed as a long-term waterbody to support water management (i.e., Active Closure Phase water management)	Active Closure Phase maintenance and management. Potentially transitioning into facilities that provide ecosystem services in the Post Closure Phase or a potential water supply for Kawatiri Energy Limited. Some waterbodies may include MSR polishing ponds that will be active for many decades into the Post Closure Phase.	Performance and compliance monitoring
10	CLOSURE WATERBODIES – ECOSYSTEM SERVICES	Established to provide ecosystem services (e.g., pit lakes rehabilitated as an artificial waterbody)	Minor post closure maintenance and management.	Performance and compliance monitoring (intensity declining with time)
11	GROUNDWATER	Groundwaters within the project areas may be affected by AMD. Any effects are expected to be minor and report to the ELF seepage network.	Efficient collection of in-pit ELF seepage is predicated on maintaining a lower phreatic surface within the backfilled material than that external to the pit.	Monitoring of groundwater levels and effects monitoring of nearby surface waters

1.4 Water Quality Objectives

Water and oxygen interacting with materials that contain sulfide minerals can generate AMD. The mine domain with the greatest source hazard risks (60-80% of total AMD load) are waste rock storage facilities (e.g., INAP, 2020), that include waste rock dumps (WRD) having no engineering controls to control sulfide mineral oxidation or the mobilisation of secondary sulfide oxidation products. Engineered landforms (ELFs) are proposed for the BPCP to minimise the generation of AMD arising from waste rock storage; details are provided in the ELF Design Philosophy Report (MWM, 2026g) and the AMD ELF Management Plan (BRL, 2026c).

Previous studies indicate several PCOC that could be elevated in BPCP AMD impacted waters. These include:

- Low pH and elevated acidity
- Elevated iron (Fe) and aluminium (Al) leading to the formation of Fe- and Al- hydroxides, the release of Lewis acidity, and the formation of hydroxide floc leading to AMD sludge formation.
- Elevated trace metals that include cadmium (Cd), cobalt (Co), copper (Cu), manganese (Mn), nickel (Ni), and zinc (Zn).
- Elevated sediment.

Water quality limits for the ESE, MFS, and UWHR have been developed by Hickey (2026).

1.5 Legacy Mining Effects

Extensive historic mining activities are present within the BPCP area, which have led to degraded water quality and the contamination of many surface waterways from AMD. BRL note the following:

- At the MFS sub-area there are numerous adits, waste rock disposal areas, and collapsed workings due to historic underground and minor outcrop mining activities. The historic underground Taipo and Koranui Mines are within the footprint of the MFS West Pit.
- Within the ESE sub-area there are several areas of historic underground workings including the Sullivan Mine, Sullivan West Mine, Escarpment Mine, Whareatea Mine, Davies & Party Mine, Plateau Mine, Coalbrookdale Mine, and Cascade Mine. For instance, AMD discharge from historic underground workings of the Denniston Plateau discharges into Cascade Creek, Waimangaroa River, Rapid Stream, and Whareatea River (near the coast where Rapid Stream enters) (Jewiss, 2018; Jewiss et al., 2020).
- The most recent mining operations on the Denniston Plateau took place at the existing open cut Escarpment Mine from 2014 to 2016 including development of infrastructure for the treatment of AMD using passive treatment technologies. These mining operations (currently under care and maintenance) are contained within the ESE sub-area footprint. The existing open cut Escarpment operation also developed MIW treatment systems and continues to treat AMD from the historic escarpment underground mine as well as the recent seepage from the Barren Valley ELF. AMD from the historic site flowed into several lakes near the Escarpment Mine all of which were acidic and severely impacted by AMD. Currently these lakes are circum-neutral and have low trace element concentrations due to the treatment processes implemented by BRL.
- The southern portion of the UWHR to the intersection of the proposed MFS Access Road has historically been mined via underground extraction and pre-existing impacts associated with the exposure of PAF materials are present. The proposed UWHR alignment is over the Coalbrookdale and Ironbridge mine underground workings. Ironbridge Mine operated between 1889 and 1944, closing due to fires. The workings stretched from Burnett's Stream to Deep Stream (Wright, 2008). Historic information suggests these underground workings are within 10 m of the proposed UWHR in some sections. The upper coal seam floor is more than 14 m below the surface, dipping to the south away from the Waimangaroa River. A drainage drive

continues to drain workings to the Waimangaroa River and this drive (as shown on historic mine plans) intersects coal floor at 475m RL suggesting workings that lie below this level are likely flooded, but all areas close to the UWHR corridor are unlikely to be flooded. Further details on historic mining activities in the area are provided by Clough & Associates (2025). The northern portion of the route from the MFS access road to Cypress has not previously been mined.

Studies completed as part of the BPCP FTAA application indicate that the proposed MFS and ESE mining activities will contribute to an improvement in water quality and aquatic ecology in several of the above AMD affected streams (e.g., Cascade Creek, V37 Creek) by the removal of some historical underground workings and the capture of associated legacy discharges. This is considered further by ESNZ (2026).

1.6 Report Objectives

The objectives of this report are to:

- Provide guidance on the interim water treatment requirements during the Construction Phase for MFS and ESE.
- Review the water treatment requirements (active and passive) during the Operational, Active Closure, and Post Closure phases when MIW will be released from ESE and MFS (after treatment).

1.7 Supporting Studies

Management of AMD and TSS to minimise the quantity and maximise the improvement in quality of water treated during the various ESE and MFS phases is addressed by the following documents:

- Water Management Infrastructure Design (BRL, 2026a)
- AMD Water Management Plan (BRL, 2026b)
- AMD ELF Management Plan (BRL, 2026c)
- Mine Closure Concept Strategy (BRL, 2026d)
- Erosion and Sediment Control Plan for Land Disturbance Activities (BRL, 2026e)

1.8 Treatment Overview

Source control engineering options can significantly reduce the quantity of AMD and TSS; however, treatment is also required due to the significant amounts of rainfall and water movement expected at MFS and ESE. Key AMD and TSS risks are addressed through an integrated approach combining source control and active and passive treatment processes:

- Source Control: Design of engineered landforms (ELFs) to minimise long term AMD loads through source control technologies and practices (MWM, 2026g; BRL, 2026c)
- Active treatment: providing reliable control of acidity, metal concentrations, and TSS (e.g., MIW) under variable flow and load conditions, ensuring compliance with discharge requirements through proven chemical and process-based technologies.

- Passive treatment: succeeding active treatment of ELF seepage, providing ongoing attenuation of residual acidity and metals, promoting long-term water quality stability and reducing operational demands.

Together, these processes provide robust risk management across the Construction, Operational, Active Closure, and Post Closure Phases for MIW.

1.9 Treatment Technology Selection: Active Treatment versus Passive Treatment

Passive systems are usually designed for relatively small flows (typically less than 50 litres per second (L/s)) unless a significant area is available for passive treatment to be successful (INAP, 2021). A common reference document (Taylor et al., 2005) provides general criteria for passive and active treatment (Table 4).

Table 4: General guidelines for selection of active versus passive treatment

TREATMENT SYSTEM	AVERAGE ACIDITY RANGE (mg CaCO ₃ /L)	AVERAGE ACIDITY LOAD (kg CaCO ₃ /day)	AVERAGE FLOW RATE (L/s)	TYPICAL pH RANGE	MAX pH ATTAINABLE
Passive	1 - 800	1 – 150	< 50	>2	7.5 – 8.0
Active	1 – 10,000	1 – 50,000	No defined limit	No defined limit	14

Source: Taylor et al. (2005).

INAP (2021) note that most successful passive treatment projects are treating less than 1,000 m³ per day, however there are two examples where treatment of 6,500 m³ per day (~75 L/s) was maintained for up to 19 years.

It is anticipated, based on experience at Stockton Mine, and the forecast peak acidity loads of ~4,500 tonnes per year (t/yr) at ESE and ~350 t/yr at MFS (Table 6 and Table 7 respectively), that during the Construction, Operational, and Active Closure Phases any MIW will be treated by active WTPs. In the Post Closure Phase there will be a transition to passive treatment technologies. If passive treatment cannot be reliably implemented because of high acidity loads, or high trace element concentrations then a longer active treatment duration will be required.

2 ACTIVE WATER TREATMENT

This section discusses active treatment of MIW during the Construction, Operational, and Active Closure Phases of the BPCP at MFS and ESE sub-areas before transition to passive treatment.

2.1 Construction Phase

Treatment of AMD and TSS is expected during the Construction Phase prior to the commissioning of the ESE and MFS water treatment plants (Figure 1) after 1-2 years. The following is noted:

- TSS will be the dominant contributor to mine impacted water during the Construction Phase due to lesser effects from ELF AMD impacted seepage at the start of the project. This will be managed by passive treatment processes (e.g., sediment ponds, check dams, floc blocks (further details in BRL, 2026e)) or, when required, small portable treatment systems will be used (discussed in Section 2.1.1).
- Minor AMD treatment is expected in the Construction Phase using small portable treatment systems (Section 2.1.2). This will either involve treatment with CaO slurry or NaOH to neutralise acidity with the addition of flocculants as required to precipitate AMD floc and TSS. Deployment of these systems depend on the nature and duration of specific construction activities and will rely on the experience of the BRL team with management of AMD at Stockton mine.
- MWM (2026d) notes that:
 - It is estimated ~ 190 tonnes of acid will be treated generating 20,000 m³ of AMD sludge at MFS over the two-year period.
 - It is estimated that ~ 60 tonnes of acid will be treated generating 10,000 m³ of AMD sludge at ESE in Year -1; and ~400 tonnes of acid will be treated generating 50,000 m³ of AMD sludge in Year 0.
 - These acidity loads seem conservative for planning purposes given the Barren Valley ELF (~356,000 bcm) generated acid loads of 10 - 20 t/yr (MWM, 2026b).
- ESE: The current Escarpment Mine Pit 3 Pit Lake (as shown in Figure 7 – north of the standpipes) and other existing water treatment infrastructure (e.g., Lake Brazil) will be used to treat and settle AMD sludge (i.e., the system is in place, except for the portable treatment plant). Treated waters will be discharged to Cascade Creek Trib (V8). Backfill of mine rock will eventually bury this AMD sludge. Pit 3 has a capacity of ~200,000 m³.
- MFS: A temporary water treatment sump of 10,000 m³ will be built near the MFS Coal Storage Pad. This will be buried by rock at the end of the MFS Construction Phase once the MFS WTP is operational. The temporary water treatment sump will be operational until the MFS WTP is constructed and will manage treatment of any AMD and TSS during the Construction Phase. Treated waters will be discharged to the Waimangaroa River above W2 (Smokestack).

2.1.1 TSS Treatment

The primary objective of TSS management during the Construction Phase is to prevent and minimise the discharge of TSS impacted water to receiving environments. This will be achieved through a combination of passive erosion and sediment control processes (e.g., BRL, 2026e), and active water

treatment using systems such as the modular Siltbuster treatment system³ when required (i.e., a Lamella Clarifier).

The Siltbuster system is a mobile water treatment system designed to remove fine TSS from impacted water systems. They are well proven in the mining and civil construction industries for managing TSS impacted water systems and dewatering discharges (Figure 3).

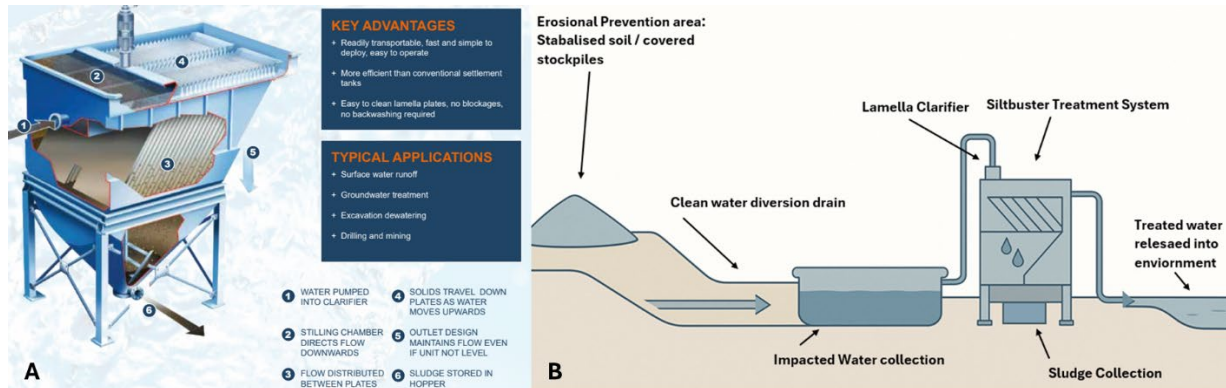


Figure 3: (A) Typical Lamella Clarifier; (B) Typical schematic of Construction Phase water treatment.

Source: <https://www.siltbuster.co.uk/wp-content/uploads/2020/10/Solutions-for-Suspended-Solids-Removal-1.pdf>

2.1.2 AMD Treatment

During the Construction Phase, small portable AMD treatment systems will be used to provide flexible, near-source neutralisation of acidic waters, allowing targeted treatment of AMD. These systems have storage and dispensing capabilities for reagents, such as $\text{Ca}(\text{OH})_2$ and NaOH for pH adjustment and metal precipitation from AMD.

Using $\text{Ca}(\text{OH})_2$ instead of CaO in the modular system enhances operator safety by reducing the risks associated with handling CaO as $\text{Ca}(\text{OH})_2$ is already hydrated and does not generate heat when mixed with water. Similar systems have been used at Stockton Mine and Reddale Coal Mine near Reefton (Figure 4).

Based on estimated acidity loads of 60 t/yr at ESE and 90 t/yr at MFS, this will require the addition of 1-2 bulk bags of $\text{Ca}(\text{OH})_2$ per week as an average but may be higher during significant rainfall events. Such quantities are manageable by portable systems.

³ <https://environz.co.nz/solutions/business/siltbuster-hire>

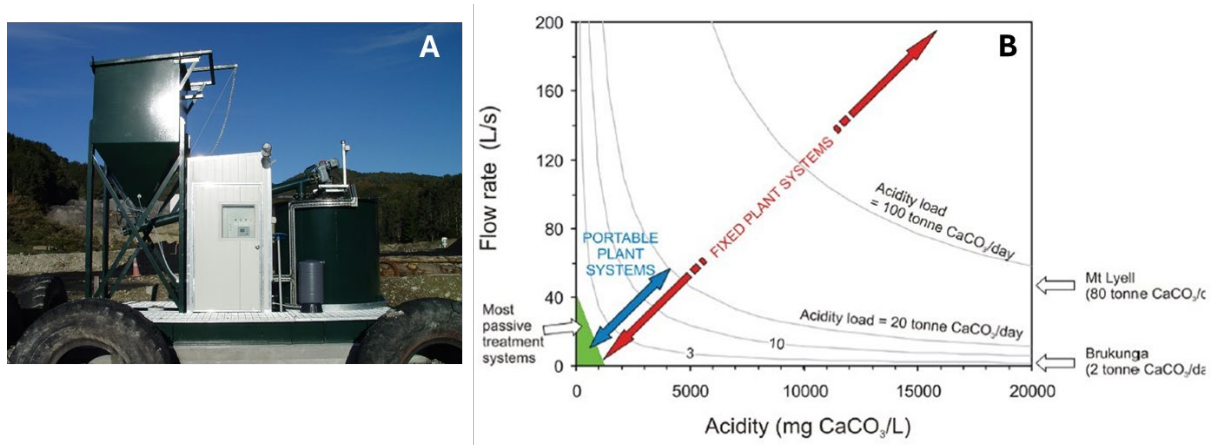


Figure 4: (A) Modular $\text{Ca}(\text{OH})_2$ dosing system at Reddale Coal Mine; (B) Selection of appropriate treatment system based on acidity load and flow rates.

Source: Taylor et al. (2005).

2.1.3 Summary – Portable Treatment Systems

Portable treatment systems are identified as a suitable technology for the Construction Phase when TSS and AMD impacted water quantities are low prior to the commissioning of the large active water treatment plants. The following summarises the advantages of these portable systems:

- Rapid mobilisation: units can be installed, commissioned, and relocated as construction advances.
- Compact footprint: suitable for constrained work areas near pits, haul roads, or construction laydowns.
- High treatment efficiency: effectively neutralises and removes silt, clay, and fine coal particles through Lamella Clarifier settlement or chemical flocculation.
- Scalable design: multiple units can be configured in series or parallel to match flow volumes.

The performance of these portable treatment systems will be monitored through routine sampling and visual inspections, with operational parameters adjusted (e.g., increase neutralent dose rate) as needed to maintain compliance. Key performance indicators include:

- TSS concentration (as assessed by turbidity) and metal concentrations: monitoring of discharge concentrations to ensure proposed consent limits can be achieved.
- Flow rate and volume: continuous tracking of treated water to verify treatment capacity and support reporting (obtained from pump rates).
- Sludge management: documentation of sludge removal frequency, volumes, and disposal locations.
- System inspection: verification of chemical dosing, mechanical function, and integrity of inflow/outflow structures.

2.2 Operational and Active Closure Phases

Permanent water treatment plants will predominantly be used to manage TSS and AMD during the Operational and Active Closure phases at the ESE and MFS mining sub-areas. The proposed locations and process schematics for the two WTPs are shown in the figures listed below:

- Figure 5 provides the ESE water treatment plant process schematic.
- Figure 6 provides the MFS water treatment plant process schematic.
- Figure 7 provides the ESE water treatment plant location.
- Figure 8 provides the MFS water treatment plant location.

To optimise sedimentation and AMD collection, water is typically stored within surge ponds where it may accumulate rapidly, due to storm events, but is then pumped to the WTP over an extended period of time relative to the capacity of the plant. This allows for optimised sedimentation and AMD treatment to be achieved.

Details on the active WTPs proposed for the ESE and MFS are provided in Process Flow (2026a,b). In summary, the WTPs will utilise the following equipment and processes to treat MIW:

- WTP Surge Ponds (the “WTP Surge Pond” and “Stockpile Surge Pond” at MFS and the Ex-Pit Seal Surge Pond at ESE) – receiving water from the run-off, seepage areas, and from pumping from the pit sumps.
- Powdered CaO silos and mixing tanks to generate a neutralising slurry for MIW water from the surge ponds.
- Pontoon mounted pumps to transfer water from the surge ponds to the acidity neutralisation tank.
- pH controlled CaO slurry dosing of AMD in the acidity neutralisation tank.
- Flocculant and metal-chelating agent dosing to CaO neutralised water prior to transfer to the Lamella Clarifiers.
- Separation of suspended and precipitated solids in the Lamella Clarifier with partial sludge return to the Lamella Clarifier in-flow (i.e., High Density Sludge (HDS) loop).
- Lamella Clarifier sludge is thickened with flocculant and pumped to a pressure filter for dewatering to create a “filter cake”. Dewatered filter cake is discharged to a bunker for loadout and trucking to disposal areas.
- Sulfuric acid (i.e., pH) trimming of the Lamella Clarifier thickener overflow (treated supernatant) to remove additional metals and meet pH compliance limits where required.
- Treated supernatant will report to a polishing pond after the pH correction before discharge to the receiving environment.
- Under high rainfall conditions the following may occur:
 - Bypass and direct discharge from pit sumps when river flows are >95th %ile and >90th %ile respectively.

- Mine pit surge sumps and WTP surge ponds spill no more than 5% of the time on average.
- This is discussed in more detail in the WLBMs reports MWM (2026e,f).

Water treatability trials conducted by Process Flow (2026b) determined that neutralisation with calcium oxide (CaO), coagulation with Metalzorb FZ, and flocculation with Rheomax 1030 effectively reduces TSS and dissolved metals in the supernatant, producing water quality consistent with ESE and MFS guideline values (Hickey, 2026).

WTP effluent discharge design standards are shown in Table 5 and are applied to WTP discharge at both ESE and MFS within the WLBMs to understand effects on the receiving environment.

Table 5: WTP effluent discharge design standards.

PARAMETER	INFLUENT (mg/L) ³	TREATED EFFLUENT CONCENTRATION (mg/L)	TREATMENT EFFICIENCY (%)
Acidity	360	2.5	99.3
Alkalinity	0.5	5.5	-
Ca	62	Calculated ¹	-
Mg	19.2	Mg input water quality ²	-
Na	3.1	Na input water quality ²	-
K	7.1	K input water quality ²	-
SO ₄	570	SO ₄ input water quality ²	-
Al	44	0.074	99.8
Fe	9.5	0.01	99.9
Ni	0.197	0.0027	98.6
Mn	1.78	0.18	89.9
Cr	0.0045	0.0011	75.6
Cd	0.00088	0.000025	97.2
Co	0.081	0.001	98.8
Cu	0.0133	0.00025	98.1
Pb	0.00116	0.00005	95.7
Tl	0.0026	0.00117	55.0
Zn	1.04	0.0058	99.4
DOC	1	0.25	75.0
TSS	16	1.5	90.6
pH	3.2	6.4	-

¹ Calcium is calculated (as is done in the water and load balance models). The amount of Ca in the WTP effluent is a function of influent Ca concentration and the amount of CaO required to neutralise the influent acidity.

² These parameters are not affected by active treatment. Hence the inflowing concentration is the same as the effluent concentration.

³ Influent data collected from Manchester Street drain at Stockton Mine.

⁴ Arsenic (As) is not assessed as previous studies on the Barren Valley ELF (MWM, 2026a) indicate that it is below the limit of reporting (< 0.001 mg/L) and data from Stockton (provided in MWM 2026a), indicates that after treatment and removal of iron (Fe), As concentrations are typically < 0.005 mg/L as compared to the ANZG (2018) 95% trigger value of 0.013 mg/L

Sludge management will comprise thickening and dewatering of sludge for final disposal into the ESE and MFS overburden ELFs. During the Active Closure Phase, AMD sludge disposal will either be onsite at an appropriate location, disposal at Stockton, or by other approved methods that may be developed

over the Operational Phase of the BPCP. Further details on AMD sludge management are provided in MWM (2026d).

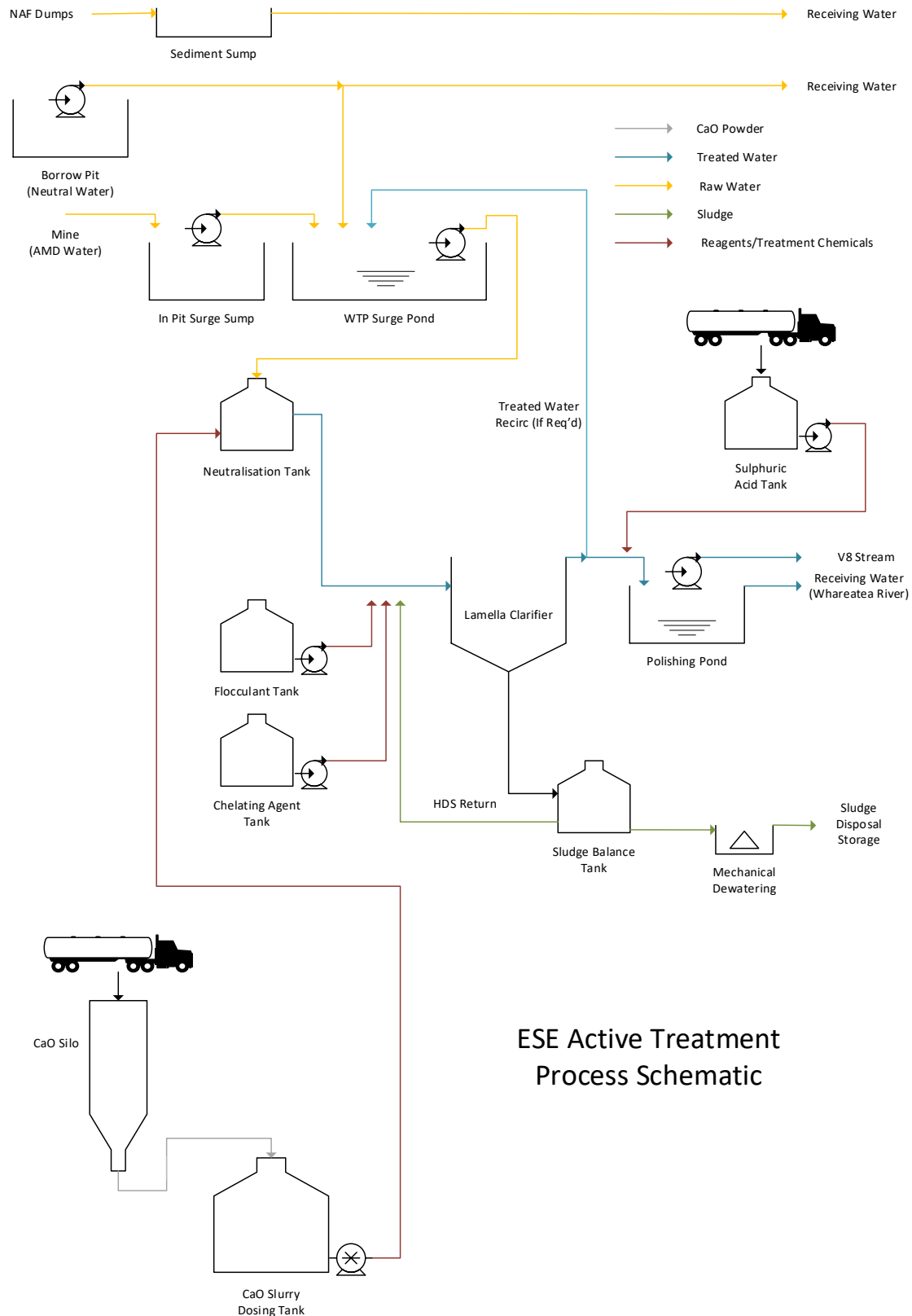


Figure 5: ESE water treatment plant process schematic

Source: Process Flow (2026a).

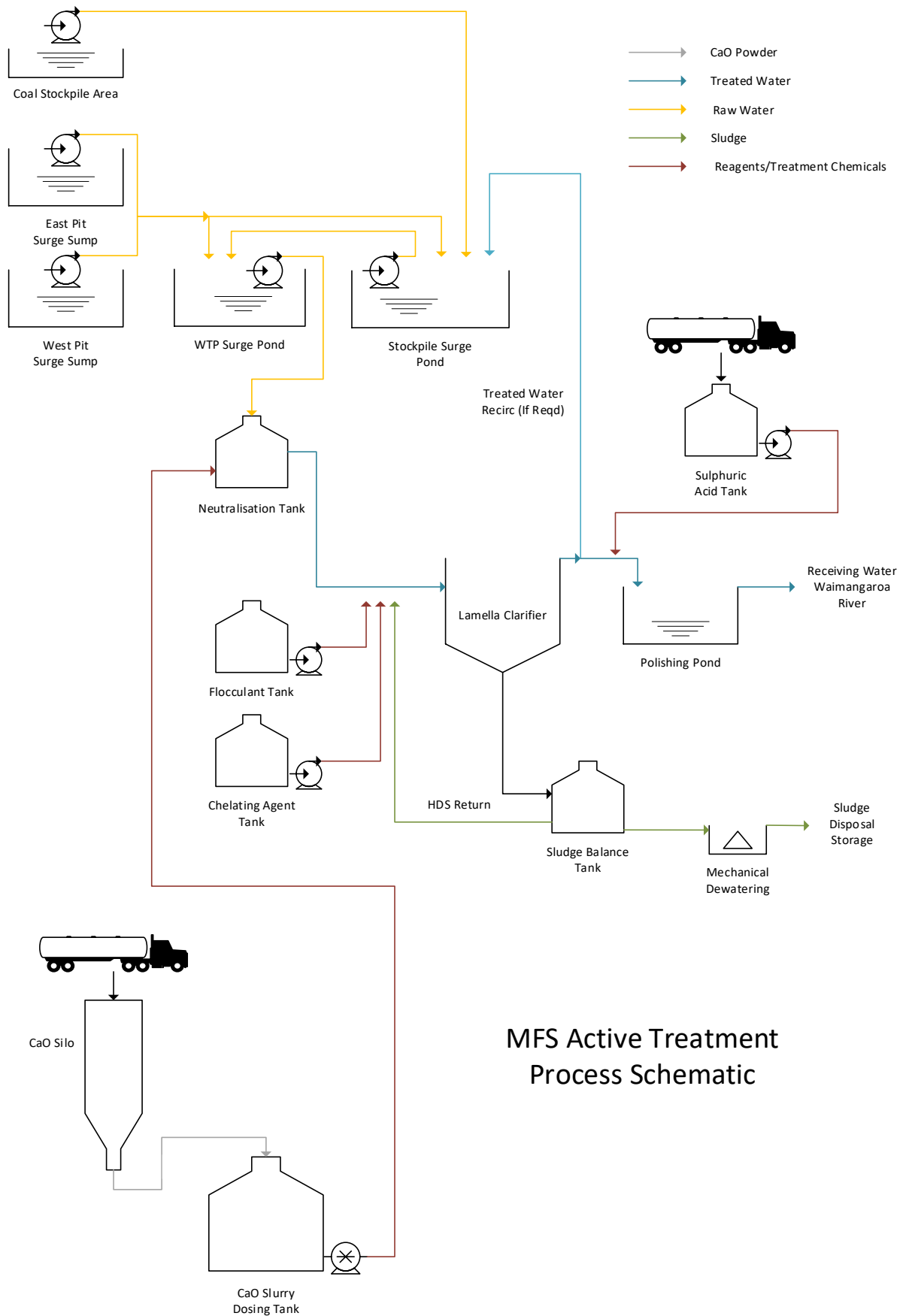


Figure 6: MFS water treatment plant process schematic

Source: Process Flow (2026a).

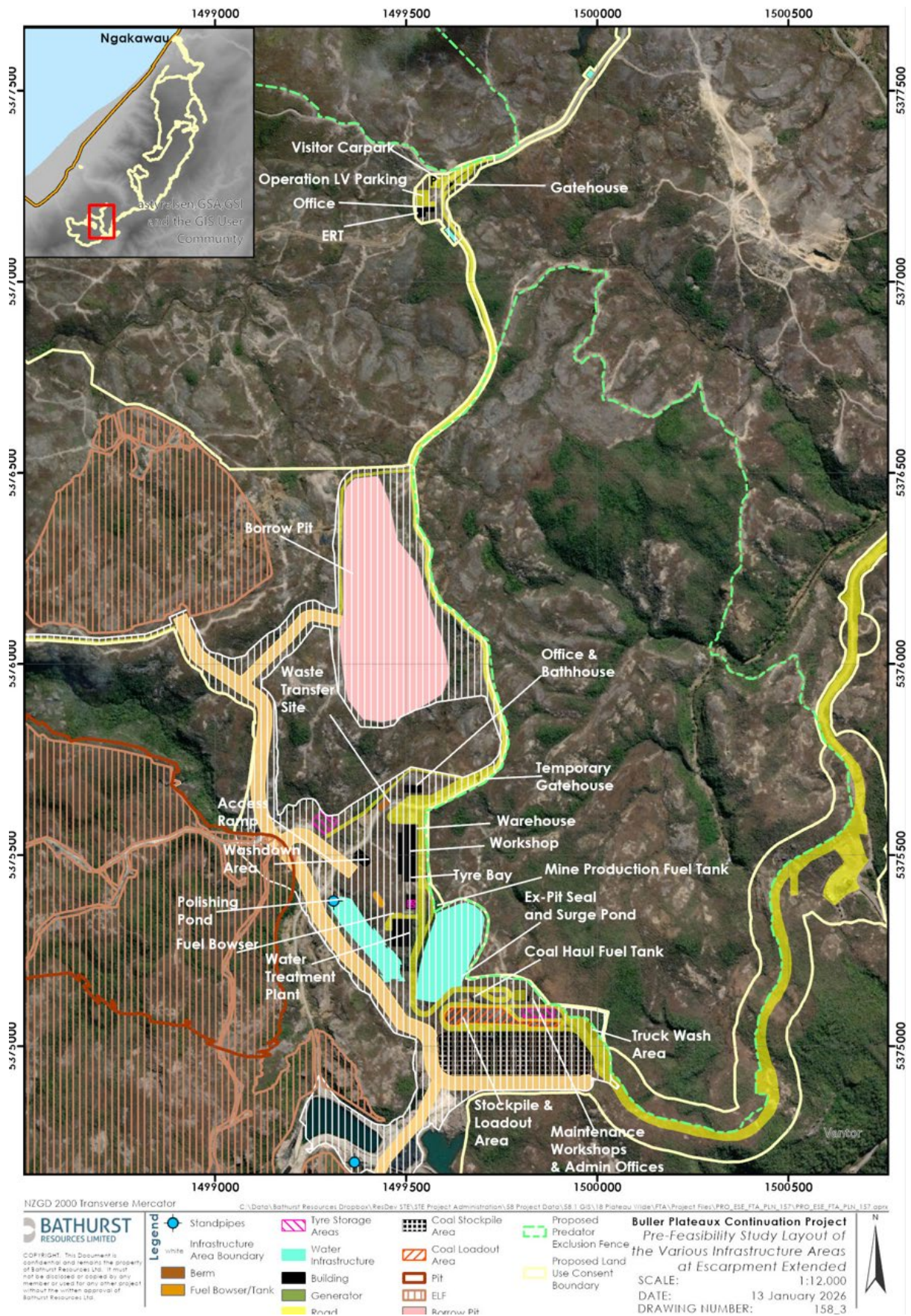


Figure 7: ESE water treatment plant in related infrastructure location map

Source: BRL (2026a)

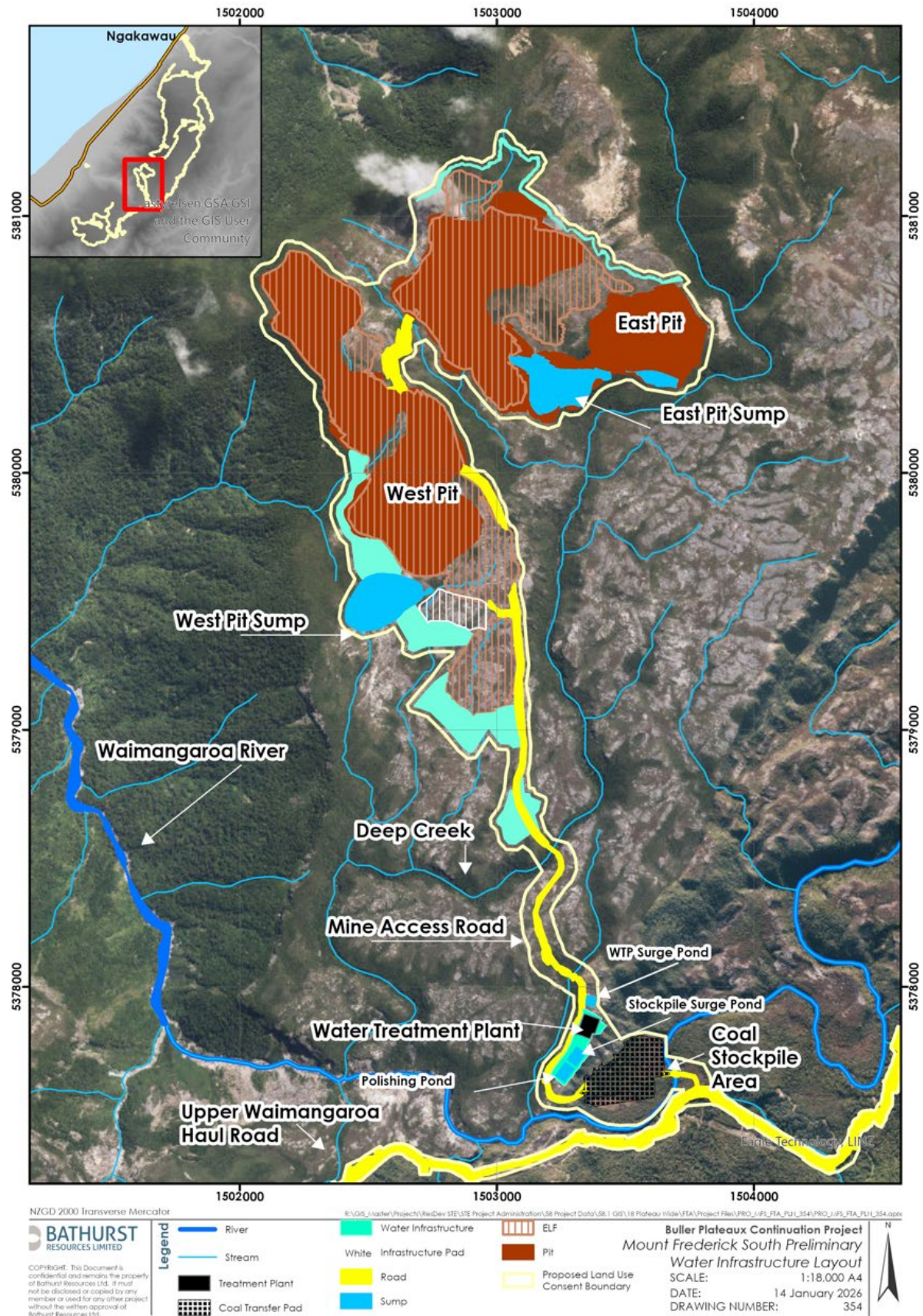


Figure 8: MFS water treatment plant location map

Source: BRL (2026b).

2.1 Active Treatment Summary

Forecasting AMD treatment requirements is essential for planning purposes to ensure the effects of TSS and AMD are managed. The WLBM for ESE and MFS were used (MWM, 2026e,f) to determine the quantity of acidity that would report to the water treatment plants. The raw WTP influent data (acidity, TSS, Al, and Fe loads) for ESE and MFS are provided in Table 3 and Table 4 respectively.

Table 6: ESE WTP Influent

INDICATIVE YEAR	MINE STAGE	ACIDITY LOAD (TONNES)	TSS (TONNES)	Al LOAD (TONNES)	Fe LOAD (TONNE)
2027	-1	61	186	7	3
2028	0	404	1,226	44	20
2029	1	724	1,499	76	33
2030	2	702	1,662	75	32
2031	3	1,426	2,041	149	65
2032	4	1,866	1,825	200	89
2033	5	2,373	2,042	255	114
2034	6	3,017	2,197	317	142
2035	7	3,774	2,351	386	173
2036	8	4,515	2,419	455	205
2037	9	4,502	1,778	452	206
2038	10	4,081	1,949	410	185
2039	11	3,200	1,845	325	146
2040	12	4,133	1,878	414	187
2041	13	4,457	1,975	444	201
2042	14	4,028	1,688	402	183
2043	15	3,384	1,703	339	154
2044	16	2,325	1,176	235	109
2045	17	1,637	1,152	167	77
2046	18	1,211	99	119	56
2047	19	1,008	99	99	47
2048	20	898	99	89	42
2049	21	807	99	80	38
2050	22	729	99	73	34
2051	23	673	99	67	31
2052	24	637	100	64	30
2053	25	604	100	61	28
2054	26	574	100	58	27
2055	27	547	100	55	26
2056	28	522	100	53	25
2057	29	508	100	51	24
Total		59,327	33,786	6,021	2,732

Green cells indicate the Construction Phase of the Project.

Indicative Year 2027 is not covered by the WLBM. Loads are based on 15% of Stage 0 based on material quantities in Stage 0 (4,348,200 bcm) versus Stage -1 being 659,20 bcm. Further details in MWM (2026d).

Table 7: MFS WTP Influent

YEAR	MINE STAGE	ACIDITY LOAD (Tonnes)	TSS (Tonnes)	Al LOAD (Tonnes)	Fe LOAD (Tonne)
2027	-1	42	128	4	2
2028	0	147	452	14	5
2029	1	89	276	9	3
2030	2	92	333	9	3
2031	3	100	345	10	4
2032	4	121	405	12	4
2033	5	144	466	14	5
2034	6	168	524	16	6
2035	7	239	719	23	9
2036	8	297	727	29	12
2037	9	309	833	30	12
2038	10	307	866	30	12
2039	11	321	773	31	13
2040	12	324	743	31	13
2041	13	315	869	30	12
2042	14	265	821	26	10
2043	15	193	391	20	8
2044	16	141	29	14	7
2045	17	46	14	5	3
2046	18	47	14	5	2
Total	20	3,706	9,730	360	146

Green cells indicate the Construction Phase of the Project, prior to treatment via the WTP. This mine phase is not covered by the WLBM. Loads are based on Stage 1 loads as a proportion of material quantities in Stage 1 compared to materials disturbed in Stage -1 and Stage 0. Further details in MWM (2026d).

Results indicate that:

- Acidity load is ~60,000 tonnes over the 30-year active treatment duration at ESE
- Acidity load is ~3,700 tonnes over the 18-year active treatment duration at MFS.

The difference in acidity loads between the two sub-areas reflects the differences in the quantity of materials disturbed (318 Mt at ESE and 37 Mt at MFS) and the sulfur content of the rock (ESE ELF: 0.28 – 0.73 wt% S; MFS ELF: 0.12 – 0.28 wt% S).

3 PASSIVE WATER TREATMENT

3.1 Introduction

Studies indicate that ~20 passive treatment systems are required for the treatment of mine affected waters at MFS and ESE, with six PTSs being established at the ESE project sub-area and 14 PTSs being established at the MFS project sub-area (and another system will be required for the ESE Coal Storage and Infrastructure pads). Flow rates reporting to these facilities range from < 1 litres per second (L/s) up to ~120 L/s and acidity loads range from ~1 tonnes per year (t/yr) up to ~ 300 t/yr.

MSRs were selected as the chosen technology for PTS based on:

- **Renewable Material:** The materials used in a MSR are derived from waste mussel shells, a by-product of the seafood industry, which supports a circular economy. Furthermore, the CO₂ within the shells, that are used for neutralisation of acidity, is renewable (i.e., not fossil CO₂).
- **Treatment Performance:** MSRs have shown to consistently remove PCOC such as acidity, Fe, and Al, and to a slightly lesser extent, trace metals such Ni and Zn under both acidic and alkaline conditions. Secondary MSR treatment (polishing pond) have been proposed for further removal of residual trace metals and secondary contaminants as required. Site-specific operational field trials will be completed in the first 1-3 years of the Operational Phase of the BPCP to validate previous laboratory studies that the designs of these MSR polishing ponds are suitable to achieve closure water quality objectives in the targeted timeframe.
- **Sludge Management:** AMD sludge (predominantly Fe and Al) is generated from the treatment of acidic AMD impacted waters. Downflow MSRs are an efficient process to remove Fe and Al, acting as a vertical flow reactor as well as a neutralising PTS with pH correction such that AMD sludge forms at the surface of the MSR. This sludge can effectively be removed as part of routine maintenance as demonstrated at existing operating MSRs. Higher acidity loads (i.e., higher dissolved Fe and Al loads) can be managed by increased maintenance frequencies once treatment performance decreases. When active treatment is still occurring after ELF's have been rehabilitated (i.e., Active Closure Phase), AMD sludge disposal will either be onsite at an appropriate location (e.g., AMD sludge disposal cells at ESE Coal Pad), disposal at Stockton, or by other approved methods that may be developed over the Operational Phase of the BPCP. In the Post Closure Phase similar locations will be used. A back-up option includes disposal to offsite landfills.

Noting: Other options for AMD sludge management will be evaluated during the Operational Phase. If studies indicate that the method can provide geochemical stability, containment integrity, and cost-effective handling to align with closure objectives then this may be implemented at a later date (with additional regulatory approval as required).

- **Maintenance:** For maintenance of the MSRs (e.g., desludging) the system or part of the system needs to be taken off-line. This could involve dosing of bypass water with CaO or NaOH, designing MSRs to incorporate bays such that individual bays can be bypassed and drained for desludging while others remain operating. MSR Polishing ponds could also be constructed deeper to accommodate all sludge generation or be desludged periodically, if required. Further details are provided in the AMD WMP (BRL, 2026b).

- **Spatial Requirements:** MSRs can be sized for the expected flow (where ~100 m² of MSR surface area with a minimum depth of 1.5 m is needed for 1 L/s) provided sufficient surface area is available. For ESE and MFS, MSR surface area requirements have been factored into mine plans based on net percolation rates of 40% into ELF's after closure (MWM, 2026i), which drives treatment requirements. Additional space is provided for the MSR polishing ponds. Space for maintenance activities (e.g., desludging, vehicle access, etc) is also required.
- **Demonstrated Experience and Longevity:** BRL has successfully implemented MSRs, with systems operating effectively for nearly a decade while showing low maintenance requirements.

While MSRs are the proposed passive treatment technology for the BPCP, other passive treatment options may be viable and have not been excluded from future consideration. Passive treatment technologies are advancing rapidly, e.g., enhanced passive treatment systems (Christenson et al., 2018)) and/or the use of a series of biogeochemical processes (i.e., a treatment train) to treat AMD characteristics (Nairn et al., 2023) may have application to the BPCP in the future.

Early construction of the MSR in the first 1-3 years of the Operational Phase will enable site-specific testing and validation through performance monitoring to demonstrate the system's effectiveness early in the project's implementation.

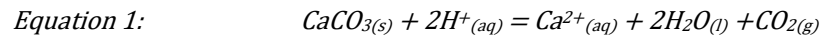
MSR treatment systems will include:

- Sediment management systems to mitigate any residual TSS and prevent the PTS from being overwhelmed with sediment (i.e., diversion of surface flow away from the MSR).
- Mussel shells to neutralise acidity (carbonate neutralisation) and precipitate Fe- and Al-hydroxides, a key component of acidity, and remove metals by adsorption / co-precipitation.
- Anaerobic treatment to remove nitrate, reduce sulfate concentrations, and precipitate metals as sulfides.
- A polishing pond to remove secondary contaminants generated in the anaerobic treatment stage (e.g., sulfide (HS⁻), ammoniacal nitrogen, and low dissolved oxygen) as well as treat residual Fe, Ni, and Zn by oxidation and adsorption.
- Sludge management, which is discussed further in MWM (2026d).

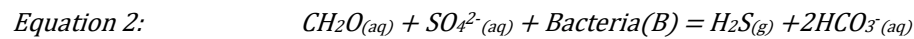
3.2 Background

In New Zealand, research into passive AMD treatment has spanned several decades. Since 2007, investigations have explored the efficacy of waste mussel shells to treat AMD impacted waters (Weber et al., 2008), offering a sustainable alternative to conventional passive treatment media. The reuse of mussel shells diverts waste from landfill and also supports circular economy outcomes and reduces the environmental footprint of treatment systems.

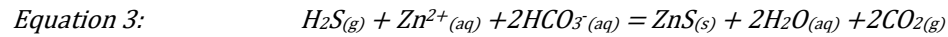
The primary objective of a mussel shell reactor (MSR) is to neutralise acidity by carbonate dissolution and by the decomposition of organic matter associated with the mussel shells over time. This serves a dual purpose (DiLoreto et al., 2016), enabling subsequent reactions that generate alkalinity and create conditions favourable for sulfide precipitation.



In addition, acidity is neutralised by alkalinity generated by sulfate reducing bacteria (SRB), for example:



Which can lead to the formation of sulfide minerals:



MSR technology has been tested, validated and operationally implemented over the last 18 years at the Stockton Coal Mine (Weber et al., 2008; McCauley et al., 2008a; McCauley et al., 2008b; McCauley et al., 2009a; McCauley et al., 2009b; McCauley et al., 2010; McCauley, 2011; Crombie et al., 2011; Weber et al., 2011, DiLoreto, 2014; Weber et al., 2015; Uster et al., 2015, Weisener et al., 2015, Diloreto, 2016a; Diloreto, 2016b; Falk et al., 2017; Buttler et al., 2019; Trumm et al., 2021) and the Escarpment Coal Mine (Roberston et al., 2017).

Further information on the MSR technology is available in MWM (2026c). Design requirements for the proposed MSR for MFS and ESE are provided in MWM (2026b).

3.3 MSR Performance

MSR treatment efficiencies for different PCOC are shown in Table 8. The work to derive these efficiencies are provided in MWM (2026c).

Table 8: MSR treatment efficiencies.

PARAMETER	TREATMENT EFFICIENCIES (%)
SO ₄	10.4
Al	99.7
Fe	80 ¹
Ni	40.2
Mn	58.6
Cd	1.89
Co	82.8
Cu	96.6
Pb	85.8
Zn	63.7

1. A nominal efficiency of 80% is used rather than the measured 99.7% to account for the ELF being sub-oxic and some Fe(II) passing through the MSR untreated.
2. PCOC such as As, Cr, and TI were not evaluated given low concentrations in influent. Further details are provided in MWM (2026a).

MSR effluent flows into a polishing pond for aerobic treatment. This promotes Fe(OH)₃ formation supporting Ni and Zn removal and oxidation of secondary contaminants. The removal efficiencies for Ni and Zn are shown in Table 9 as determined by MWM (2026c).

Table 9: MSR polishing pond treatment of MSR Stage 1 treated effluent

PARAMETER	TREATMENT EFFICIENCIES (%)
Fe	99.0

PARAMETER	TREATMENT EFFICIENCIES (%)
Zn	59.0
Ni	12.5

Studies indicate the pH of MSR effluent can be ~pH 8 (MWM, 2026c). This may require a pH correction or mixing/dilution with surface flows so that water quality is compliant with proposed water quality pH limits at downstream compliance monitoring locations. pH correction may use ferric chloride (FeCl_3), which will also support the removal of trace metals such as Zn and Ni. Ferric chloride dosing would involve a small dosing system (e.g., a 1,000L IBC connected to a small battery-operated dosing pump).

3.4 Post Closure Treatment of AMD at ESE and MFS

Data presented in this report indicates that the transition from active treatment of all ELF seepage to passive treatment technologies would be in approximately FY 2058 (transition to passive treatment of CON ELF basal seepage). The following variables will influence this timeframe:

- The ability to treat higher flow rates and acidity loads.
- Passive treatment technology advances over the next few decades.
- Water quality objectives and community expectations.
- Accuracy of geochemical models.
- Unforeseen changes to mining schedules (i.e., delays).
- Financial drivers to switch from an existing active treatment plant (sunk capex) to a passive treatment system (new capex).

Other passive treatment technologies are available for passive treatment of AMD waters for the BPCP. Although MSR are the preferred technology (MWM, 2026c), other systems may also be viable and could be assessed during the early phases of the project.

There are potential treatment capacity risks for long term passive treatment of AMD impacted waters associated with ELF basal seepage. To identify this treatment capacity risk (which is based on industry guidance (e.g., INAP, 2021)) for each ELF basal sub-catchment, the flow rate and acidity load are highlighted in Table 10 as:

- **Green:** $\leq$ ~50 t/yr acidity.
- **Green:** $\leq$ ~50 L/s average flow rate.
- **Orange:** $<$ ~100 t/yr acidity (two reactors may be required) but $>$ 50 t/yr acidity.
- **Orange:** $<$ ~100 L/s average flow rate (two reactors may be required) but $>$ 50 L/s average flow rate.
- **Red:** $>$ ~100 t/yr acidity (multiple reactors may be required).
- **Red:** $>$ ~100 L/s average flow rate (multiple reactors may be required).

Hence, Table 10 presents data for the proposed MSRs including:

- The estimated flow rate, which is based on a net percolation rate of 40%.

- The acidity load (range), which considers with the benefits of limestone additional and without the benefits of limestone addition for estimated acidity loads.
- The acidity load design for the MSR and the estimated start date of the MSR based on the WLBM.

The outcome from the analysis in Table 10 indicates that two MSR treatment systems (CON MSR and WWH MSR) may have capacity constraints. Further work is required to confirm that multiple MSR reactors will work and/or the use of other technologies that can increase treatment rates / treatment efficiencies (MWM, 2026c) are required. This work will be completed during the Operational Phase of the BPCP. The proposed MSR are shown in Figure 9 and Figure 10.

Table 10. MSR treatment capacity summary.

MSR	FLOW RATE (L/S) ¹	ACIDITY LOAD RANGE (t/yr) ^{2,3}	ACIDITY LOAD AT MSR START DATE (t/yr) ²	MSR ACTIVATION DATE (FY) ⁴	COMMENTS
BVE	13.9	21.1 (42.7)	38.2	2058	No issues anticipated
CON	75.3	86.0 (174.4)	174.4	2058	Potential capacity constraints (flow and load). Consider: 1. Multiple MSR (possibly up to 4) 2. Increased desludging to maintain optimal flow rates 3. Other treatment technologies. 4. Longer term active treatment
NSUL-Closure	18	(14.0) ²	5.1	2046	No issues anticipated: NAF ELF – treatment for Zn + other PCOC
PPG	2.76	(1.6) ²	0.1	2058	No issues anticipated: NAF ELF – treatment for Zn + other PCOC
ESC	2.36	3.1 (6.2)	11.9	2030	No issues anticipated
WWH	117	153.1 (310.4)	299.1	2058	Potential capacity constraints (flow and load). Consider: 1. Multiple MSR (possibly up to 6) 2. Increased desludging to maintain optimal flow rates. 3. Other treatment technologies. 4. Longer term active treatment
MSR1	4.63	5.8 (11.7)	11.2	2045	No issues anticipated
MSR2	1.15	1.4 (2.9)	2.7	2045	No issues anticipated
MSR3	3.12	2.0 (4.1)	3.8	2045	No issues anticipated
MSR4	3.12	5.3 (10.7)	16.1	2045	No issues anticipated
MSR5	14.3	16.7 (25)	24.2	2045	No issues anticipated
MSR6	3.39	4.0 (5.5)	5.3	2045	No issues anticipated
MSR7	15.2	17.7 (29.6)	28.5	2045	No issues anticipated
MDC1	0.45	(0.1)	0.1	2029	No issues anticipated; potential to use low S overburden (i.e., <0.015 wt%) and remove the need for Post Closure Phase passive treatment.
MDC2	0.40	(0.1)	0.1	2038	No issues anticipated; potential to use low S overburden (i.e., <0.015 wt%) and remove the need for Post Closure Phase passive treatment.
MSR8	23.9	29.1 (43.5)	43.3	2047	No issues anticipated
MSR9	2.99	3.4 (5.2)	5.1	2047	No issues anticipated
MSR10	1.84	2.3 (2.8)	2.7	2047	No issues anticipated
MSR11	2.20	2.6 (5.2)	8.6	2029	No issues anticipated
MSR12	2.21	2.6 (5.3)	8.9	2029	No issues anticipated

1. Final catchment data as provided by BRL in the WLBM

2. From BRL rehabilitation model data
3. Numbers relate to oxygen flux based on limestone being available (1.35 t/ha/yr) and numbers in brackets represent the potential acidity load if the limestone was exhausted (2.7 t/ha/yr). Numbers are prior to exclusion of occluded zones in the ELF (35%).
4. As provided in the WLBMs.

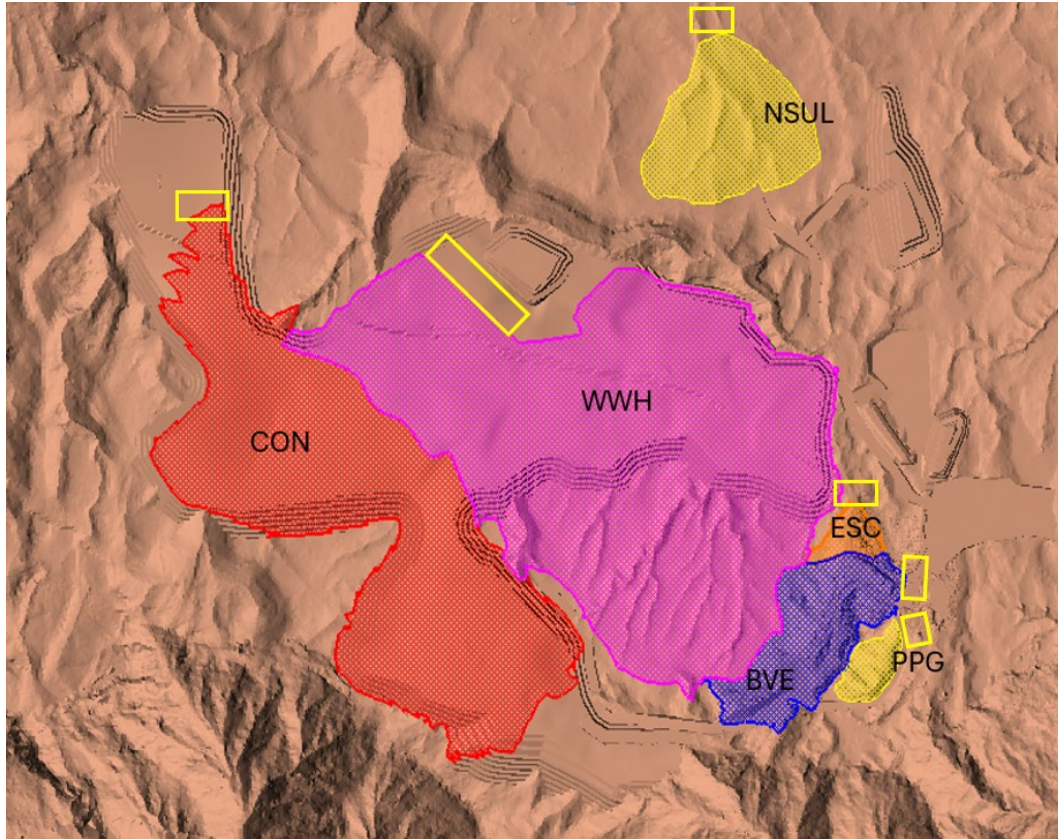


Figure 9: Escarpment Extended Project ELF basal sub-catchments and MSR locations.

MSR locations shown by yellow boxes

Source: pers. comm. Huw Parker (BRL), email dated, 20 December 2024; Jon Gane (email dated 27 February 2025)

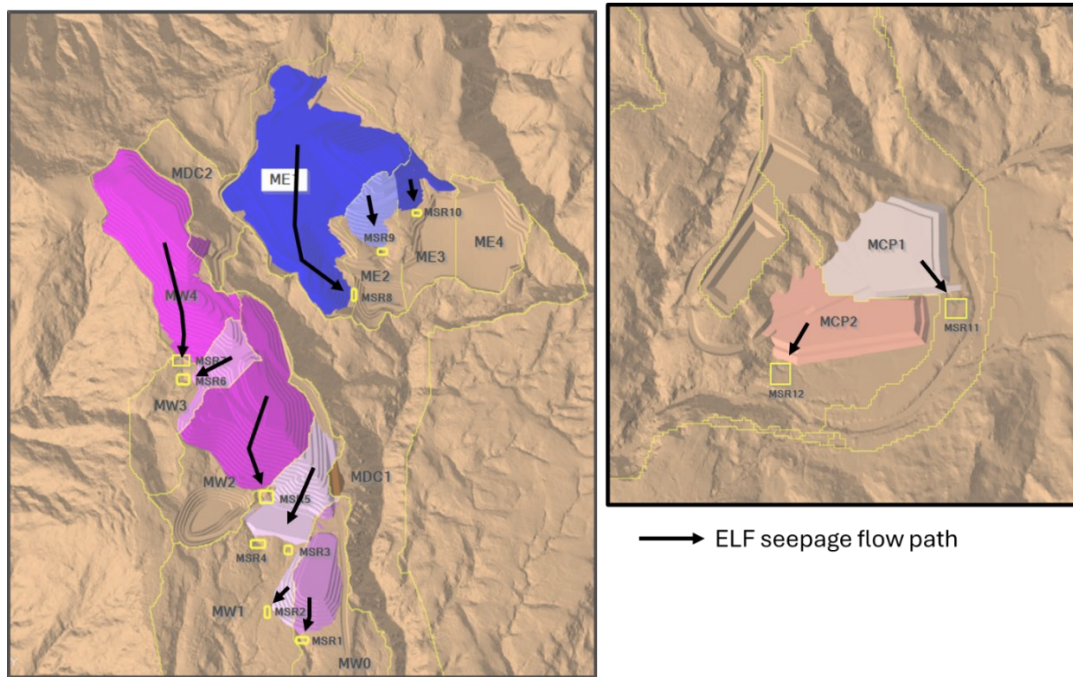


Figure 10: Mount Frederick South Project ELF basal sub-catchments and MSR locations

MSR locations shown by yellow boxes.

Source: pers. comm. Huw Parker (BRL), email dated, 20 December 2024; Jon Gane (email dated 27 February 2025).

3.5 Climate Change

Climate change is likely to increase rainfall at the MFS and ESE project sub-areas. An increase in rainfall will potentially result in an increase in net percolation into ELF basins and hence a greater quantity of ELF basal water that will require treatment.

To manage this risk, climate change was implemented in the WLBW for MFS and ESE (MWM, 2026e,f) using a precipitation multiplication factor (Figure 11) that was applied to the generated precipitation timeseries. The multiplication factor represents a uniform 9% increase in rainfall from 2025 to 2100 with no change of precipitation from 2100. This was based off climate change projections for New Zealand (Ministry for the Environment, 2018), utilising the RCP 6.0 scenario.

The effect is unlikely to be observed during the Operational and Active Closure phases of the BPCP but could be seen during the Post Closure Phase (i.e., passive treatment). Hence it is recommended that MSRs are designed to have an additional 10% capacity to accommodate potential additional climate change related flows (i.e., 10% additional surface area).

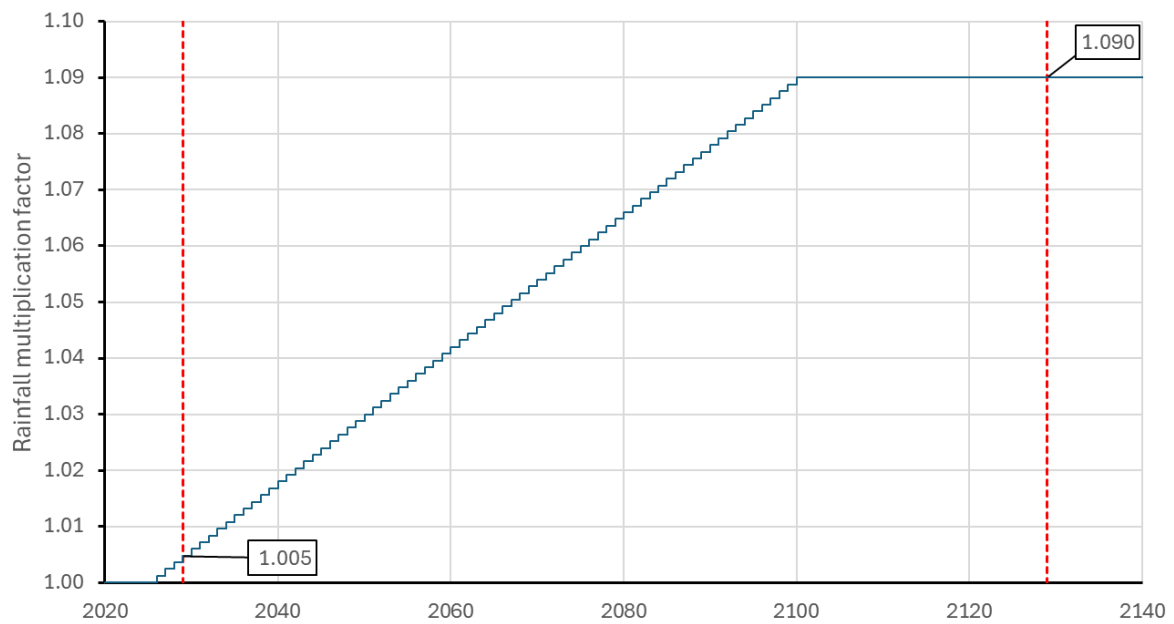


Figure 11: Multiplication factors used to represent influence of climate change on future precipitation (relative to historic data).

Red dashed lines indicate model start/stop dates

Source of climate change predictions: Ministry for the Environment, 2018, Table 11, West Coast Hokitika, rcp 6.0

Increase of annual precipitation applied directly to the rainfall dataset with the assumption this is more conservative than the 1986–2005 time series referenced by Ministry for the Environment (2018)

4 SUMMARY

4.1 Discussion

Studies undertaken as part of the assessment of environmental effects for the BPCP for ESE and MFS sub-areas highlight that management of MIW and the treatment of AMD and TSS are critical priorities. The following is required to achieve the proposed water quality limits (as determined by Hickey, 2026) for the BPCP:

- pH correction to achieve water quality limits at water quality compliance monitoring locations.
- Treatment of acidity.
- Treatment of key PCOC that include: Fe, Al, TSS, and trace metals that include Cd, Co, Cu, Mn, Ni, and Zn.

Water treatment efficiencies for active and massive treatment have been presented as a summary. These treatment efficiencies are introduced in the WLBM (MWM, 2026e,f) to understand potential effects of the project on receiving waters.

4.2 Management Approach

Management of AMD and TSS to minimise the treatment of water during the various BPCP mine stages is addressed by the following documents:

- Water Management Infrastructure Design (BRL, 2026a)
- AMD Water Management Plan (BRL, 2026b)
- AMD ELF Management Plan (BRL, 2026c)
- Mine Closure Concept Strategy (BRL, 2026d)
- Erosion and Sediment Control Plan for Land-Disturbance Activities (BRL, 2026e)

These documents utilise the knowledge obtained by this report and other reports on MIW.

4.3 Recommendations

The following recommendations are provided from this report.

- MSR can effectively treat flow rates > 50 L/s (as recommended by international literature (INAP, 2021) by ensuring sufficient space is available to build larger passive treatment systems (i.e., 1 L/s per 100 m² of MSR surface area).
- It is expected that MSR can also handle higher acidity loads than those proposed by international literature by ensuring regular AMD sludge removal and the addition of shells to replace those consumed in the upper layers of the MSR. Studies can be undertaken in the first few years of the project to validate these expectations (i.e., once the first ELFs are completed (e.g., ESC ELF)).
- Site-specific operational field trials will be completed in the first 1-3 years of the Operational Phase of the BPCP to validate previous laboratory studies that MSR polishing ponds can

achieve final water quality limits (PCOC and secondary contaminants) in the proposed timeframes (i.e., once the first ELF's are completed (e.g., ESC ELF)).

- The work undertaken at MFS and ESE will lead to betterment of some waterways (e.g., Rapid Stream and Cascade Creek). It is recommended that water quality and ecology monitoring is undertaken to understand betterment of waterways. The approach is discussed in ESNZ (2026). This should include quantification of the change in PCOC loads at suitable monitoring locations to support these studies.

4.3.1 *Climate Change Effects*

Climate change is likely to increase rainfall at the MFS and ESE project sub-areas. An increase in rainfall will potentially result in an increase in net percolation into ELF's and hence a greater quantity of ELF basal water that will require treatment.

The effect is unlikely to be observed during the Operational and Active Closure phases of the BPCP but could be seen during the Post Closure Phase (i.e., passive treatment). Hence it is recommended that MSR are designed to have an additional 10% capacity to accommodate these additional flows (i.e., 10% additional surface area).

4.3.2 *Performance Monitoring*

Performance monitoring is required to ensure the WTP, MSR, and MSR Polishing Ponds are working to design expectations. The following is proposed:

- Flow monitoring for water treatment (active and passive) influent and effluent flow rates. Water treatment by-pass flow (quality and quantity) should also be monitored.
- Water quality monitoring is recommended for water treatment (active and passive) influent and effluent. Monitoring parameters and frequency should be based on key water quality risks that will be influenced by influent water quality, treatment efficiencies, and secondary contaminants.
- Monitoring of the MSR polishing pond influent and effluent is recommended to confirm that secondary contaminants are being managed.
- Performance monitoring will validate the quantity of Fe that passes through the MSR and whether any FeCl_3 dosing is required for the polishing pond to treat residual Ni and Zn (i.e., validate whether 20% of influent Fe reporting to the polishing pond is reasonable).

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6 LIMITATIONS

Attention is drawn to the document “Limitations”, which is included in ... of this report. The statements presented in this document are intended to provide advice on what the realistic expectations of this report should be, and to present recommendations on how to minimise the risks associated with this project. The document is not intended to reduce the level of responsibility accepted by Mine Waste Management, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in doing so.

APPENDIX A LIMITATIONS

This Document has been provided by Mine Waste Management Ltd (MWM) subject to the following limitations:

This Document has been prepared for the particular purpose outlined in MWM's proposal and no responsibility is accepted for the use of this Document, in whole or in part, in other contexts or for any other purpose.

The scope and the period of MWM's services are as described in MWM's proposal, and are subject to restrictions and limitations. MWM did not perform a complete assessment of all possible conditions or circumstances that may exist at the site referenced in this Document. If a service is not expressly indicated, do not assume it has been provided. If a matter is not addressed, do not assume that any determination has been made by MWM in regard to it.

Conditions may exist which were undetectable given the limited nature of the enquiry MWM was retained to undertake with respect to the site. Variations in conditions may occur between investigatory locations, and there may be special conditions pertaining to the site which have not been revealed by the investigation and which have not therefore been taken into account in the Document. Accordingly, additional studies and actions may be required.

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MINE WASTE MANAGEMENT

GREENROAD GROUP

APPENDIX O PASSIVE TREATMENT SYSTEM DESIGN TOOLKIT

Passive Treatment System Design Toolkit

Buller Plateaux Continuation Project

20 July 2026

J-NZ0453-005-R-FINAL



Passive Treatment System Design Toolkit

Buller Plateaux Continuation Project

Document Number: J-NZ0453-005-R-FINAL

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EXECUTIVE SUMMARY

Bathurst Resource Limited (BRL) is seeking to obtain authorisation through the Fast-track Approvals Act (FTAA) to progress development and mining of the coal resources across the wider Buller Plateaux. This Project is referred to as the Buller Plateaux Continuation Project (BPCP or Project). Mine Waste Management Limited (MWM) has developed this memorandum to support BRL with the assessment of environmental effects (AEE) for the BPCP.

Background

Acid and Metalliferous Drainage (AMD) is a general term used to describe waters impacted chemically by mining activities and can contain significant quantities of metals, metalloids, salts, and acidity. AMD is typically generated by the excavation of rocks that contain sulfide minerals, such as pyrite. When exposed to oxygen and water, these minerals oxidise, generating acidity and releasing metals / metalloids. AMD is expected from materials that will be disturbed by the BPCP.

This report provides the design criteria for mussel shell bioreactors (MSRs) that will be used to treat AMD from toe seepage of engineered landforms (ELFs) that are proposed as part of the BPCP.

Objectives

The objectives of this report are to:

- Provide a summary of the multi-component analysis (MCA) undertaken for the selection of the preferred passive treatment system (PTS) for the BPCP that being MSR.
- Provide a summary of relevant MSR literature to demonstrate the applicability and robustness of the technology for treating AMD-impacted waters.
- Present empirical data on MSR treatment efficiencies, hydraulic retention times (HRT), sizing requirements, and estimated operational lifespans.
- Provide the MSR design criteria for the BPCP.
- Recommend monitoring and performance evaluation requirements to verify treatment effectiveness, support compliance reporting, and guide long-term optimisation.

Multi-Component Analysis

MSR were selected as the chosen technology for PTS based on:

- **Renewable Material:** The materials used in a MSR are derived from waste mussel shells, a by-product of the seafood industry, which supports a circular economy. Furthermore, the CO₂ within the shells, used for neutralisation of acidity, is renewable.
- **Treatment Performance:** MSRs have shown to consistently remove PCOC such as acidity, Fe, and Al, and to a slightly lesser extent, trace metals such Ni and Zn under both acidic and alkaline conditions. Secondary MSR treatment (polishing pond) have been proposed for further removal of residual trace metals and secondary contaminants as required. Site-specific operational field trials will be completed in the first 1-3 years of the Operational Phase of the

BPCP to validate previous laboratory studies that the designs of these MSR polishing ponds are suitable to achieve closure water quality objectives in the targeted timeframe.

- **Sludge Management:** AMD sludge (predominantly Fe and Al) is generated from the treatment of acidic AMD impacted waters. Downflow MSRs are an efficient process to remove Fe and Al, acting as a vertical flow reactor (VFR) as well as a neutralising PTS with pH correction such that AMD sludge forms at the surface of the MSR. This sludge can effectively be removed as part of routine maintenance as demonstrated at existing operating MSRs. Higher acidity loads (i.e., higher dissolved Fe and Al loads) can be managed by increased maintenance frequencies once treatment performance decreases. When active treatment is still occurring after ELF's have been rehabilitated (i.e., Active Closure Phase), AMD sludge disposal will either be onsite at an appropriate location (e.g., AMD sludge disposal cells at ESE Coal Pad), disposal at Stockton, or by other approved methods that may be developed over the Operational Phase of the BPCP. In the Post Closure Phase similar locations will be used. A back-up option includes disposal to offsite landfills.

Noting: Other options for AMD sludge management will be evaluated during the Operational Phase. If studies indicate that the method can provide geochemical stability, containment integrity, and cost-effective handling to align with closure objectives then this may be implemented at a later date (with additional regulatory approval as required).

- **Maintenance:** For maintenance of the MSRs (e.g., desludging) the system or part of the system needs to be taken off-line. This could involve dosing of bypass water with CaO or NaOH, designing MSRs to incorporate bays such that individual bays can be bypassed and drained for desludging while others remain operating. MSR Polishing ponds could also be constructed deeper to accommodate all sludge generation or be deslugged periodically, if required. Further details are provided in the AMD WMP (BRL, 2026c).
- **Spatial Requirements:** MSRs can be sized for the expected flow (where ~100 m² of MSR surface area with a minimum depth of 1.5 m is needed for 1 L/s) provided sufficient surface area is available. For ESE and MFS, MSR surface area requirements have been factored into mine plans based on net percolation (NP) rates of 40% into ELF's after closure (MWM, 2025i), which drives treatment requirements. Additional space is provided for the MSR polishing ponds. Space for maintenance activities (e.g., desludging, vehicle access, etc) is also required.
- **Demonstrated Experience and Longevity:** BRL has successfully implemented MSRs, with systems operating effectively for nearly a decade while showing low maintenance requirements.

While MSRs are the proposed passive treatment technology for the BPCP, other passive treatment options may be viable and have not been excluded from future consideration. Passive treatment technologies are advancing rapidly, e.g., enhanced passive treatment systems (Christenson et al., 2018)) and/or the use of a series of biogeochemical processes (i.e., a treatment train) to treat AMD characteristics (Nairn et al., 2023) may have application to the BPCP in the future.

Early construction of the MSR in the first 1-3 years of the Operational Phase will enable site-specific testing and validation through performance monitoring to demonstrate the system's effectiveness early in the Project's implementation

MSR Design Criteria

Passive treatment using MSR will utilise two treatment stages:

- Stage 1: MSR treatment to remove PCOC within the MSR substrate.
- Stage 2: MSR Polishing Pond treatment to remove additional quantities of trace metals such as Zn and Ni through adsorption to Fe-hydroxides and treatment of secondary contaminants (e.g., ammoniacal nitrogen, hydrogen sulfide, etc).

The following key design criteria are provided for the MSR:

- MSR are designed for long term flow rates and loads that are a function of oxygen flux rates through the proposed ELF cover system.
- MSR are not designed for high sediment loads (e.g., sediment derived from erosion). High sediment loads will choke the MSR surface leading to poor flow rates and poor treatment performance. Sediment control structures are needed to ensure surface flows are directed away from the MSR stage 1 treatment system.
- Downflow MSR design to enable effective AMD sludge removal.
- MSR surface area design to accommodate anticipated flow rates where ~100 m² will treat 1 L/s and an additional similar sized facility is required as a MSR Polishing Pond. Flow rates are based on 40% NP of rainfall into each ELF.
- Shell depth of 1.5 m with shells being either weathered or fresh.
- Hydraulic residence time (HRT) of 24 hours within the MSR and equivalent minimum 24 hours HRT in the MSR Polishing Pond.
- MSR AMD sludge removal (desludging) is likely to be required every ~5 years. The specific timing will be determined by performance monitoring.
- Performance monitoring of influent and effluent water quality and flow rates.

BRL have been operating MSR for over 10 years at three sites, demonstrating experience in the design, operation, and maintenance of such systems. Further details of each MSR are provided in MWM (2025a).

Detailed Design

During the first 1-3 years of the Operational Phase, the following work needs to be completed for ELF seepage to validate the approach will achieve closure water quality objectives:

- Performance monitoring of ELF seepage to confirm flow rates and water quality that will require treatment.

- Detailed design of passive treatment systems.
- Mussel shell supply remains a key factor for implementation. Previous studies (Weber et al., 2015; Trumm et al., 2015;) indicate that significant quantities of shells are generated in New Zealand (e.g., 140,000 tonnes of shells annually), however these need to be procured for the Project, when other market forces may limit availability. Hence, It is recommended that other PTS technologies should also be assessed if a market study suggests mussel shells are of limited supply. Data indicates that ~50,000 m³ of shells would be required to construct 20 MSR.
- Confirm the benefits of Fe and Al addition to the MSR Polishing Pond to improve trace metal removal.
- Determine methods of aeration for the MSR Polishing Pond, if required and confirm secondary contaminants are successfully treated.
- Confirm opportunities for MSR sludge disposal during the Post Closure Phase (e.g., disposal to pit voids and/or disposal to Stockton).
- Confirm the requirement to remove shells in the MSR from below the Al- and Fe- hydroxide layers with time. If a slow buildup of precipitates occurs, then these materials may require disposal as AMD sludge

BRL (2025) have developed a MSR Design for the WWH ELF (Appendix H). This provides further details of how the MSR will be constructed. Similar designs will be completed for other MSR that will be required for the BPCP.

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1 INTRODUCTION

Bathurst Resources Limited (BRL) is seeking to obtain authorisation through the Fast-track Approvals Act (FTAA) to progress development and mining of the coal resources across the wider Buller Plateaux. This Project is referred to as the Buller Plateaux Continuation Project (BPCP or Project).

The purpose of the BPCP is to re-consent the existing infrastructure and mining operations associated with the existing Stockton Mine and provide access to additional coal mining areas across the Buller Plateaux, as the coal resource in the current Stockton Mine is close to depletion, and further coal resources for blending are required. There are five key Project sub-areas:

- Stockton mining area (Stockton)
- Mount Frederick South (MFS)
- Escarpment Extended (ESE)
- Upper Waimangaroa Haul Road (UWHR)
- Cypress mining area (Cypress)

1.1 Background

Acid and Metalliferous Drainage (AMD) is a general term used to describe waters impacted chemically by mining activities and can contain significant quantities of metals, metalloids, salts, and acidity. AMD is typically generated by the excavation of rocks that contain sulfide minerals, such as pyrite. When exposed to oxygen and water, these minerals oxidise, generating acidity and releasing metals / metalloids. AMD is expected from materials that will be disturbed by the BPCP.

This report provides the design criteria for mussel shell bioreactors (MSRs) that will be used to treat AMD from toe seepage of engineered landforms (ELFs) that are proposed as part of the BPCP.

1.2 Report Objectives

The objectives of this report are:

- Provide a summary of the multi-component analysis (MCA) undertaken for the selection of the preferred passive treatment system (PTS) for the BPCP.
- Provide a summary of relevant MSR literature to demonstrate the applicability and robustness of the technology for treating AMD-impacted waters.
- Present empirical data on MSR treatment efficiencies, hydraulic retention times (HRT), sizing requirements, and estimated operational lifespans.
- Provide the MSR design criteria for the BPCP.
- Recommend monitoring and performance evaluation requirements to verify treatment effectiveness, support compliance reporting, and guide long-term optimisation.

1.3 Report Structure

This report provides a summary of the following technical documents:

- **Appendix A:** Abbreviations
- **Appendix B:** Multi-Component Analysis Approach (MWM, 2026g).
- **Appendix C:** Escarpment Mine - MSR Performance Review (MWM, 2026b).
- **Appendix D:** MSR Mn Treatment Efficiencies (MWM, 2026e).
- **Appendix E:** MSR Treatment - Secondary Contaminants (MWM, 2026c).
- **Appendix F:** Escarpment Mine MSR Maintenance Summary (MWM, 2026d)
- **Appendix G:** MSR Sludge Trials (MWM, 2026f).
- **Appendix H:** Whareatea MSR Design (BRL, 2025).
- **Appendix I:** Treatment of Secondary MSR Contaminants (MWM, 2026i)

2 INTRODUCTION TO AMD

The purpose of this section is to provide background on AMD for the BPCP including materials that are susceptible to AMD (source hazard) and potential effects of AMD.

AMD is a general term used to describe waters impacted chemically by mining activities and can contain significant quantities of metals, metalloids, salts, and acidity. AMD is typically generated by the excavation of rocks that contain sulfide minerals, such as pyrite. When exposed to oxygen and water, these minerals oxidise, generating acidity and releasing metals / metalloids.

2.1 AMD Source Hazards

AMD on the Buller Plateaux is characterised by high acidity and elevated metal concentrations. Materials that will contribute to AMD within the BPCP include the Brunner Coal Measures (BCM), host to economic coal resources, and the overlying Kaiata Mudstone (KMS).

Regional variability for AMD source hazards across the Project sub-areas (i.e., Stockton, MFS, ESE, and the UWHR) is heavily influenced by paleo-depositional environment of the BCM and to a lesser extent the KMS. The BCM form the foundational layer of a transgressive sequence of fluvial to estuarine high sulfur sedimentary rocks consisting of clastic sediments and coal seams. The sequence is 70 to 130 m thick and was deposited in a fluvio-paralic environment consisting of braided and meandering streams within a deltaic, barrier, tidal environment. The BCM are conformably overlain by, and laterally interfingered with, the Eocene marine KMS, which has increasing carbonate content upwards away from the BCM contact (Flores and Sykes, 1996). Geochemical AMD risks decrease away from the BCM/KMS contact such that at approximately 30 m above the BCM/KMS contact (Hughes, 2007) the acid generating potential is equivalent to the net acid neutralisation capacity (ANC) resulting in a net acid producing potential (NAPP) of ~0 kg H₂SO₄ per tonne of rock. Materials stratigraphically higher (younger) above the NAPP = 0 surface are non-acid forming (NAF) and materials below the NAPP = 0 surface are potentially acid forming (PAF) as shown in Figure 1.

As noted in literature (e.g., Pope et al., 2010), fluvial systems tend to be lower in pyrite compared to marine-influenced systems. The BCM at ESE and MFS Project sub-areas have a lower sulfur content than at the adjacent Stockton Coal Mine and accordingly the AMD risks at ESE and MFS are lower. This lower sulfur/AMD risk at ESE and MFS is due to the depositional environment being strongly influenced by fresh water fluvial sediments (low sulfur) south of Stockton with occasional periodic marine incursions (high sulfur), whereas the depositional environment at Stockton was predominantly a marine-influenced environment with higher sulfur materials (e.g., estuarine).

The BCM are typically deficient in acid neutralising carbonate minerals such that the oxidation of pyrite typically leads to the rapid formation of AMD with little time lag to acid onset (Weber et al., 2008).

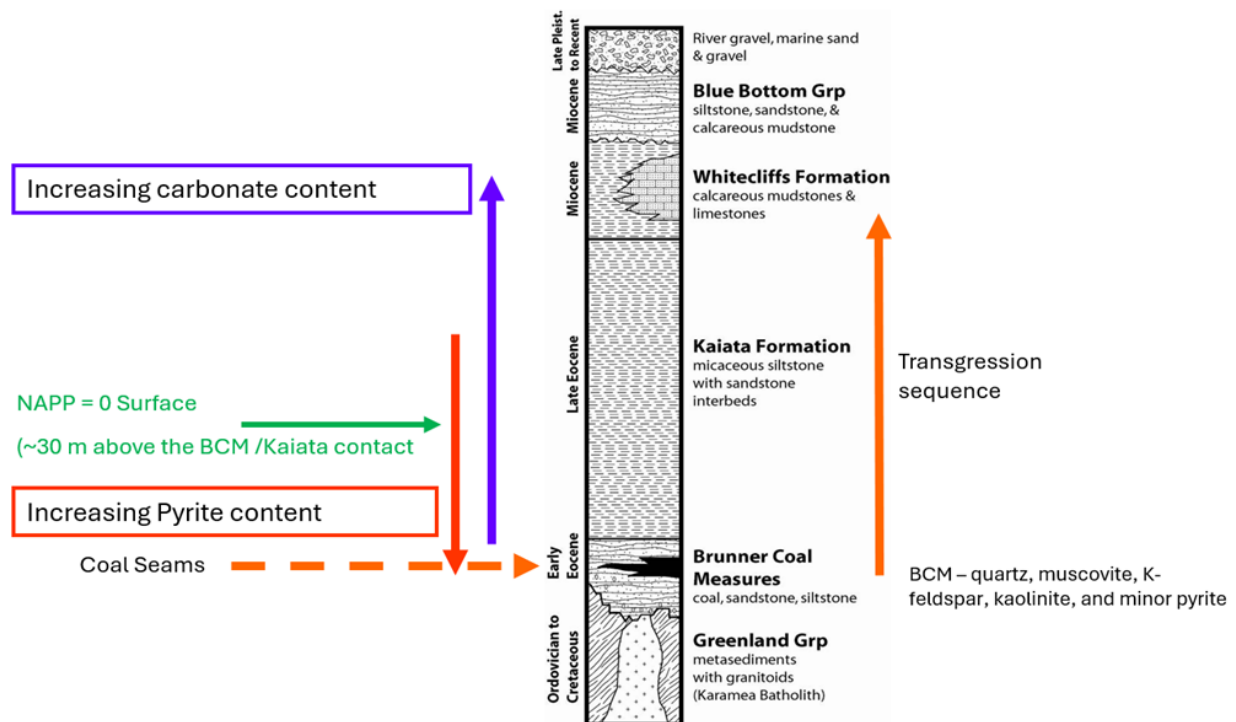


Figure 1: Stratigraphic column of the Denniston and Stockton Plateaux.

Water and oxygen interacting with materials that contain sulfide minerals can generate AMD. The mine domain with the greatest source hazard risks (60-80% of the total AMD load for any project) are waste rock storage facilities (e.g., INAP, 2020), that include waste rock dumps (WRDs), having no engineering controls to reduce sulfide mineral oxidation or the mobilisation of secondary sulfide oxidation products.

PAF waste rock disposal in engineered landforms (ELFs) is proposed for ESE and MFS to minimise the generation of AMD arising from waste rock storage. Further details are provided in the ELF Design Philosophy Report (MWM, 2026h), which explains source control technologies for prevention and minimisation of AMD.

2.2 Potential Effects

Previous studies have indicated several potential constituents of concern (PCOC) that could be elevated in BPCP AMD impacted waters. These include:

- Elevated total suspended solids (TSS).
- AMD which is typically low pH and elevated acidity, sulfate (SO_4), and PCOC that include aluminium (Al), iron (Fe), and lesser amounts of trace metals that include cadmium (Cd), cobalt (Co), copper (Cu), manganese (Mn), nickel (Ni), and zinc (Zn).

Although source control engineering options can reduce the quantity of AMD and its effects, treatment is often required. Treatment includes active and passive treatment systems. The BPCP proposes to use active treatment technologies during the Operational Phase and Active Closure Phase and once loads decrease in the Post Closure Phase, the treatment of water will shift to passive treatment technologies. This report assesses passive treatment systems.

3 PASSIVE TREATMENT TECHNOLOGY SELECTION

A MCA was undertaken to evaluate PTS options for managing AMD during the closure phases of the BPCP after cessation of active treatment. The aim was to identify a technically defensible and context-appropriate passive treatment approach aligned with Project constraints and objectives.

3.1 Approach

The MCA followed a two-stage approach:

- **Screening-Level Assessment:** An initial evaluation to quickly identify and eliminate options that do not meet the fundamental requirements or are unsuitable based on high-level criteria.
- **Conceptual Short-Listed Options Assessment:** A detailed evaluation of the options that pass the screening stage. This phase focuses on a conceptual-level analysis to further assess the viability and risks of each short-listed option in alignment with the Project objectives.

Further details are provided in Appendix B.

3.2 Preferred Technology

Mussel shell bioreactors (MSR) were selected as the chosen technology:

- **Renewable Material:** The material used in a MSR are derived from waste mussel shells, a by-product of the seafood industry, which supports a circular economy. Furthermore, the CO₂ within the shells, that are used for neutralisation of acidity, is renewable (i.e., not fossil CO₂).
- **Treatment Performance:** MSRs have shown to consistently remove PCOC such as acidity, Fe, and Al, and to a slightly lesser extent, trace metals such Ni and Zn under both acidic and alkaline conditions. Secondary MSR treatment (polishing pond) have been proposed for further removal of residual trace metals and secondary contaminants as required. Site-specific operational field trials will be completed in the first 1-3 years of the Operational Phase of the BPCP to validate previous laboratory studies that the designs of these MSR polishing ponds are suitable to achieve closure water quality objectives in the targeted timeframe.
- **Sludge Management:** AMD sludge (predominantly Fe and Al) is generated from the treatment of acidic AMD impacted waters. Downflow MSR are an efficient process to remove Fe and Al, acting as a VFR as well as a neutralising PTS with pH correction such that AMD sludge forms at the surface of the MSR. This sludge can effectively be removed as part of routine maintenance as demonstrated at existing operating MSRs. Higher acidity loads (i.e., higher dissolved Fe and Al loads) can be managed by increased maintenance frequencies once treatment performance decreases. When active treatment is still occurring after ELF's have been rehabilitated (i.e., Active Closure Phase), AMD sludge disposal will either be onsite at an appropriate location (e.g., AMD sludge disposal cells at ESE Coal Pad), disposal at Stockton, or by other approved methods that may be developed over the Operational Phase of the BPCP. In the Post Closure Phase similar locations will be used. A back-up option includes disposal to offsite landfills.

Noting: Other options for AMD sludge management will be evaluated during the Operational Phase. If studies indicate that the method can provide geochemical stability, containment integrity, and cost-effective handling to align with closure objectives then this may be implemented at a later date (with additional regulatory approval as required).

- **Maintenance:** For maintenance of the MSRs (e.g., desludging) the system or part of the system needs to be taken off-line. This could involve dosing of bypass water with CaO or NaOH, designing MSRs to incorporate bays such that individual bays can be bypassed and drained for desludging while others remain operating. MSR Polishing ponds could also be constructed deeper to accommodate all sludge generation or be desludged periodically, if required. Further details are provided in the AMD WMP (BRL, 2026).
- **Spatial Requirements:** MSR can be sized for the expected flow (where ~100 m² of MSR surface area with a minimum depth of 1.5 m is needed for 1 L/s) provided sufficient surface area is available. For ESE and MFS, MSR surface area requirements have been factored into mine plans based on NP rates of 40% into ELF's after closure (MWM, 2026i), which drives treatment requirements. Additional space is provided for the MSR polishing ponds. Space for maintenance activities (e.g., desludging, vehicle access, etc is also required).
- **Demonstrated Experience and Longevity:** BRL has successfully implemented MSRs, with systems operating effectively for nearly a decade while showing low maintenance requirements.

3.3 Recommendations

While MSRs are the proposed passive treatment technology for the BPCP, other passive treatment options may still be viable and further assessments of alternative systems may be warranted to optimise long-term performance and cost-effectiveness.

Current models suggest that transitioning from active to passive treatment for ELF seepage will begin during the Operational Phase once ELF rehabilitation is completed with full transition to passive treatment expected at MFS and ESE within 20 years. Transition from active treatment to passive treatment will be influenced by the ability to meet water quality objectives, but could also be influenced by:

- Magnitude of PCOC load from final landform / ELF structures at closure.
- The rate of PCOC load decay from final landform / ELF structures.
- Financial drivers to switch from an existing active treatment plant (sunk capex, high opex) to a passive treatment system (new capex, low opex), when it may be cheaper to continue running the WTP rather than commit new capex.
- The ability to treat higher flow rates and acidity loads.
- Passive treatment technology advances over the next few decades.
- Water quality objectives and future community expectations on water quality standards.
- Changes to the mine plan.

Early construction of the MSR in the first 1-3 years of the Operational Phase will enable site-specific testing and validation through performance monitoring to demonstrate the system's effectiveness early in the Project's implementation.

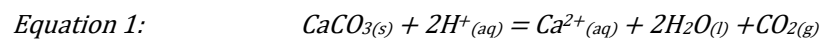
4 MSR BACKGROUND

This section provides a summary and review of the MSR technology to demonstrate its reliability and proven record for the treatment of AMD impacted waters.

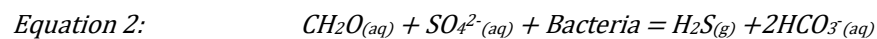
4.1 Introduction

In New Zealand, research into passive AMD treatment has spanned several decades. Notably, since 2007, investigations have explored the efficacy of waste mussel shells to treat AMD impacted waters (Weber et al., 2008), offering a sustainable alternative to conventional passive treatment media. The reuse of mussel shells not only diverts waste from landfill but also supports circular economy outcomes and reduces the environmental footprint of treatment systems.

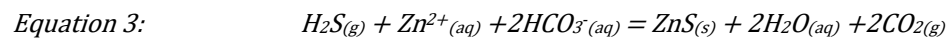
The primary objective of a MSR is to neutralise acidity by carbonate dissolution and by the decomposition of organic matter associated with the mussel shells over time. This serves a dual purpose (DiLoreto et al., 2016), enabling subsequent reactions that generate alkalinity and create conditions favourable for sulfide precipitation.



In addition, acidity is neutralised by alkalinity generated by sulfate reducing bacteria, for example:



Which can lead to the formation of sulfide minerals:



Equation 1 explains the primary mechanism for how acidity associated with AMD is neutralised resulting in the hydrolysis of Fe and Al and the concurrent dissolution of shells that provide the neutralisation. Equation 2 explains how alkalinity is generated that can also contribute to alkalinity export from the MSR, which can provide benefits for downstream environments that are affected by AMD (i.e., neutralisation).

4.2 Literature Summary

The following section summarises key studies that have been completed that relate to the use of mussel shells to treat AMD. The studies demonstrate the significant efforts over ~20 years to test, validate, and operationally implement the MSR technology. Six MSR have been constructed in New Zealand to operationally treat AMD from coal mining operations.

Table 1: MSR research summary

YEAR	LOCATION	SUMMARY	REFERENCES
2007	Stockton Coal Mine	Pilot-scale down-flow cells were constructed in 2007 with 300 mm layers of crushed mussel shells under waste rock to treat acidic drainage within a waste rock dump. Results showed that the shell layer effectively increased pH and enhanced metal removal.	Weber et al. (2008)
2008	Stockton Coal Mine	Monthly monitoring of AMD sites presented elevated trace metal concentrations and low pH, prompting lab tests of sulfate-reducing bioreactors (SRBs) using alkaline wastes like mussel shells, stack dust, and limestone. SRBs with 20-30%	McCauley et al. (2008a)

YEAR	LOCATION	SUMMARY	REFERENCES
		mussel shells showed the best metal removal (over 96% for Fe and >99% for most metals) and generated near-neutral effluent, outperforming limestone-only systems.	
2008	Stockton Coal Mine	AMD from Manchester Street Seep was treated in lab-scale bioreactors using organic and alkaline waste materials, with MSRs outperforming limestone by removing over 98% of metals and neutralising acidity efficiently.	McCauley et al. (2008b)
2009	Stockton Coal Mine	AMD sites showed high concentrations of metals like Fe and Al exceeding environmental guidelines. Mesocosm tests demonstrated that biogeochemical reactors (BGCRs) using mussel shells and organic materials effectively raised pH above 6.7 and removed over 98% of metals, suggesting BGCRs as a cost-effective passive treatment alternative to existing limestone dosing systems.	McCauley et al. (2009a)
2009	Stockton Coal Mine	Six anaerobic bioreactors using organic and alkaline waste materials were tested for AMD treatment, with mussel shells outperforming limestone in removing metals and sulfate. Removal efficiencies depended on bioreactor design and loading rates, achieving up to 99% metal removal and over 94% sulfate removal under optimal conditions.	McCauley et al. (2009b)
2010	Stockton Coal Mine	BGCRs using mussel shells and organic materials were tested as passive treatment for AMD with high metal concentrations and low pH. Lab-scale trials showed these reactors could raise pH above 6.7 and remove over 98% of metal loads, highlighting their potential as a cost-effective alternative to conventional lime-based treatments.	McCauley et al. (2010)
2011	Stockton Coal Mine	To explore more cost-effective alternatives, researchers tested BGCR using mussel shells and organic materials (e.g. pine bark, wood fragments, compost). Mesocosm trials showed BGCRs increased pH to ≥ 6.7 and removed $\geq 98.2\%$ of metal loads from AMD. Design criteria for effective treatment were developed, including optimal loading rates and hydraulic residence times. Tracer studies revealed that cylindrical reactor designs performed better than trapezoidal ones, which suffered from short-circuiting. A staged passive system, sedimentation, BGCR, then aerobic wetland is recommended.	McCauley (2011)
2011	Stockton Coal Mine, Manchester Street.	A passive MSR was trailed as a low-cost alternative to traditional limestone dosing AMD treatment. The reactor successfully raised pH from below 3 to above 7 and removed 96-99% of metals, achieving payback in just 480 days and demonstrating long-term operational	Crombie et al. (2011)
2013	Coal Mines New Zealand	Mussel shells have been effectively used in New Zealand as a sustainable and low-cost alternative to limestone in passive bioreactors for treating AMD. Trials show that MSR, especially in upward-flow configurations, enhance alkalinity generation, metal removal, and long-term system performance by maintaining reducing conditions and preventing clogging.	Uster et al. (2013)
2014	Stockton Coal Mine	A MSR operated at the Stockton Coal Mine for three years successfully treated AMD generated from the highly acidic BCMs. The system developed distinct geochemical layers with a redox gradient from oxidizing at the top to strongly reducing at the base. Chemical analysis showed significant removal of metals like Al, Fe, Zn, and trace metals such as Thallium (Tl), primarily through pH-driven co-precipitation and sorption onto carbonate and oxyhydroxide phases, confirming the reactor's long-term AMD neutralisation capability.	DiLoreto (2014)
2014	Stockton Coal Mine	Researchers in New Zealand have successfully used waste green-lipped mussel shells as an alternative to limestone in passive bioreactors for treating AMD, demonstrating superior performance in alkalinity generation and metal removal. Both lab and field trials, including full-scale systems, have shown mussel shells to be an effective, sustainable, and low-cost	Uster et al. (2014)

YEAR	LOCATION	SUMMARY	REFERENCES
		solution, especially when used alone or in upward-flow reactor designs that promote long-term reducing conditions and minimize permeability loss.	
2014	3 Active Coal Mines in New Zealand	This study tested three small-scale up-flow mussel shell reactors, which raised pH to near 8 and achieved high removal rates for Fe, Al, Zn, and Ni (95 - >99%), with lower removal of Mn. The up-flow design successfully established reducing conditions, enhancing sulfide formation and metal removal while preventing iron hydroxide buildup, suggesting it is a promising configuration for mussel shell-based AMD treatment.	Trumm and Ball (2014)
2015	Stockton Coal Mine	This paper reviews seven years of research on using waste mussel shells in vertical flow successive alkalinity producing systems for passive treatment of AMD in New Zealand, highlighting the shells high ANC and ability to support sulfate-reducing bacteria. Field trials presented metal removal efficiencies of 96–99% for Fe, Al, Ni, and Zn, with system longevity linked to permeability changes caused by sludge layers forming during treatment.	Weber et al. (2015)
2015	Lab-based	This study evaluated four up-flow sulfate reducing bioreactors (SRBR) using waste mussel shells or limestone and organic materials to treat mine-influenced water over 10 months, testing two hydraulic retention times (3 and 10 days). Metal analysis showed effective removal and stable retention of contaminants like Fe, Cu, Zn, and Ni in sulfide or organic-bound forms, with mussel shells supporting long-term passive treatment and influencing metal mobility and distribution within the bioreactor substrates.	Uster et al. (2015a)
2015	Active Coal Mine on the South Island of New Zealand	This study tested up-flow mussel shell reactors as a passive treatment for AMD, aiming to maintain reducing conditions and prevent iron hydroxide buildup that can clog traditional down-flow systems. The up-flow design effectively raised pH from 2.9 to 8, removed 95 - 99% of metals like Fe, Zn, and Ni, and supported strong sulfate-reducing bacterial activity, suggesting it is a promising method for treating AMD, particularly with high iron concentrations.	Trumm et al. (2015)
2015	Stockton Coal Mine	This study tested SRBRs mussel shells and limestone to treat AMD from a coal mine in New Zealand, finding that all systems improved water quality by raising pH and removing most dissolved metals. Mussel shell-based SRBRs outperformed limestone in alkalinity generation and metal removal, especially with longer hydraulic retention times, demonstrating their effectiveness as a low-cost, sustainable AMD treatment option.	Uster et al. (2015b)
2015	Lab-based	Lab-scale bioreactor trials in New Zealand using waste mussel shells as an alternative to limestone demonstrated superior treatment of mining-influenced water (MIW), with higher alkalinity generation and greater metal removal, especially under longer hydraulic retention times. MSR consistently raised pH above 6 and removed over 97% of Al and up to 95% of Fe, highlighting their effectiveness and potential as a sustainable passive treatment solution.	Uster (2015)
2015	Stockton Coal Mine	A full-scale MSR at the Stockton Coal Mine has effectively treated AMD consistently removing ~99% of metals and neutralising acidity since 2012. Detailed autopsies and biogeochemical studies reveal that the system maintains effective vertical flow and uniform treatment through complex redox and microbial processes, supporting its potential for broader global application.	Weisner et al. (2015)
2016	Stockton Coal Mine	A full-scale MSR at the Stockton Coal Mine effectively treated AMD, raising pH from 3.4 to 8.3 and removing ~99% of Al and Fe and >90% of Ni, TI, and Zn. Located in the Whirlwind catchment, the MSR's performance was investigated through a comprehensive analysis of its chemical, microbial, and physical processes. Results highlighted the system's strong	Diloreto (2016)

YEAR	LOCATION	SUMMARY	REFERENCES
		AMD neutralisation and metal removal capabilities, supporting its potential as a globally transferable passive treatment technology.	
2016	Stockton Coal Mine	This study evaluated a full-scale MSR for passive AMD treatment, which effectively increased pH from 3.4 to 8.3 and removed up to 99% of dissolved metals like Al, Fe, Ni, TI, and Zn. Geochemical and microbial analyses revealed a redox gradient that supported specialised microbial communities driving metal and sulfur cycling, highlighting MSR as a low-cost, effective solution suitable for large-scale use, especially in developing regions.	DiLoreto et al. (2016)
2017	Bellvue Mine	This research investigates the effectiveness of using mussel shells as a calcium carbonate source in a diversion well to treat AMD at Bellvue Mine, comparing it to traditional limestone systems. A diversion well using mussel shells, never trialed in New Zealand, was installed to assess its performance during high-flow events, with water chemistry analyses used to evaluate its treatment capability.	Forbes et al. (2017)
2017	Escarpment Mine	A MSR was constructed at the Escarpment Mine to passively treat acidity and dissolved metals from mining-affected areas, including waste rock, pit lakes, and highwalls. The bioreactor significantly improved water quality, increasing pH from ~3.5 to ~7.9 and reducing metal concentrations by two orders of magnitude, demonstrating its effectiveness as a low-cost, low-maintenance treatment solution.	Roberston et al. (2017)
2017	Coal Mines in New Zealand	This study tested an up-flow MSR system designed to treat AMD by promoting reducing conditions throughout the reactor and preventing iron hydroxide buildup. Three reactors in series showed distinct microbial communities and metal precipitation patterns, with results linking microbial diversity, especially sulphate-reducing bacteria, to effective removal of iron and trace metals like cobalt and manganese.	Trumm et al. (2017)
2017	Lab-based	Adding nutrients to SRBR significantly enhanced the activity of sulfate-reducing bacteria, resulting in over a 15-fold increase in sulfate removal from MIW. This finding demonstrates that nutrient supplementation can greatly improve the effectiveness and reliability of passive SRB-based treatment systems.	Christenson et al. (2017)
2017	Stockton Coal Mine	This study examined microbial activity and sulfate-reducing conditions within a mussel shell-based passive bioreactor at Stockton Coal Mine. Findings showed favourable physicochemical and biological conditions for metal sulfide precipitation, with mussel shells supporting key microbial communities like Desulfotomaculum and Pseudomonas that enhance zinc immobilisation and ARD treatment effectiveness.	Falk et al. (2017)
2018	Bellvue Mine	This research tested the effectiveness of a mussel shell-based diversion well for treating AMD at the Bellvue Mine, comparing it to a traditional limestone-based system. Results showed that while mussel shells provided some treatment, limestone was more effective at increasing pH and reducing dissolved metal concentrations.	Forbs et al. (2018)
2019	Lab-based	This study compared SRBRs using mussel shells versus limestone as alkalinity sources to treat AMD over ten months, finding that MSR achieved greater metal and acidity removal at similar retention times. Metal analyses showed iron, zinc, and manganese precipitated as sulfides and carbonates, with mussel shells providing enhanced alkalinity release and metal sorption surfaces, leading to better overall treatment performance than limestone.	Uster et al. (2019)

YEAR	LOCATION	SUMMARY	REFERENCES
2019	Stockton Coal Mine	A MSR used for AMD remediation at a Stockton Coal Mine produced sludge whose storage and reuse risks were studied under oxic and anoxic conditions. Results showed that anoxic burial reduces metal mobility and risks by promoting sulfide mineral formation, while oxic conditions increase metal mobility but may allow sludge reuse as an oxygen barrier or soil amendment, with microbial activity influencing these outcomes.	Butler et al. (2019)
2021	Stockton Coal Mine	This study presents the first full-scale up-flow mussel shell reactor for acid mine drainage treatment, which increased pH from 2.74 to 6.94 and removed over 97% of Fe, Al, Zn, and Ni. The upflow design maintained reducing conditions that promoted sulfide formation over hydroxides, enhancing treatment efficiency and avoiding permeability issues common in downflow systems.	Trumm et al. (2021)
2022	Echo Coal Mine	This study reports on the first full-scale up-flow MSR used at an active mine to treat AMD, which successfully increased pH from 3.3 to 7.2 and removed over 83% of key metals. The up-flow design maintained reducing conditions throughout the reactor, promoting sulfate reduction and sulfide formation while avoiding permeability issues common in downflow systems.	Trumm et al. (2022)
2024	Echo Coal Mine	This study discusses the ongoing performance of the Echo Mine upflow MSR and the effects of hydraulic residence time on treatment performance.	Trum et al. (2024)

5 REVIEW

The following section provides a high-level summary of previous studies conducted for MSRs operating at BRL sites. Three MSR were examined in detail:

- The Tara MSR (at the Canterbury Coal Mine, New Zealand).
- The Whirlwind MSR (at the Stockton Coal Mine, New Zealand).
- The Barren Valley (BV) MSR (at the Escarpment Coal Mine, New Zealand).

Further details are provided in Appendix C, Appendix D, and Appendix E of this report.

5.1 MSR Physical Characteristics

Physical properties for the three MSR are presented in Table 2. Data indicates that:

- Despite its smaller average plan area of 94 m², the Tara MSR has the longest residence time at 5.57 days due to low average flow rates.
- Conversely, the Whirlwind MSR exhibits the shortest average hydraulic residence time (HRT) at 0.79 days, while the BV-MSR falls intermediary with an average residence time of 0.85 days.
- The total pore volume of the mussel shells within each MSR varies with the Whirlwind MSR at 190 m³, the Tara MSR at 74 m³, and the BV-MSR at 275 m³.

Table 2: MSR design comparisons.

PARAMETER	WHIRLWIND MSR	TARA MSR	BV-MSR
Average plan dimensions (m) (shell layer)	14.0 x 21.5	5 x 24	10 x 35
Average plan area (m ²) (shell layer)	302	94	350
Average shell depth (m)	1.2	1.5	1.5
Ponding depth on top of MSR (m)	0.2 – 0.6	1.0	0.2 – 0.4
Freeboard (m)	0.8 – 0.4	0.5	0.2
Volume of shells (m ³)	366.0	55.0	470.0
Average Flow rate (L/s)	2.80	0.06	3.35
Assumed porosity	0.52	0.52	0.52
Volume of shells (m ³ /m ²)	1.23	1.29	0.99
Shells pore volume (m ³ /m ²)	0.63	0.79	0.79
Total shells pore volume (m ³)	190.1	74.0	275.4
Calculated residence times (days)	0.79	5.57	0.85

Residence times are based on average flow rates. Actual inflows may fluctuate, as observed at BV ELF, and should be considered in detailed design.

5.2 Factors Influencing MSR Treatment Efficiencies

The following sections provide a summary of factors influencing MSR treatment efficiencies. Further details can be found in MWM (2026b) (presented in Appendix C).

5.2.1 Hydraulic Residence Times

MSR water quality data suggest that residence time can influence metal removal. A residence time of 24 hours was selected. Further details are provided in Appendix C.

5.2.2 Geochemical Conditions and pH Dependency

Studies indicate that the following geochemical processes could be influencing adsorption of trace metals such as Ni and Zn within MSR and the associated treatment efficiency:

- Precipitation of $\text{Fe}(\text{OH})_3$ under oxic circum-neutral conditions to form the upper Fe-sludge layer at suitable concentrations.
- Precipitate of higher quantities of $\text{Al}(\text{OH})_3$ under oxic / sub-oxic conditions.

Trials were undertaken by Process Flow (Appendix C). Results indicate that the addition of Al and Fe to MSR effluent (circum-neutral pH) removed >50% of the Zn in solution. This helps demonstrate the mechanism of adsorption of Zn onto Al- and Fe- hydroxides. Data shows that an additional treatment step after the MSR may be necessary (e.g., an aerated polishing pond with Fe addition) for remove Fe and Zn (and +/- other trace metals).

5.2.3 Biogeochemical Processes

SRB generated alkalinity ranged from 4.71 to 5.76 kg CaCO_3 per m^3 of shells per year across the three MSRs, indicating a consistent rate of alkalinity production (based on sulfate differences in MSR influent and effluent). This also implies that sulfide generation rates are comparable, suggesting that sulfide production is not the primary factor influencing the observed differences in Ni and Zn removal efficiencies. Dissolved organic carbon (DOC) and sulfide concentrations have been assessed in the three MSR as higher DOC concentrations can enable higher sulfide concentrations, which in turn can facilitate higher metal removal rates.

Further work is required to understand the bioavailable labile carbon availability in MSR, the mechanics of SRB alkalinity generation, quantification of metal removal by sulfides, and whether this can be optimised to improve the MSR treatment efficiency.

5.3 AMD Sludge Generation

The neutralisation of AMD by MSR generates a Fe- and Al- AMD sludge near the surface of the MSR as acidity is neutralised by the shells and pH increases. This causes the formation of Fe- and Al- hydroxides with (orange) $\text{Fe}(\text{OH})_3$ forming first and then at depth with the MSR the formation of (white) $\text{Fe}(\text{OH})_3$ (Figure 2). Desludging (i.e., removal) of this AMD sludge is required periodically.

Studies have indicated that two mechanisms can drive desludging including:

- Reduced permeabilities due to sludge accumulation leading to overflow of the MSR and the bypass of untreated AMD.
- Reduced treatment efficiencies for trace metals such as Zn leading to sub-optimum performance.

Studies suggest for the BV MSR at the existing Escarpment mine that desludging is required for at least 8 years for sludge accumulation risks and for 5 years for reduced efficiencies due to acid remobilisation of adsorbed metals such as Zn. Further details are provided in Appendix C and Appendix F.

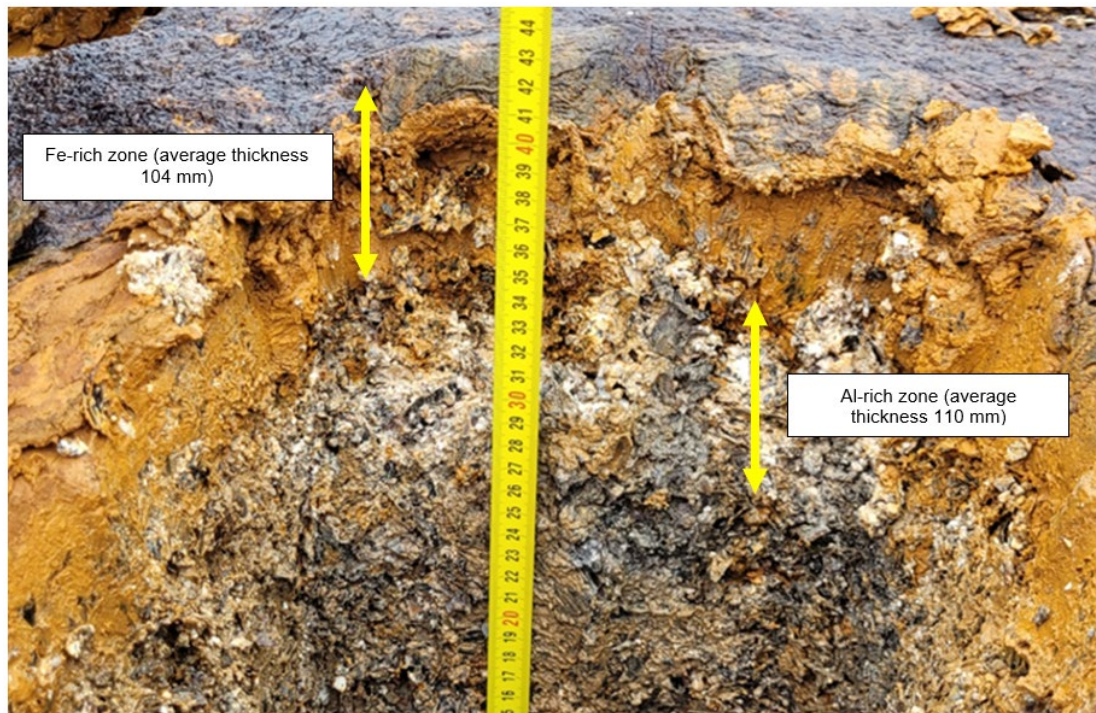


Figure 2: Sludge and Fe and Al precipitation zones within the BV-MSR.

Based on an average MSR AMD sludge depth of 110 m

5.4 MSR Secondary Contaminants

Secondary contaminants include various compounds that are byproducts of the MSR treatment of AMD impacted waters that may adversely affect the effluent water quality (e.g., hydrogen sulfide (H_2S), ammoniacal nitrogen (Amm-N), and low dissolved oxygen (DO) waters). Further discussion of these secondary contaminants is provided in Appendix E.

Management / treatment of these secondary contaminants to be compliant with water quality objectives is undertaken by aeration within the MSR polishing pond. This process is undertaken successfully at the Canterbury Coal Mine (Tara MSR) and further details are provided in Appendix E. A similar approach will be undertaken at the BPCP.

6 BPCP MSR DESIGN CRITERIA

The following section outlines the conceptual design criteria for the MSR for the BPCP. The key design criteria include:

- Flow rate
- Influent water quality and treatment efficiency

6.1 Flow Rate

MSR design criteria are based on the empirical data available that a MSR with a surface area of ~100 m² can effectively treat 1 L/s. This is based on flow rates into the BV ELF and the Whirlwind MSR and the available surface area. The following comments are provided:

- Higher flow rates up to 2 L/s per ~100 m² of surface area are possible (e.g., Whirlwind MSR) for fresh shells, although this decreases with the development of AMD sludge.
- AMD sludge formation can reduce the permeability of the MSR. Studies (Appendix C) show that the establishment of an AMD sludge layer (~104 mm thick) reduces the effective infiltration rate to ~1 x 10⁻⁵ m/s. This flow rate for an established reactor can be used to size the surface area of MSR but is comparable to the design flow rate of ~100 m² to treat 1 L/s.
- Performance monitoring is required to validate the MSR flow rate is performing to design expectations.

6.2 Hydraulic Residence Time

Studies over many decades (e.g., Weber et al., 2015) have demonstrated that a HRT of 24 hours within a MSR is suitable to remove the dominant acidity load from AMD impacted drainage. MSR are sized to have a surface area suitable for the design flow rate (~100 m² per 1L/s flow), which provides some conservatism as higher flows can be accommodated. To achieve the design HRT of 24 hours, the MSR requires a shell thickness of ~1.5 m. Previous studies indicate that the porosity within the MSR shell layer is 0.72 (McCauley, 2011). This means the HRT for 1.5 m of shell (1 m² surface area) for having 0.01 L/s is 1.25 days.

The HRT of 24 hours is a reasonable estimate of treatment duration. This may require adjustment, based on PCOC loads, flow rates, and treatment efficiencies. Performance monitoring will be required to validate and optimise the treatment process under site-specific conditions.

6.3 Sediment Control

MSR are not designed for high sediment loads (e.g., sediment derived from erosion). High sediment loads will choke the MSR surface leading to poor flow rates through the shells and hence poor treatment performance. Sediment control structures are needed to ensure surface flows are directed away from the MSR Stage 1 treatment system. Sediment control structures could include the following:

- Installation of settling ponds or diversion channels to capture sediment before entering the MSR.
- Sediment barriers (e.g., bunds around the MSR) or silt fences.

MSR bunds also need to be covered by geotextile or similar as armouring against high rainfall events. In high rainfall environments the bund materials can contribute to sediment runoff to the MSR.

Routine inspections and maintenance of sediment control structures are required to ensure sediment loads to the MSR are minimised.

6.4 Treatment Efficiency

This section summarises the expected treatment performance for the proposed MSR. Performance is based on observed treatment efficiencies (empirical data from BV MSR: Appendix C) and laboratory trials (Process Flow, 2026) where two stages are proposed:

Stage 1: MSR

- Treatment efficiencies are derived from BV MSR for all PCOC (except Zn).
- A treatment efficiency of 63.7% is used for Zn based on the first 6 years of the BV MSR (after this the performance decreased to ~20%). Therefore, maintenance is required every ~5 years to ensure Zn treatment efficiencies remain comparable (noting this will be dependent on acidity load and performance monitoring is required).
- Iron (Fe) removal efficiencies are 99.7% but have been reduced to 80% to acknowledge that reduced Fe(II) from sub-oxic ELF's may have a lower treatment efficiency (as observed by Trumm et al. (2024) who showed a removal of 86% in an upflow reactor).

Stage 2: MSR Polishing Pond

- A polishing pond is proposed to enable the oxidation of secondary contaminants and encourage the hydrolysis of Fe as $(Fe(OH)_3)$.
- It is assumed that all Fe hydrolyses (99.8% effective).
- Laboratory trials (Process Flow, 2026; and Appendix C) demonstrates that 59.4% of the Zn can be removed through adsorption as this Fe hydrolyses. This is included in the model.
- It is proposed that ferric chloride ($FeCl_3$) dosing could be employed if the quantity of Fe is low in ELF seepage or the treatment efficiency through the MSR is higher than anticipated.

Table 3: MSR treatment efficiencies.

PARAMETER	TREATMENT EFFICIENCIES (%)	REFERENCE
Stage 1: MSR reactor treatment		
Ca	-254 ¹	BV MSR
SO ₄	10.4	BV MSR
Al	99.7	BV MSR
Fe	80 ³	BV MSR
Ni	40.2	BV MSR
Mn	58.6	BV MSR
Cd	1.89	BV MSR
Co	82.8	BV MSR
Cu	96.6	BV MSR
Pb	85.8	BV MSR
Zn	63.7	BV MSR
Stage 2: MSR Polishing Pond Treatment of MSR Stage 1 Effluent		

PARAMETER	TREATMENT EFFICIENCIES (%)	REFERENCE
Fe	99.0	Process flow Ltd (2026)
Zn	59.0	Process flow Ltd (2026)
Ni	12.5	Process flow Ltd (2026)

1. *Negative values for Ca indicate that the concentration increases through the treatment process (i.e., the shells dissolve as part of the acidity neutralisation step).*
2. *A nominal efficiency of 80% is used rather than the measured 99.7% to account for the ELF being sub-oxic and some Fe(II) passing through the MSR untreated.*

6.5 Mussel Shell Reactor Conceptual Design

The proposed passive treatment strategy for ESE and MFS involves a two-stage treatment system:

1. Stage 1: Mussel Shell Reactor (Primary Treatment):

MSR treatment to remove PCOC within the MSR substrate (e.g., composed of fresh or weathered mussel shells).

2. Stage 2: Polishing Pond (Secondary Treatment):

MSR effluent flows into a polishing pond for aerobic treatment. This promotes Fe^{3+} hydroxide formation for further Zn removal and oxidation of secondary contaminants. The Polishing Pond will be the same size as the MSR providing ~24 hours residence time.

The following design criteria are proposed:

- While MSR design is based on the highest anticipated flow rates for the ELF (e.g., 40% of net percolation) this may be a conservative number and performance monitoring is required to confirm the expected flows.
- A HRT of one day is proposed as the baseline design criterion. This duration balances effective treatment (e.g., pH buffering, metal precipitation, adsorption) with the spatial limitations typical of constructed ELFs.
- The thickness of shell layer should be a minimum of 1.5 m, which is comparable to other operating designs (e.g., Whirlwind and BV ELF MSRs).
- A minimum depth of water cover for the shells is designed as 0.30 m. This provides a water cover to manage any odours from the shells and equalises flow through the shell substrate.
- A minimum freeboard depth of 0.50 m is required to allow for reduced permeability of the reactor and provide additional surge capacity for higher flows/rainfall events.
- A design factor of 2 is applied to the MSR spatial requirements to account for the inclusion of a Polishing Pond. If the Polishing Pond is excavated to the same depth as the MSR then there will be a greater residence time in the Polishing Pond compared to the MSR. The polishing Pond can therefore be shallower or deeper; the exact dimensions being determined as part of detailed design.
- A MSR overflow should be included in the design in case of higher than anticipated flow rates. Overflow should report to the MSR polishing pond where partial treatment is anticipated.
- MSR will be designed as downflow to enable efficient AMD sludge removal.

- Collection of ELF toe seepage and piping to the MSR may be required in some instances where real estate is limited.
- Poorly ventilated locations close to the MSR discharges can lead to elevated hydrogen sulfide gas (H₂S). MSR design should avoid the construction of closed/confined spaces.

6.6 Construction Material Requirements

Various materials will be required to construct and maintain the MSR this includes

- Mussel shells: Chipped shells (fresh / weathered) need to be sourced for the construction of the MSR and then during ongoing maintenance activities.
- Pipework: Influent and effluent HDPE pipes to convey AMD to the MSR and treated effluent to downstream discharge location and/or polishing ponds.
- MSR Lining: HDPE or low permeability rock liners may be required to minimise basal seepage, dependent on site-specific conditions. Noting that in downflow MSR, the basal seepage is generally treated.
- Underdrainage: Perforated pipes PVC pipes within the shell layer should be used to collect effluent uniformly and maintain hydraulic performance. There is no need to provide a gravel drainage medium around these pipes as the shells are suitable.
- Risers: Each MSR and Polishing Pond will have a riser from the basal drainage network to control the water level. These will be constructed from PVC pipework and will be adjustable so that the pond height can be adjusted.
- Overflow: MSR are designed to treat the expected flow rates from net percolation. Variations in flow rates are anticipated to be minor, however a spillway should be designed for all MSR with spill to the MSR polishing pond.
- Monitoring equipment including, for instance, v-notch weirs, continuous stage height loggers (to obtain flow rates) and continuous pH and electrical conductivity (EC) loggers.

7 MAINTENANCE AND PERFORMANCE MONITORING

The following section summarises the MSR maintenance requirements.

7.1 MSR Inspections

Regular inspections are recommended to support performance monitoring and early detection of treatment inefficiencies. These inspections should include:

Inspection of any upstream sediment management infrastructure (e.g., systems constructed to ensure surface water is excluded from the MSR).

- Inspection of the MSR and the Polishing Pond inlet and outlets for blockages or potential blockages.
- Assessment and monitoring of flow rates to confirm whether AMD sludge accumulation is slowing down treatment rates.
- Assessment of the water level and freeboard within the MSR, particularly in relation to the spillway.
- Measurements of MSR sludge accumulation depth and permeabilities to ensure flow rates remain acceptable.
- Inspection of the polishing pond, including visual assessment of water clarity, odour, algal growth, and sludge accumulation.
- Safety feature checks that have been established.

7.2 Sludge Management and Maintenance Requirements

Two mechanisms can drive desludging including:

- Reduced permeabilities due to sludge accumulation leading to overflow of the MSR and the bypass of untreated AMD.
- Reduced treatment efficiencies for trace metals such as Zn leading to sub-optimum performance.

7.2.1 Reduced Permeability

Sludge removal rates will be a function of PCOC influent loads. For the BPCP, the estimated water quality for ELF seepage is a function of sulfur content and average height (thickness) of each ELF as compared to the BV-ELF.

As water quality is a direct driver of AMD sludge generation rates these data can be used to estimate desludging rates. Calculations suggest that desludging may be required annually for MSR treating high acidity loads to decades for MSR treating low acidity loads (Appendix F), which will be confirmed by performance monitoring (flow rate and treatment efficiency). When desludging is undertaken the shells should be replenished to ensure the design specification of 1.5 m is maintained.

7.2.2 *Treatment Efficiencies*

Performance monitoring is required for all MSRs to validate that treatment is effective. A decrease in treatment efficiencies for PCOC such as Zn, suggest that desludging is required and that additional shells are required to ensure that carbonate derived acid neutralisation processes occur in the upper shell layers, not the $\text{Al}(\text{OH})_3$ layer.

7.3 **Performance Monitoring**

Performance monitoring is required to ensure the MSR and MSR Polishing Ponds are working to design expectations. The following is proposed:

- Flow monitoring for influent and effluent flow rates for the MSR and MSR Polishing Pond. By-pass flow should also be monitored.
- Monthly water quality monitoring is recommended for MSR influent and MSR Polishing Pond effluent. Monitoring parameters and frequency should be based on key water quality risks that will be influenced by influent water quality, treatment efficiencies, and secondary contaminants.
- Performance monitoring will validate the quantity of Fe that passes through the MSR and whether any $\text{Fe}(\text{Cl}_3)$ dosing is required for the polishing pond to treat residual Ni and Zn.

7.4 **Adaptive Management**

Adaptive management will be an important component of operating MSR to treat AMD during the closure phase of the BPCP. Adaptive management will be supported by performance monitoring and planning for key risks. Risks and adaptive management of these risks are identified in the AMD Management Plan.

8 DETAILED DESIGN

The following recommendations are provided for further work that needs to be undertaken as part of the detailed design phase of works.

8.1 Overview: Further Work

Further work needs to be completed as part of the detailed design stage to close out remaining uncertainties and ensure closure water quality objectives can be achieved. This needs to include:

- Performance monitoring of ELF seepage to confirm flow rates and water quality that will require treatment.
- Detailed design of passive treatment systems.
- Ensure an adequate supply of shells are available¹..
- Confirm the benefits of Fe and Al addition to the MSR Polishing Pond to remove trace metals
- Determine methods of aeration for the MSR Polishing Pond and confirm secondary contaminants are successfully treated.
- Confirm opportunities for MSR sludge disposal during the closure phase (i.e., disposal to pit voids).

8.2 WWH ELF MSR Conceptual Design

BRL (2025) have developed a MSR Design for the WWH ELF (Appendix H). This provides further details of how the MSR will be constructed. Similar designs will be completed for other MSR that will be required for the BPCP.

8.3 Detailed Design

Studies should resolve minor outstanding design issues as the first engineered landforms are closed and rehabilitated (e.g., ESC ELF basal sub-catchment) These ELFs will then provide site specific data that will enable trials to be undertaken and detailed design elements to be resolved. This will provide confidence in design inputs such that detailed design of each MSR can be undertaken. Individual design plans for each MSR will be developed.

¹ Mussel shell supply remains a key factor for implementation. Previous studies (Weber et al., 2015; Trumm et al., 2015;) indicate that significant quantities of shells are generated in New Zealand (e.g., 140,000 tonnes of shells annually), however these need to be procured for the Project, when other market forces may limit availability. Hence, It is recommended that other PTS technologies should also be assessed if a market study suggests mussel shells are of limited supply

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10 LIMITATIONS

Attention is drawn to the document “Limitations”, which is included in Appendix J of this report. The statements presented in this document are intended to provide advice on what the realistic expectations of this report should be, and to present recommendations on how to minimise the risks associated with this project. The document is not intended to reduce the level of responsibility accepted by Mine Waste Management, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in doing so.

APPENDIX A ABBREVIATIONS

ABBREVIATION	DEFINITION
AEE	Assessment of environmental effects
AeWs	Aerobic wetlands
ALDs	Anoxic limestone drains
Al	Aluminium
AMD	Acid and metalliferous drainage, including low metal saline drainage
Amm-N	Ammoniacal nitrogen
ANC	Acid neutralisation capacity
BCM	Brunner Coal Measures
BOD	Biochemical oxygen demand
BPCP	Buller Plateaux Continuation Project
BRL	Bathurst Resources Limited
BV	Barren Valley
BV-ELF	Barren Valley engineered landform
Co	Cobalt
Cu	Copper
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DVG	Default guideline value
EC	Electrical conductivity
ELF	Engineered landform
E-PTS	Enhanced passive treatment systems
FTA	Fast-track Approvals Act
FTAA	Fast-track Approval Act 2024
FHT	Falling head test
HRT	Hydraulic retention time
IBCs	Intermediate bulk containers
KMS	Kaiata Mudstone
LCM	Loose cubic metres
LOR	Limit of reporting
MCA	Multi-component analysis
MIW	Mining-influenced water
Mn	Manganese
MSR	Mussel shell bioreactor

ABBREVIATION	DEFINITION
MWM	Mine Waste Management Limited
NAF	Non-acid forming
NMD	Neutral metalliferous drainage
NP	Net percolation
NPR	Neutralisation potential ratio
OLC	Open limestone channel
PAF	Potentially acid forming
PCOC	Potential constituents of concern
PTS	Passive treatment system
QA/QC	Quality assurance and quality control
SLBs	Slag leaching beds
SO ₄	Sulfate
SOP	Standard operating procedure
SPLP	Synthetic precipitation leaching procedure
SRB	Sulfate reducing bacteria
SRBR	Sulfate reducing bioreactors
TARP	Trigger action response plan
Tl	Thallium
TSS	Total suspended solids
UC	Uncertain
UWHR	Upper Waimangaroa Haul Road
VFR	Vertical flow reactor
WQ Ref Value	Water quality reference value
WRD	Waste rock dump
WTPs	Water treatment plants
Zn	Zinc

APPENDIX B MCA - MSR

Passive Treatment of AMD: Options Assessment

Buller Plateaux Continuation Project

21 July 2026

J-NZ0453-008-R-FINAL



Passive Treatment of AMD: Options Assessment

Buller Plateaux Continuation Project

Document Number: J-NZ0453-008-R-FINAL

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EXECUTIVE SUMMARY

Bathurst Resource Limited (BRL) is seeking to obtain authorisation through the Fast-track Approvals Act (FTAA) to progress development and mining of the coal resources across the wider Buller Plateaux. This project is referred to as the Buller Plateaux Continuation Project (BPCP or Project). Mine Waste Management Limited (MWM) has developed this memorandum to support BRL with the assessment of environmental effects (AEE) for the BPCP.

The objectives of this report are to identify options for passive treatment systems (PTS) for waters impacted by acid and metalliferous drainage (AMD) at closure of the BPCP by undertaking a multi-component analysis (MCA) to select the best practicable option.

Objectives

The objectives for this report are to:

- Provide a literature review of PTS.
- Use an MCA to conduct an initial screening-level of options for PTS of AMD and then evaluate the shortlisted option. The MCA covers:
 - Assessing the cost, feasibility, reliability, and control effectiveness of options.
 - Confirming the selected approach is best suited to meet water quality guidelines / future resource consents (e.g., long-term water quality expectations).
 - Ensuring the selected PTS option accounts for environmental and human health.
- Identify the preferred PTS technology.

Preferred Technology

Mussel shell bioreactors (MSRs) were selected as the chosen technology:

- **Renewable Material:** The materials used in a MSR are derived from waste mussel shells, a by-product of the seafood industry, which supports a circular economy. Furthermore, the CO₂ within the shells, used for neutralisation of acidity, is renewable.
- **Treatment Performance:** MSRs have shown to consistently remove PCOC such as acidity, Fe, and Al, and to a slightly lesser extent, trace metals such Ni and Zn under both acidic and alkaline conditions. Secondary MSR treatment (polishing pond) have been proposed for further removal of residual trace metals and secondary contaminants as required. Further site-specific operational field trials are required in the first 1-3 years of the Operational Phase of the BPCP to validate previous laboratory studies that the designs of these MSR polishing ponds are suitable to achieve closure water quality objectives in the targeted timeframe.
- **Sludge Management:** AMD sludge (predominantly Fe and Al) is generated from the treatment of acidic AMD impacted waters. Downflow MSRs are an efficient process to remove Fe and Al, acting as a vertical flow reactor as well as a neutralising PTS with pH correction such that AMD sludge forms at the surface of the MSR. This sludge can effectively be removed as part

of routine maintenance as demonstrated at existing operating MSRs. Higher acidity loads (i.e., higher dissolved Fe and Al loads) can be managed by increased maintenance frequencies once treatment performance decreases. When active treatment is still occurring after ELF's have been rehabilitated (i.e., Active Closure Phase), AMD sludge disposal will either be onsite at an appropriate location (e.g., AMD sludge disposal cells at ESE Coal Pad), disposal at Stockton, or by other approved methods that may be developed over the Operational Phase of the BPCP. In the Post Closure Phase similar locations will be used. A back-up option includes disposal to offsite landfills.

Noting: Other options for AMD sludge management will be evaluated during the Operational Phase. If studies indicate that the method can provide geochemical stability, containment integrity, and cost-effective handling to align with closure objectives then this may be implemented at a later date (with additional regulatory approval as required).

- **Maintenance:** For maintenance of the MSRs (e.g., desludging) the system or part of the system needs to be taken off-line. This could involve dosing of bypass water with CaO or NaOH, designing MSRs to incorporate bays such that individual bays can be bypassed and drained for desludging while others remain operating. MSR Polishing ponds could also be constructed deeper to accommodate all sludge generation or be desludged periodically, if required. Further details are provided in the AMD WMP (BRL, 2026)
- **Spatial Requirements:** MSRs can be sized for the expected flow (where ~100 m² of MSR surface area with a minimum depth of 1.5 m is needed for 1 L/s) provided sufficient surface area is available. For ESE and MFS, MSR surface area requirements have been factored into mine plans based on net percolation rates of 40% into ELF's after closure (MWM, 2026i), which drives treatment requirements. Additional space is provided for the MSR polishing ponds. Space for maintenance activities (e.g., desludging, vehicle access, etc is also required).
- **Demonstrated Experience and Longevity:** BRL has successfully implemented MSRs, with systems operating effectively for nearly a decade while showing low maintenance requirements.

Recommendations

While MSRs are the proposed passive treatment technology for the BPCP, other passive treatment options may be viable and have not been excluded from future consideration. Passive treatment technologies are advancing rapidly, e.g., enhanced passive treatment systems (Christenson et al., 2018)) and/or the use of a series of biogeochemical processes (i.e., a treatment train) to treat AMD characteristics (Nairn et al., 2023) may have application to the BPCP in the future.

Early construction of the MSR in the first 1-3 years of the Operational Phase will enable site-specific testing and validation through performance monitoring to demonstrate the system's effectiveness early in the project's implementation.

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1 **INTRODUCTION**

Bathurst Resource Limited (BRL) is seeking to obtain authorisation through the Fast-track Approvals Act (FTAA) to progress development and mining of the coal resources across the wider Buller Plateaux. This project is referred to as the Buller Plateaux Continuation Project (BPCP or Project). Mine Waste Management Limited (MWM) has developed this report to support BRL with the assessment of environmental effects (AEE) for the BPCP.

The objectives of this report are to identify options for passive treatment systems (PTS) for waters impacted by acid and metalliferous drainage (AMD) at closure of the BPCP by undertaking a multi-component analysis (MCA) to select the best practicable option.

A MCA is a structured approach to optioneering studies to determine the preferred go forward option. The MCA provides a robust, transparent, and repeatable decision-making structure, highlighting the key considerations and the values attributed to them and providing opportunities for stakeholder and community participation. The MCA is designed to be a decision-making tool, rather than just providing an 'end score' for a preferred water management option.

1.1 **Background**

The purpose of the BPCP is to re-consent the existing infrastructure and mining operations associated with the existing Stockton Mine and provide access to additional coal mining areas across the Buller Plateaux, as the coal resource in the current Stockton Mine is close to depletion, and further coal resources for blending are required. There are five key project sub-areas:

- Stockton mining area (Stockton)
- Mount Frederick South (MFS)
- Escarpment Extended (ESE)
- Upper Waimangaroa Haul Road (UWHR)
- Cypress mining area (Cypress)

1.2 **Objectives**

The objectives for this report are to:

- Provide a literature review of PTS.
- Use an MCA to conduct an initial screening-level of options for PTS of AMD and then evaluate the shortlisted option. The MCA covers:
 - Assessing the cost, feasibility, reliability, and control effectiveness of options.
 - Confirming the selected approach is best suited to meet water quality guidelines / future resource consents (e.g., long-term water quality expectations).
 - Ensuring the selected PTS option accounts for environmental and human health.
- Identify the preferred PTS technology.

This document outlines the background, methodology, and rationale of the MCA, which was used to support the evaluation of potential PTS options (provided in Appendix B).

2 BACKGROUND

The following section provides an overview of AMD, active and passive treatment of AMD, and the applicable water quality reference values that have been used as a basis for optioneering.

2.1 Introduction to AMD

AMD on the Buller Plateaux is characterised by high acidity and elevated metal concentrations. Materials that will contribute to AMD within the BPCP include the Brunner Coal Measures (BCM), host to economic coal resources, and the overlying Kaiata Mudstone (KMS).

Regional variability for AMD source hazards across the Project sub-areas (i.e., Stockton, MFS, ESE, and the UWHR) is heavily influenced by paleo-depositional environment of the BCM and to a lesser extent the KMS. The BCM form the foundational layer of a transgressive sequence of fluvial to estuarine high sulfur sedimentary rocks consisting of clastic sediments and coal seams. The sequence is 70 to 130 m thick and was deposited in a fluvioparalic environment consisting of braided and meandering streams within a deltaic, barrier, tidal environment. The BCM are conformably overlain by, and laterally interfingered with, the Eocene marine KMS, which has increasing carbonate content upwards away from the BCM contact (Flores and Sykes, 1996). Geochemical AMD risks decrease away from the BCM/KMS contact such that at approximately 30m above the BCM/KMS contact (Hughes, 2007) the acid generating potential is equivalent to the net acid neutralisation capacity resulting in a net acid producing potential (NAPP) of ~0 kg H₂SO₄ per tonne of rock. Materials stratigraphically higher (younger) above the NAPP = 0 surface are non-acid forming (NAF) and materials below the NAPP = 0 surface are potentially acid forming (PAF) as shown in Figure 1.

As noted in literature (e.g., Pope et al., 2010), fluvial systems tend to be lower in pyrite compared to marine-influenced systems. The BCM at ESE and MFS project sub-areas have a lower sulfur content than at the adjacent Stockton Coal Mine and accordingly the AMD risks at ESE and MFS are lower. This lower sulfur/AMD risk at ESE and MFS is due to the depositional environment being strongly influenced by fresh water fluvial sediments (low sulfur) south of Stockton with occasional periodic marine incursions (high sulfur), whereas the depositional environment at Stockton was predominantly a marine-influenced environment with higher sulfur materials (e.g., estuarine).

The BCM are typically deficient in acid neutralising carbonate minerals such that the oxidation of pyrite typically leads to the rapid formation of AMD with little time lag to acid onset (Weber et al., 2008).

Water and oxygen interacting with materials that contain sulfide minerals can generate AMD. The mine domain with the greatest source hazard risks (60-80% of the total AMD load for any project) are waste rock storage facilities (e.g., INAP, 2020), that include waste rock dumps (WRDs), having no engineering controls to reduce sulfide mineral oxidation or the mobilisation of secondary sulfide oxidation products.

PAF waste rock disposal in engineered landforms (ELFs) is proposed for ESE and MFS to minimise the generation of AMD arising from waste rock storage. Further details are provided in the ELF Design Philosophy Report (MWM, 2026d), which explains source control technologies for prevention and minimisation of AMD.

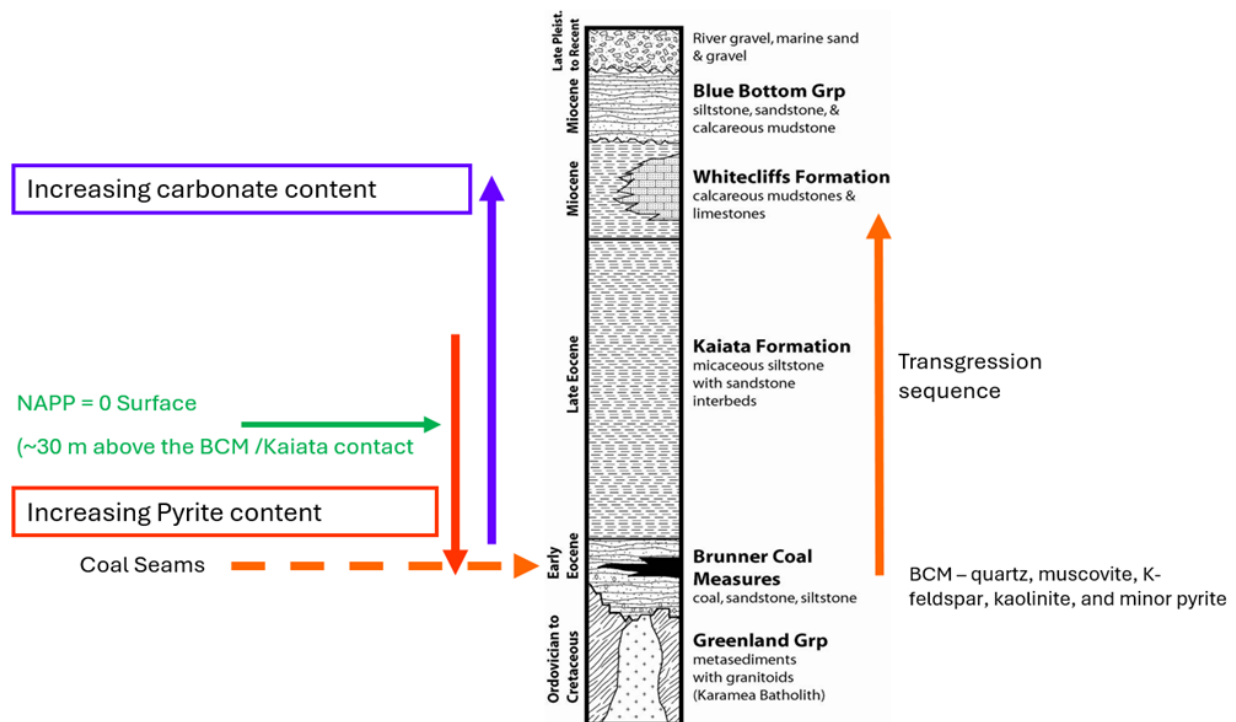


Figure 1: Stratigraphic column of the Denniston and Stockton Plateaux.

2.2 Potential Effects

Waters interacting with materials that contain BCM and KMS materials can generate AMD. The mine domain with the greatest source hazard risks (60-80% of total AMD load) are waste rock storage facilities (e.g., INAP, 2020), that include waste rock dumps (WRD), having no engineering controls to control sulfide mineral oxidation or the mobilisation of secondary sulfide oxidation products.

ELFs are proposed for MFS and ESE to minimise the risks of waste rock storage. Further details are provided in the ELF design philosophy report (MWM, 2026d) that explains source control technologies (prevention and minimisation of AMD).

Previous studies have indicated several potential constituents of concern (PCOC) that could be elevated in BPCP AMD impacted waters. These include:

- Elevated total suspended solids (TSS).
- AMD which is typically low pH and elevated acidity, sulfate (SO₄), and potential constituents of concern (PCOC) that include aluminium (Al), iron (Fe), and lesser amounts of trace metals that include cadmium (Cd), cobalt (Co), copper (Cu), manganese (Mn), nickel (Ni), and zinc (Zn).

Although source control engineering options can reduce the quantity of AMD and its effects, treatment is often required. Treatment includes active and passive treatment systems. The BPCP proposes to use active treatment technologies during the Operational Phase and Active Closure Phase once loads decrease in the Post Closure Phase, the treatment of water will shift to passive treatment technologies. This report assesses passive treatment systems.

2.3 Types of AMD Treatment Systems

A number of AMD treatment options are available. This section discusses general industry guidance on active and passive AMD treatment.

While AMD prediction, prevention and minimisation remain the focus of best practice mine site water management strategies, when AMD generation is unavoidable, appropriate treatment technologies need to be implemented. Treatment technologies are commonly categorised as either “active” or “passive”, both potentially combining physical, biological and chemical approaches.

Active treatment involves regular reagent and labour inputs for continued operation, compared with passive treatment that only requires occasional maintenance and replenishment of materials. The purpose of both types of treatment is to lower acidity and metal/ metalloid concentrations, raise pH and often lower sulfate concentrations and salinity.

Treatment of AMD is potentially a costly part of mining operations and may become a long-term liability if not managed correctly. Therefore, it is best practice to prevent and minimise AMD in the first instance and then treat the subsequent reduced loads. Treatment of AMD may be required for:

- Downstream water uses or ecosystem protection (to achieve compliance with discharge, surface or groundwater quality criteria).
- Reuse of water on-site (e.g., process water to lower operating costs).
- Protection of process-critical and/or expensive on-site infrastructure (i.e., to lower operating costs).

2.3.1 Active Treatment Systems

Active treatment of AMD involves routine reagent addition and regular maintenance. Active systems are used for both operational mine sites and post closure scenarios. Although effective, active treatment systems generally have high capital and operational costs; and requires specialised equipment and skilled personnel to operate, maintain, and monitor the active treatment system, which is often unfeasible for Post Closure AMD management.

Active acidity neutralisation is typically achieved by adding alkaline reagents, such as CaO, Ca(OH)₂ Mg(OH)₂ or NaOH to raise the pH of AMD-impacted waters. As the pH increases, dissolved metals (for example, Fe³⁺) hydrolyse, transitioning into insoluble precipitates like Fe(OH)₃ (see Table 1). Metals can also be removed by adsorbing onto Fe(OH)₃ and Al(OH)₃ precipitates such that reaching the minimum metal hydroxide solubility pH is not always necessary to reduce PCOC below discharge criteria.

Table 1: Theoretical minimum metal hydroxide solubility pH.

METAL	pH CORRESPONDING TO MINIMUM METAL HYDROXIDE SOLUBILITY
Ferric iron, Fe ³⁺	~ 3.5
Antimony, Sb ²⁺	~ 4.2
Aluminium, Al ³⁺	~ 4.5
Lead, Pb ²⁺	~ 6.5
Copper, Cu ²⁺	~ 7.0
Ferrous iron, Fe ²⁺	~ 8.0

METAL	pH CORRESPONDING TO MINIMUM METAL HYDROXIDE SOLUBILITY
Zinc, Zn^{2+}	~ 8.5
Nickel, Ni^{2+}	~ 9.3
Cadmium, Cd^{2+}	~ 10.0
Manganese, Mn^{2+}	~ 10.6

Source: INAP (2009).

Active water treatment is proposed for the BPCP at MFS and ESE. Active water treatment has been ongoing at the Stockton mine for almost 20 years.

2.3.2 Passive Treatment Systems

Passive treatment systems (PTS) are typically, though not exclusively, based on aggregate carbonate materials, with or without organic matter. These systems rely on natural physical, geochemical, and biological processes to treat water impacted by AMD.

In contrast to active treatment systems which require the regular addition of neutralising materials to manage AMD, PTS are designed with a finite supply of neutralising material, eliminating the need for continuous inputs, but requiring periodic maintenance or replenishment. Most PTS utilise the dissolution of neutralising materials, such as limestone or mussel shells, to treat AMD, and require adequate residence time and carbonate material to ensure effective dissolution. The design of PTS must address slow reaction rates (relative to active treatment) and focus on minimising armouring, where neutralising materials are coated with metal precipitates or gypsum, reducing effectiveness.

Incorporating organic matter can help regulate the redox state of the system, thereby reducing armouring by redox sensitive species such as Fe. The lifespan of a PTS is determined by the amount of neutralising material and/or organic matter it contains. Currently, PTS are primarily employed in post-closure scenarios for treating low acidity loads rather than at active mine sites.

Passive systems, in general, can only handle relatively small flows (<50 L/s) unless a significant area is available (INAP, 2021). Table 2 provides general design criteria for active and passive treatment systems, however the following caveats are noted:

- Data are based on studies that are now 20 years old and technologies have advanced.
- Data are provided as broad guidelines. For instance, a flow of 50 L/s at an acidity of 800 mg/L is equivalent to ~3.5 t/day.
- Often a key constraint on PTS is available surface area, hence one reason why larger systems may not have been constructed (spatial constraints and/or the costs for larger systems compared to the cost of active treatment (which might be less costly).

INAP (2021) note that “Under neutral to slightly acidic conditions, much higher flows can be treated through passive treatment, especially where sufficient real estate is available and where the concentrations of iron, which is often the largest problematic dissolved constituent, can be decreased through aeration”. INAP (2021) also note that “most successful passive treatment projects are treating less than 1,000 m³ per day”, however there are two examples where treatment of 6,500 m³ per day (~75 L/s) was maintained for up to 19 years. These higher-flow systems were treating net alkaline or mildly acidic drainage with relatively low contaminant loads.

Table 2: General guidelines for selection active versus passive treatment.

TREATMENT SYSTEM	AVERAGE ACIDITY RANGE (mg CaCO ₃ /L)	AVERAGE ACIDITY LOAD (kg CaCO ₃ /DAY)	AVERAGE FLOW RATE (L/s)	TYPICAL pH RANGE	MAX pH ATTAINABLE
Passive	1 - 800	1 – 150	< 50	>2	7.5 – 8.0
Active	1 – 10,000	1 – 50,000	No defined limit	No defined limit	14

Source: Taylor et al. (2005).

At closure of the BPCP there will be a number of landforms that will require passive treatment includes circum-neutral seepage from NAF ELF's and acidic seepage from PAF ELF's.

A summary of passive treatment technologies is provided in Appendix C. This list is not an exhaustive literature review. Rather the purpose is to demonstrate that many options are available for the treatment of AMD impacted waters.

3 PROJECT TREATMENT OPTION REQUIREMENTS

The following section examines the key PTS design criteria for the BPCP, which includes:

- Flow rate.
- Acidity loads, especially the quantity of Fe and Al, which influence sludge accumulation rates and permeability of PTS.
- PCOC such as Co, Mn, Ni, and Zn that can have lesser removal efficiencies compared to Fe and Al removal.
- Polishing ponds to manage secondary contaminants and redox sensitive metals such as Fe.

3.1 Water Quality Reference Values

Table 3 outlines the water quality consent conditions (RC10193) of the existing Escarpment Coal Mine for the Whareatea downstream monitoring site (W-M2). These values are used in this report as a water quality reference value (WQ Ref Value) to inform PTS design targets, recognising that actual consent conditions may differ for future discharges.

The maximum observed concentrations from the Barren Valley engineered landform (BV-ELF, located at the existing Escarpment Coal Mine), including flow rates and acidity loads, are presented to provide guidance on PTS requirements. The parameters highlighted in red represent the PCOC that must be treated to meet the WQ Ref Value.

Table 3: Median consent limits at monitoring site W-M2 (Escarpment Mine).

PARAMETER	REFERENCE VALUES		OBSERVED MAXIMUM CONCENTRATIONS FROM THE BV-ELF
pH (pH units)	4.5 - 6.5		2.80 ¹
Flow rate (L/s)	-		3.35
Acidity to pH 8.3 (mg CaCO ₃ /L)	-		183
Acidity Load (t CaCO ₃ /year)	-		13.9
Sulfate (mg/L)	-		386
Median Concentrations			
TSS (mg/L)	15		-
Turbidity (NTU)	15		-
Dissolved Fe + Mn (mg/L)	1.1		15.4 / 0.81 ²
Dissolved Al (mg/L)	0.5		22.8
Median pH	pH > 5.5	pH < 5.5	
Dissolved Cd (mg/L)	0.0003	0.0012	0.0003
Dissolved Cr (mg/L)	0.05	0.2	0.001
Dissolved Co (mg/L)	0.044	0.18	0.0393
Dissolved Cu (mg/L)	0.002	0.0013	0.0193
Dissolved Pb (mg/L)	0.0065	0.026	0.0045
Dissolved Ni (mg/L)	0.017	0.068	0.46
Dissolved Zn (mg/L)	0.012	0.054	3.29

1- pH values presented represent the lowest (minimum) observed pH value.

2- Observed maximum concentrations presented are the maximum concentrations e.g., maximum Fe concentration / maximum Mn concentration.

A hyphen (-) indicates that there are no available data.

3.2 Estimated Flow Rates and Associated Acidity Loads from Proposed ELF

To estimate the water quality (e.g., acidity) for each of the ELF basal sub-catchments associated with the BPCP, the model approach presented in MWM (2026a, 2026b) was used. This provides the water quantity (L/s) and quality (mg/L) for each ELF that will require treatment in the Post Closure Phase.

The risks for passive treatment (flow rate and acidity loads) are presented in Table 4 for each ELF basal sub-catchment where:

Suitable:

- **Green:** ≤ ~50 t/yr acidity.
- **Green:** ≤ ~50 L/s average flow rate.

Suitable but two systems may be required:

- **Orange:** < ~100 t/yr acidity (two reactors may be required) but > 50 t/yr acidity.
- **Orange:** < ~100 L/s average flow rate (two reactors may be required) but > 50 L/s average flow rate.

Suitable but multiple systems may be required:

- **Red:** > ~100 t/yr acidity (multiple reactors may be required).
- **Red:** > ~100 L/s average flow rate (multiple reactors may be required).

Table 4. Basal ELF sub-catchment estimated outputs.

ELF LOCATIONS	BASAL ELF SUB-CATCHMENT	PLAN AREA ¹ (ha)	AVERAGE HEIGHT (m)	FLOW RATE (L/S) ¹	ACIDITY LOAD RANGE (t/yr) ²
ESE	BVE	22.5	35.1	13.9	38.2
ESE	CON	96.9	35.7	75.3	174.4
ESE	NSUL - Closure	24.0	15.49	18	5.1
ESE	PPG	3.8	17.6	2.76	0.1
ESE	ESC	3.4	59.7	2.36	11.9
ESE	WWH	170.7	19.5	117	299.1
MFS	MSR1	6.12	14.5	4.63	11.2
MFS	MSR2	1.51	12.6	1.15	2.7
MFS	MSR3	2.17	12.6	3.12	3.8
MFS	MSR4	6.05	12.6	3.12	16.1
MFS	MSR5	18.9	19.1	14.3	24.2
MFS	MSR6	4.45	10.1	3.39	5.3
MFS	MSR7	20.1	11.9	15.2	28.5
MFS	MDC1	0.59	9.0	0.45	0.1

ELF LOCATIONS	BASAL ELF SUB-CATCHMENT	PLAN AREA ¹ (ha)	AVERAGE HEIGHT (m)	FLOW RATE (L/S) ¹	ACIDITY LOAD RANGE (t/yr) ²
MFS	MDC2	0.51	6.4	0.40	0.1
MFS	MSR8	31.4	18.4	23.9	43.3
MFS	MSR9	3.83	12.7	2.99	5.1
MFS	MSR10	2.41	8.4	1.84	2.7
MFS	MSR11	2.92	6.6	2.20	8.6
MFS	MSR12	2.90	7.8	2.21	8.9

1. Final catchment data as provided by BRL in the WLBM

2. Acidity loads are based on the activation date of the MSR as per the water and load balance models.

4 MULTI-COMPONENT ANALYSIS

The following sections provides a summary of the MCA undertaken for the identified PTS options for the BPCP. The evaluation process is guided by the treatment requirements outlined in Section 3, which serve as the framework for determining the appropriateness of each PTS option. The assessment is conducted in two stages to progressively refine the selection of options:

- **Screening-Level Assessment:** An initial evaluation to quickly identify and eliminate options that do not meet the fundamental requirements or are unsuitable based on high-level criteria.
- **Conceptual Short-Listed Options Assessment:** A detailed evaluation of the options that pass the screening stage. This phase focuses on a conceptual-level analysis to further assess the viability and risks of each short-listed option in alignment with the project objectives.

Each stage of assessment builds upon the previous stage to ensure that only the most feasible and appropriate PTS options are carried forward for further development and consideration. A full breakdown of the methodology and rationale is provided in Appendix B.

4.1 Methodology

The methodology developed for the MCA has been adapted from the Sustainable Remediation Forum UK Framework (Bardos et al., 2020) and the CRC Care National Remediation framework (CRC CARE, 2019). These documents were used to assist in providing the framework and principles from a systematic, process-based, holistic approach for the consideration, application, and documentation of sustainability parameters during the remediation processes.

Figure 2 provides a breakdown structure used in the MCA decision-making process, which provides the basis for the MCA adopted. The MCA approach provides a robust, transparent, and repeatable decision-making structure, highlighting the key considerations and the values attributed to them and providing opportunities for stakeholder and community participation. The MCA is designed to be a decision-making tool, rather than just providing an 'end score' for a preferred water management option.

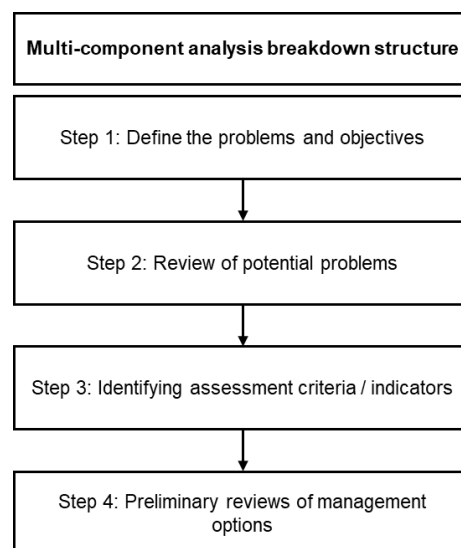


Figure 2. Framework of the multi-component analysis.

Adapted from Bardos et al. (2020) and CRC CARE (2019).

4.2 Screening Level Assessment

PTS are generally capable of treating a range of PCOC. The environmental conditions within the PTS (i.e., oxidising or anaerobic) can play a role in what constituents are treated. The required PTS depends on the specific PCOC that require treatment.

For the BPCP, treatment is required for PCOC that includes Fe, Mn, Al, Cd, Co, Cr, Cu, Pb, Mn, Ni, and Zn (Table 3). Figure 3 presents a simple way to select the most suitable PTS based on the expected PCOC (INAP, 2021). Hence, a combination of oxidising and anaerobic environment is considered ideal for the treatment of AMD associated with the BPCP based on the known PCOCs.

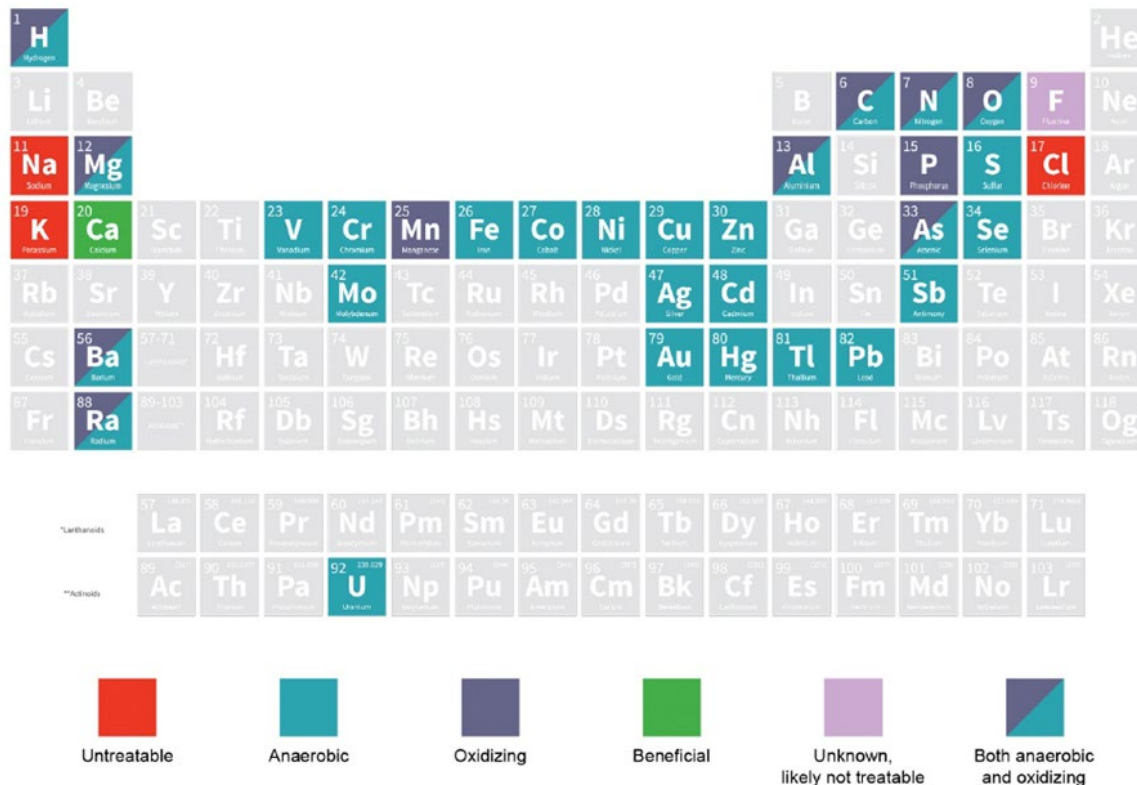


Figure 3. Periodic Table for Passive Treatment of AMD.

Source: INAP (2021).

Table 5 summarises the screening-level options considered feasible for the BPCP. A high-level summary of each PTS, the MCA analysis results, and the sensitivity analysis is provided in Appendix C and Appendix D. Options deemed feasible for the BPCP are highlighted (blue) and are progressed through to the short-list assessment process.

Table 5. PTS options selection rationale.

TREATMENT OPTION	SUITABILITY	RATIONALE
Anoxic Limestone Drains (ALDs)	Unsuitable	Limited effectiveness under anaerobic conditions; constrained by slope and space requirements.
Open Limestone Channel (OLC)	Unsuitable	High maintenance; reliant on steep terrain; low treatment performance. Unlikely to be suitable for removal of trace metals such as Zn.
Anaerobic Wetlands	Potentially suitable	Applicable in high-flow areas with sufficient flat land and available footprint.
Aerobic Wetlands (AeWs)	Potentially suitable	May be used in combination with MSRs at larger flow sites, depending on available space.
Slag Leaching Beds (SLBs)	Potentially suitable	Viable for moderate flows in space-constrained areas; less favourable than MSRs due to limited material availability.
Reducing agents – zero valent iron	Unsuitable	Only applicable in select locations with low to moderate acidity and flow, particularly where space or chemical reactivity is limited.
Diversion Well	Unsuitable	Only applicable in areas with sufficient hydraulic head; may serve as pre-treatment for high-flow acidic discharges.
Vertical flow reactors (VFR)	Potentially suitable	Suitable where higher Fe hydrolysis and metal adsorption is needed; may enhance Ni and Zn removal under slightly higher pH conditions; performance depends on influent chemistry and hydraulic constraints. Noting that MSRs can act as a VFR.
Mussel Shell Reactors (MSRs)	Preferred	Compact and effective for most sub-catchments; carbonate neutralisation of acidity and organic matter promotes reducing (anaerobic) conditions; low operational requirements; acts as a VFR; an aerobic polishing pond is advantageous for the management of secondary products. Limitations on flow rate are based on spatial availability (100m ² to treat 1 L/s).

4.3 Short-Listed Options

Table 6 presents the short-listed PTS options for each ELF sub-catchment. High-level summaries of the short-listed options are further discussed in Appendix D.

Table 6. Short-listed treatment options for ELF sub-catchments.

ELF SUB-CATCHMENT	FLOW (L/s)	ACIDITY LOAD (t/yr) ¹	SUITABLE TREATMENT OPTION(S)
BVE	13.9	21.1 (42.7)	MSR or VFR
CON	75.3	86.0 (174.4)	Multiple MSRs in series, with AeWs or VFR as secondary stage
NSUL - Closure	18.0	(14.0)	MSR for neutral mine drainage
PPG	2.76	(1.6)	MSR for neutral mine drainage
ESC	2.2	3.1 (6.1)	MSR or VFR
WWH	117	153.1 (310.4)	AeWs or MSR; VFR as enhancement option
MSR1	4.6	5.8 (11.7)	MSR
MSR2	1.2	1.4 (2.9)	MSR or VFR
MSR3	3.1	2.0 (4/1)	MSR
MSR4	3.1	5.3 (10.7)	MSR or SLB
MSR5	14.3	16.7 (27.2)	MSR or SLB
MSR6	3.4	4.0 (6.7)	MSR
MSR7	15.2	17.7 (29.6)	MSR or SLB or VFR
MDC1	0.45	(0.1)	MSR for neutral mine drainage

ELF SUB-CATCHMENT	FLOW (L/s)	ACIDITY LOAD (t/yr) ¹	SUITABLE TREATMENT OPTION(S)
MDC2	0.40	(0.1)	MSR for neutral mine drainage
MSR8	23.9	29.1 (43.5)	MSR or AeWs
MSR9	3.0	3.4 (4.2)	MSR
MSR10	1.84	2.3 (3.2)	MSR
MSR11	2.20	2.6 (5.2)	MSR or VFR
MSR12	2.21	2.6 (5.3)	MSR

1. where numbers relate to oxygen flux loads and numbers in brackets represent the potential acidity load if the limestone was exhausted.

4.4 Preferred PTS Technology

The evaluation of PTS focused on identifying technologies that can treat the PCOC loads while offering long-term performance with minimal maintenance. One PTS technology was preferred for the BPCP as this means simplification of the approach to passive treatment at closure and enable cost optimisation (design cost, material costs, maintenance costs, reporting and performance monitoring costs).

MSRs were identified as the preferred passive treatment technology for the majority of ELF sub-catchments based on MCA outcomes and site-specific constraints and was selected as the preferred PTS technology for the PBCP. Key advantages include:

- A compact design, allowing installation in areas with limited space and scalability for low to high flow conditions.
- Effective PCOC removal through a combination of oxic and reducing (anaerobic) conditions, supporting long-term passive treatment performance.
- Capability of treating both acidic drainage and neutral-metalliferous drainage.
- Downflow MSRs are preferred to minimise AMD sludge removal (e.g., maintenance) rather than upflow MSRs where sludge management is complicated.
- Demonstrated performance, with successful implementation at other BRL sites (e.g., Escarpment, Stockton, and Canterbury Coal Mines).
- Acceptance by regulators (e.g., West Coast Regional Council, Canterbury Regional Council)

A number of limitations / risks were identified for MSRs including:

- Mussel shell supply remains a key factor for implementation. Previous studies (Weber et al., 2015; Trumm et al., 2015;) indicate that significant quantities of shells are generated in New Zealand (e.g., 140,000 tonnes of shells annually), however these need to be procured for the Project, when other market forces may limit availability. Hence, it is recommended that other PTS technologies should also be assessed if a market study suggests mussel shells are of limited supply.
- Ability to remove trace metals (e.g., Co, Ni, Zn) to achieve WQ Ref Values. Studies have been completed as part of the BPCP AEE to improve the treatment efficiencies for trace metals (e.g., MWM, 2026c). This involved the use of a secondary polishing pond for additional PCOC removal.

- Generation of secondary contaminants. Anaerobic treatment of sulfate-rich mine impacted waters can lead to the formation of secondary contaminants such as hydrogen sulfide (HS^-) and ammoniacal nitrogen. Studies have been completed as part of this AEE to understand these effects (MWM, 2026e) and subsequent management requirements.

5 SUMMARY

This section provides a summary of the MCA and recommendations.

5.1 Preferred Technology

Based on the outcomes of the MCA, MSRs are recommended as the preferred PTS technology for the BPCP. This recommendation is supported by the following considerations:

- **Renewable Material:** The materials used in a MSR are derived from waste mussel shells, a by-product of the seafood industry, which supports a circular economy. Furthermore, the CO₂ within the shells, used for neutralisation of acidity, is renewable.
- **Treatment Performance:** MSRs have shown to consistently remove PCOC such as acidity, Fe, and Al, and to a slightly lesser extent, trace metals such Ni and Zn under both acidic and alkaline conditions. Secondary MSR treatment (polishing pond) have been proposed for further removal of residual trace metals and secondary contaminants as required. Further site-specific operational field trials are required in the first 1-3 years of the Operational Phase of the BPCP to validate previous laboratory studies that the designs of these MSR polishing ponds are suitable to achieve closure water quality objectives in the targeted timeframe.
- **Sludge Management:** AMD sludge (predominantly Fe and Al) is generated from the treatment of acidic AMD impacted waters. Downflow MSRs are an efficient process to remove Fe and Al, acting as a vertical flow reactor as well as a neutralising PTS with pH correction such that AMD sludge forms at the surface of the MSR. This sludge can effectively be removed as part of routine maintenance as demonstrated at existing operating MSRs. Higher acidity loads (i.e., higher dissolved Fe and Al loads) can be managed by increased maintenance frequencies once treatment performance decreases. When active treatment is still occurring after ELF's have been rehabilitated (i.e., Active Closure Phase), AMD sludge disposal will either be onsite at an appropriate location (e.g., AMD sludge disposal cells at ESE Coal Pad), disposal at Stockton, or by other approved methods that may be developed over the Operational Phase of the BPCP. In the Post Closure Phase similar locations will be used. A back-up option includes disposal to offsite landfills.

Noting: Other options for AMD sludge management will be evaluated during the Operational Phase. If studies indicate that the method can provide geochemical stability, containment integrity, and cost-effective handling to align with closure objectives then this may be implemented at a later date (with additional regulatory approval as required).

- **Maintenance:** For maintenance of the MSRs (e.g., desludging) the system or part of the system needs to be taken off-line. This could involve dosing of bypass water with CaO or NaOH, designing MSRs to incorporate bays such that individual bays can be bypassed and drained for desludging while others remain operating. MSR Polishing ponds could also be constructed deeper to accommodate all sludge generation or be desludged periodically, if required. (e.g., AMD sludge disposal cells at ESE Coal Pad)
- **Spatial Requirements:** MSRs can be sized for the expected flow (where 100 m² of MSR surface area with a minimum depth of 1.5 m is needed for 1 L/s) provided sufficient surface

area is available. For ESE and MFS, MSR surface area requirements have been factored into mine plans based on net percolation rates of 40% into ELFs after closure (MWM, 2026i), which drives treatment requirements. Additional space is provided for the MSR polishing ponds. Space for maintenance activities (e.g., desludging, vehicle access, etc is also required).

- **Demonstrated Experience and Longevity:** BRL has successfully implemented MSRs, with systems operating effectively for nearly a decade while showing low maintenance requirements.

5.2 Recommendations

While MSRs are the proposed passive treatment technology for the BPCP, other passive treatment options may be viable and have not been excluded from future consideration. Passive treatment technologies are advancing rapidly, e.g., enhanced passive treatment systems (Christenson et al., 2018)) and/or the use of a series of biogeochemical processes (i.e., a treatment train) to treat AMD characteristics (Nairn et al., 2023) may have application to the BPCP in the future.

Early construction of the MSR in the first 1-3 years of the Operational Phase will enable site-specific testing and validation through performance monitoring to demonstrate the system's effectiveness early in the project's implementation.

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7 LIMITATIONS

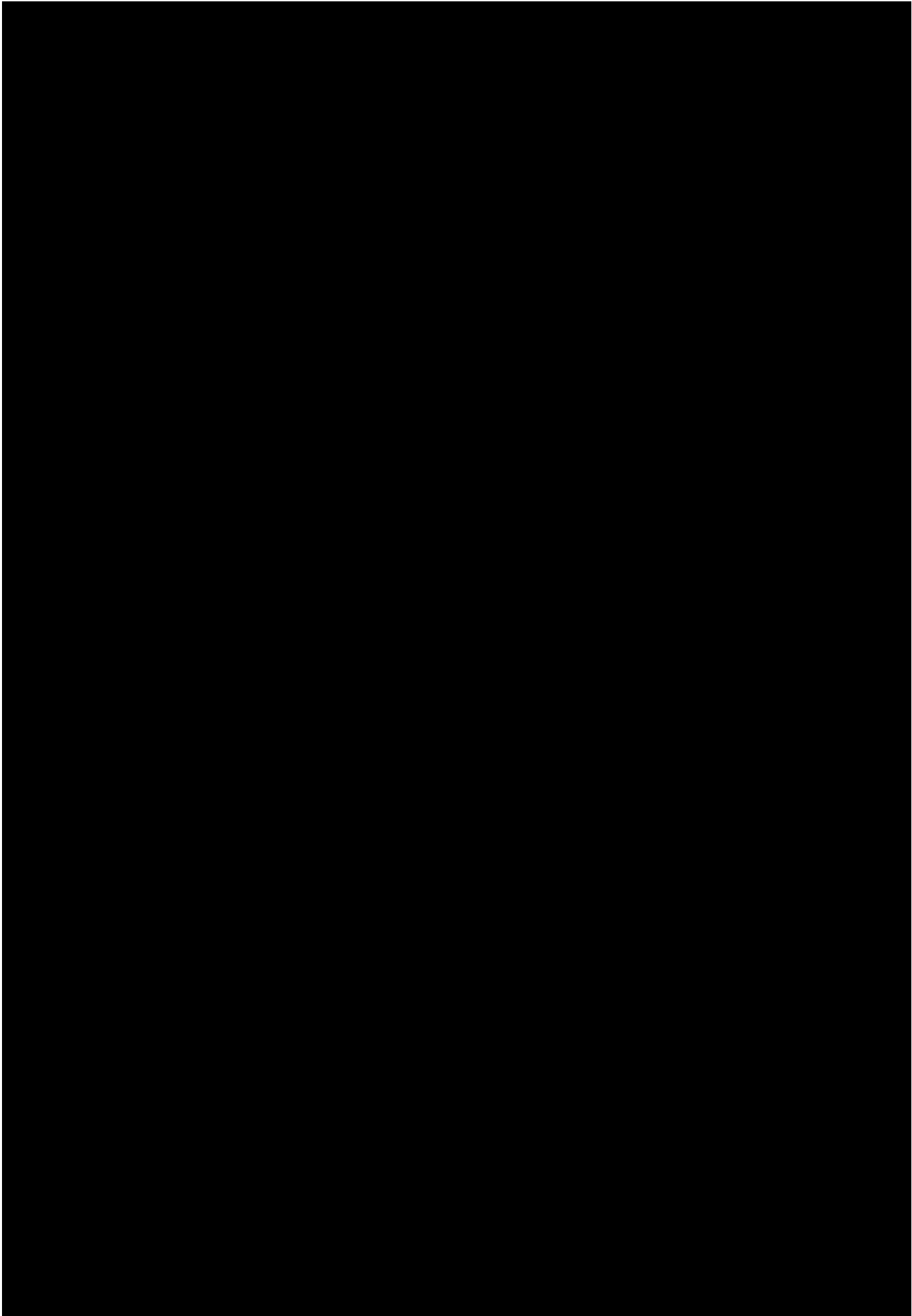
Attention is drawn to the document “Limitations”, which is included in Appendix E of this report. The statements presented in this document are intended to provide advice on what the realistic expectations of this report should be, and to present recommendations on how to minimise the risks associated with this project. The document is not intended to reduce the level of responsibility accepted by Mine Waste Management, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in doing so.

APPENDIX A ABBREVIATIONS

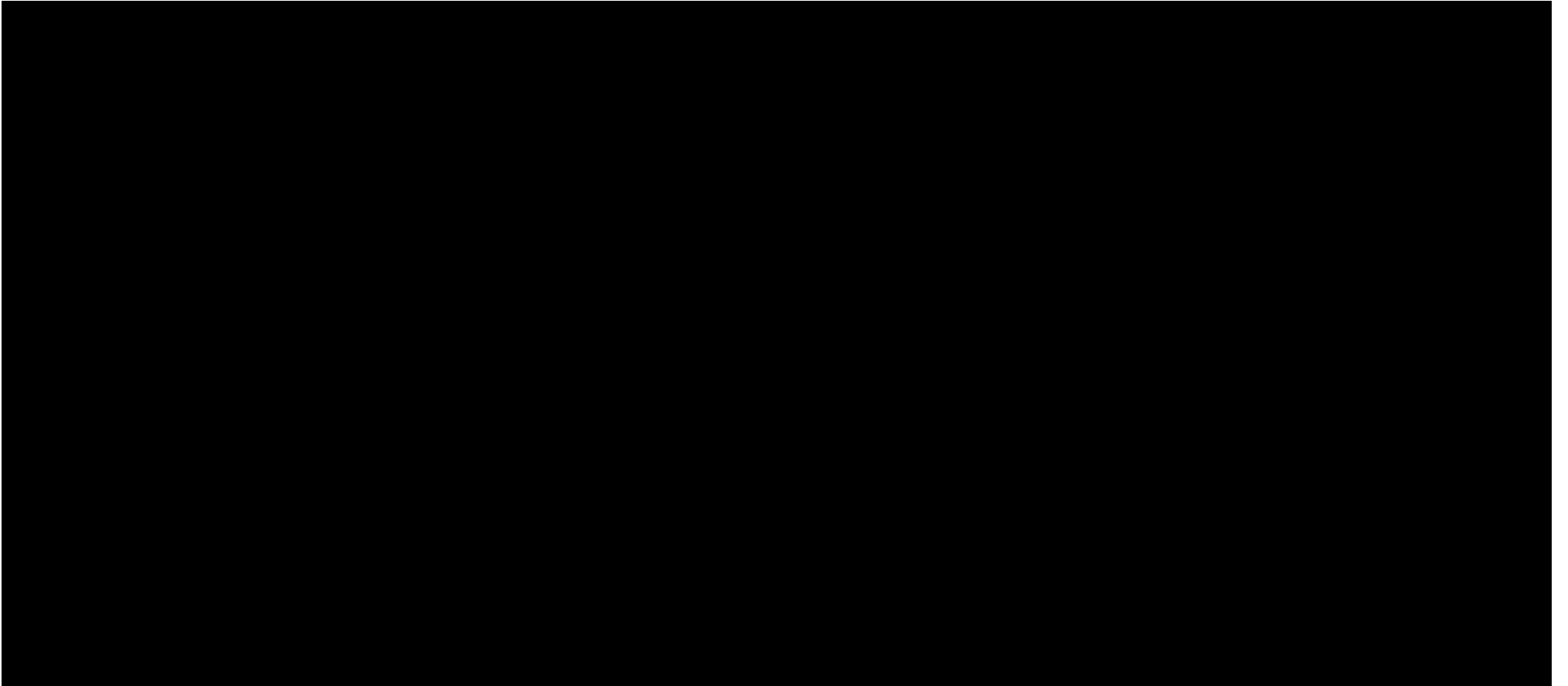
ABBREVIATION	DEFINITION
Al	Aluminium
ALDs	Anoxic Limestone Drains
AMD	Acid and metalliferous drainage
AEE	Assessment of environmental effects
AeWs	Aerobic Wetlands
BPCP	Buller Plateaux Continuation Project
BCM	Bruner Coal Measures
BRL	Bathurst Resources Ltd
BV-ELF	Barren Valley engineered landform
Cd	Cadmium
Co	Cobalt
Cd	Cadmium
ELF	Engineered Landform
ESE	Escarpment Extended
Fe	Iron
FTAA	Fast-track Approval Act 2024
KMS	Kaiata mudstone
MCA	Multi-component analysis
MFS	Mount Fred South
Mn	Manganese
MSR	Mussel shell reactor
MWM	Mine Waste Management Ltd
NAF	Non-acid forming
NAPP	Net acid producing potential
Ni	Nickel
OLC	Open Limestone Channel
PAF	Potentially acid forming
PCOC	Potential Constituents of Concern
PTS	Passive treatment system
SLBs	Slag Leaching Beds
SO ₄	Sulfate
TSS	Total suspended solids
UWHR	Upper Waimangaroa Haul Road

ABBREVIATION	DEFINITION
VFR	Vertical flow reactor
WQ Ref Value	Water quality reference value
WRD	Waste Rock Dump
Zn	Zinc

APPENDIX B MCA METHODOLOGY AND RATIONALE







Ranking Calculations

To determine the relative score for each water management option, the weightings for each sub-category were applied to the 10-point scoring scale; this was done to determine the overall score. The MCA involved several steps to convert individual scores and weightings for each category and sub-category into a single score for each option. These steps are outlined below:

1. A score between 1 and 10 was assigned for each water management option under each sub-category. The scores assigned were then adjusted using the equation below in order to normalise the scores.

$$WS = \frac{AS \times SC_w}{100}$$

This calculation converts the overall sub-category weightings to percentages so that the sum of the normalised sub-category weightings within a sub-category is 100%. This normalisation is necessary so that the number of sub-categories associated with each category does not influence the results.

Where:

- *WS is the weight score (i.e., the normalised score).*
- *AS is the assigned score (i.e., the assigned score between 1 and 10).*
- *SC_w is the sub-category weighting.*

2. The individual WS for each water management option were then summed to get a total rating.

$$Total\ Rating = \sum WS (for\ each\ option)$$

The resulting score is a value between 1 and 10 and provides a means to evaluate the relative ranking of various options considered. The highest option score represents the preferred option(s).

Sensitivity Calculations

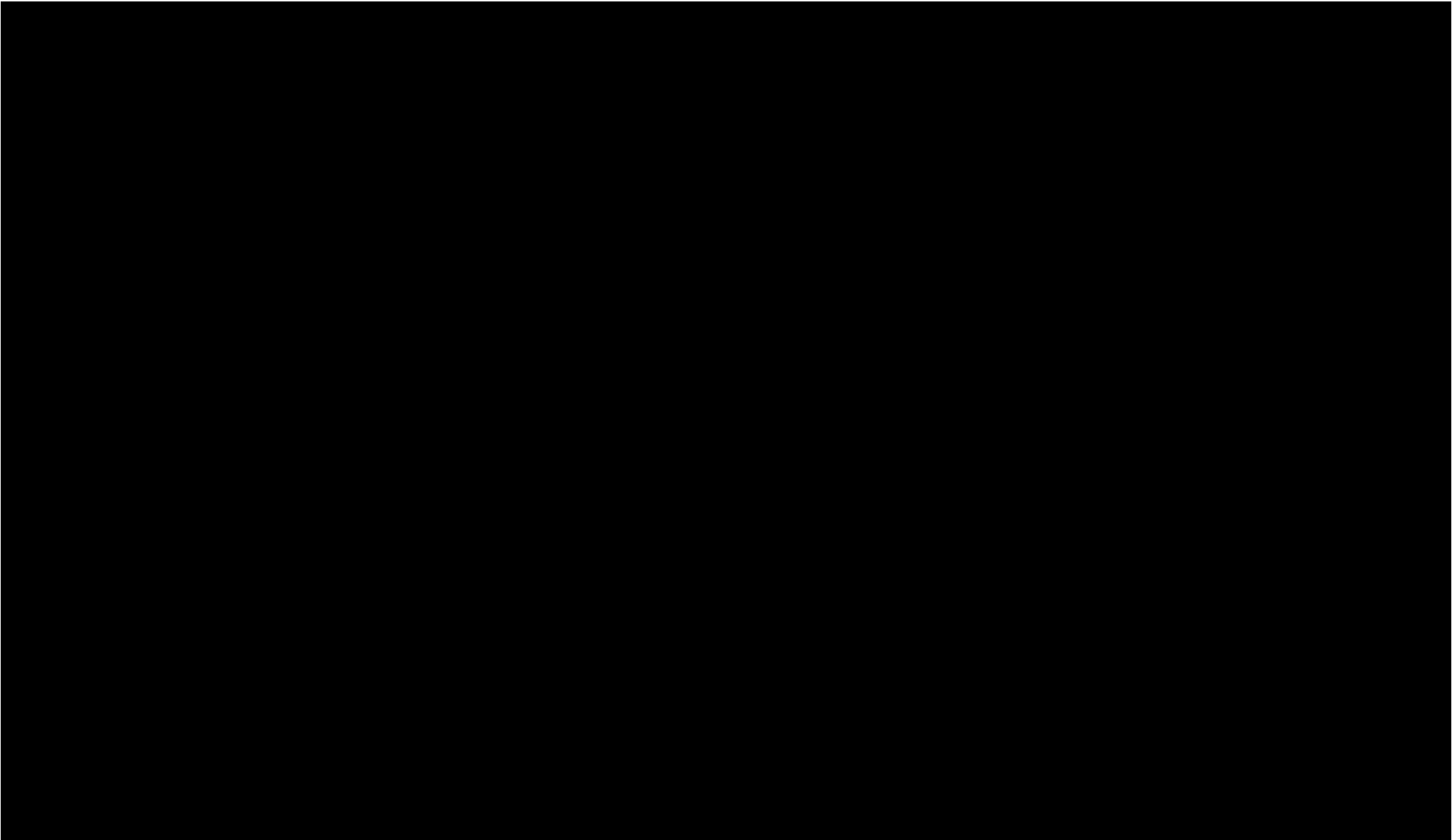
The sensitivity analysis in Table 12 tests the robustness of the MCA outcomes by applying equal weightings to all assessment categories. This approach evaluates whether the preferred option remains valid when no priority is given to any criterion (e.g. cost or environmental performance). The following steps were undertaken:

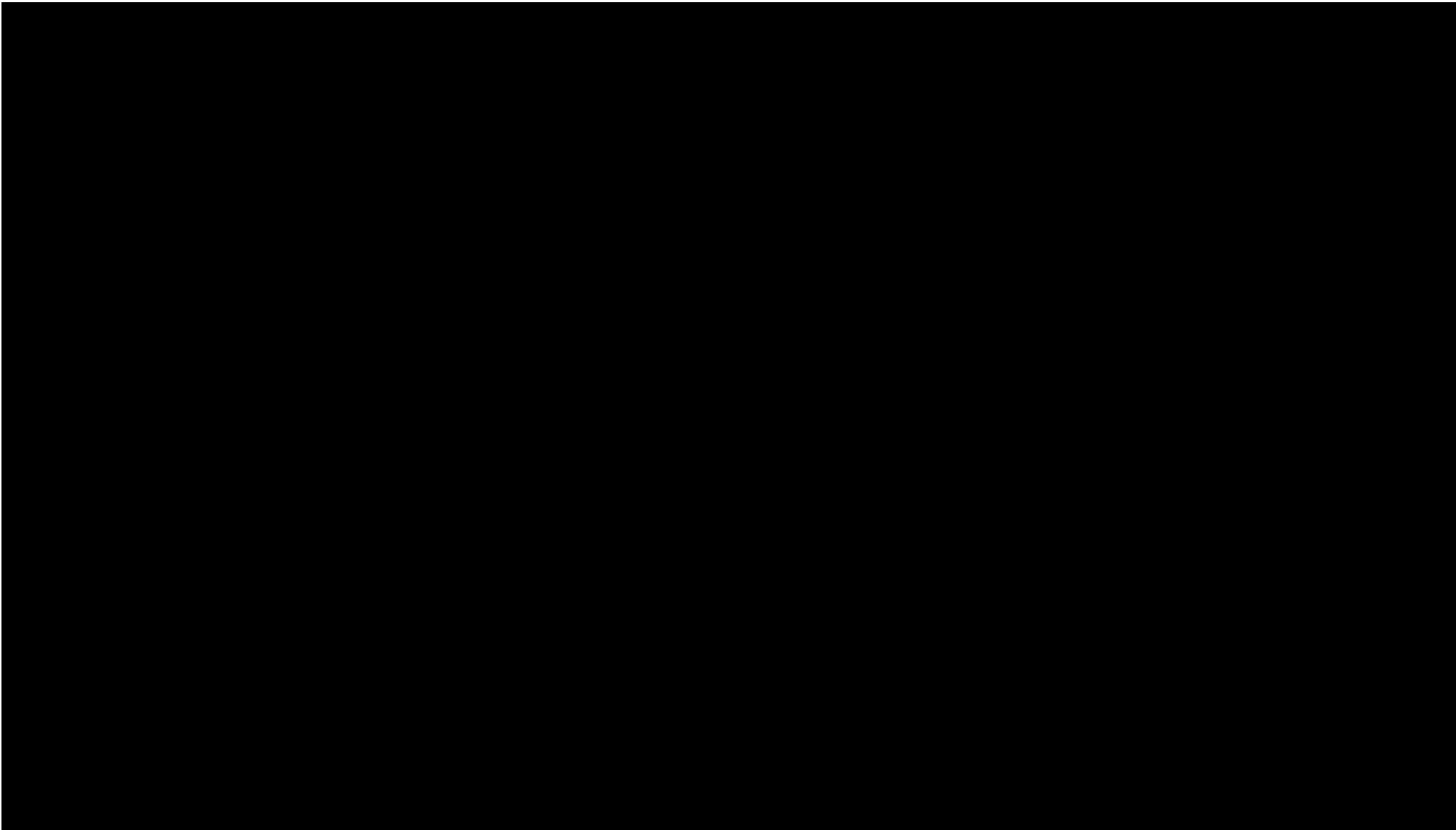
- All seven sub-categories were assigned equal weightings of 14.3%, removing any bias from the original weighting structure.
- Treatment options were re-scored using these equal weightings while retaining the original sub-category scores.
- The resulting Total Rating shows how each option performs when all criteria are considered equally important.

APPENDIX C PASSIVE TREATMENT SYSTEM OPTIONS LIST AND MCA

Table 10. Potential passive treatment options.

TREATMENT OPTIONS	DESCRIPTION	MAXIMUM INFLUENT FLOW RATE (L/s)	TREATABLE ACIDITY CONCENTRATIONS (mg CaCO ₃ /L)	REQUIRED TOPOGRAPHY	REFERENCES
Anoxic Limestone Drains (ALDs)	Buried channel constructed with small or large limestone. Anoxic AMD flows into the ALD where alkalinity is added through limestone dissolution allowing for a reducing environment	<15	<500	Flat area	Taylor, Pape, & Murphy, 2005; Ziemkiewicz et al., 1994; Ziemkiewicz, Skousen, & Simmons, 2003
Open Limestone Channel (OLC)	Large channel constructed with small or large limestone placed in areas with steep slopes. AMD flows into the OLC becoming neutralised and oxidised	<20	<500	Long, narrow land, can be used in a steep environment (slope > 20%)	Taylor, Pape, & Murphy, 2005; Trumm, 2010; Ziemkiewicz et al., 1994
Anaerobic Wetlands	Used for when AMD has net acidity. Organic-rich substrates are used while limestone or mussel shells are used for acid neutralisation as alkalinity is generated through sulfate reduction	<15	<500	Large flat area	Taylor, Pape, & Murphy, 2005; Trumm, 2010
Aerobic Wetlands (AeWs)	Large shallow pond (0.5 - 1 m) usually lined with soil or limestone gravel and have emergent wetland species planted. AMD flows through as oxidation is facilitated precipitating oxides and hydroxides	Long residence time	<300	Large flat area	Ziemkiewicz, Skousen, & Simmons, 2003; Taylor, Pape, & Murphy, 2005; Trumm, 2010.
Slag Leaching Beds (SLBs)	Rectangular chamber (IBC tank) filled with steel slag. AMD flows horizontally or vertically through the slag dissolving CaO and neutralising the acidity present	<20	<500	Large flat area	Taylor, Pape, & Murphy, 2005; Trumm, 2010; Ziemkiewicz et al., 1994; Ziemkiewicz, Skousen, & Simmons, 2003
Reducing agents – zero valent iron	Zero-valent iron (ZVI) is a cost-effective, non-toxic moderate reducing reagent that can oxidise organic pollutants	-	-	Large flat area	Liu & Wang, 2019
Diversion Well	Round chamber filled with crushed limestone. AMD flows into chamber out pipe near bottom of well creating turbulence which abrades particles preventing armouring. Water flows upward and out of chamber	<1,000	<500	Steep topography/limited area	Skousen et al., 2017; Taylor, Pape, & Murphy, 2005; Trumm, 2010; Ziemkiewicz et al., 1994; Ziemkiewicz, Skousen, & Simmons, 2003
Vertical flow reactor (VFR)	Downflow or upflow treatment beds with alternating organic and limestone layers. Promote Fe hydrolysis and sulfate reduction, enhancing metal adsorption.	<10	<800	Moderate slope	Hedin et al., 1994; Taylor, Pape, & Murphy, 2005; DiLoreto, 2013; Butler et al., 2019
Mussel Shell Reactors (MSRs)	AMD water flows through a saturated pond/reactor filled with mussel shells which are also covered by water. The system is designed to reuse any DO as water passes through the organic matter	1 L/s per 100 m ² (based on site-specific designs such as BV-ELF)	<500	Flat area	Crombie et al., 2011; Weber et al., 2015; Weisener et al., 2015; Ulster, et al., 2015; Robertson et al., 2017; Trumm et al., 2022





APPENDIX D POTENTIALLY SUITABLE PTS OPTIONS LIST

Short Listed Options

The following section provides a high-level summary of the preferred and suitable PTS options. For the BPCP the use of anaerobic treatment systems will require a downstream polishing pond to prevent the discharge of anoxic or sulfide-rich water to receiving environments.

Wetlands – Potentially Suitable Option

Constructed wetlands can be designed in either an aerobic or anaerobic configuration. Aerobic wetlands are typically shallow ponds that allow for metal oxidation, hydrolysis, and particle settling, and may include limestone for neutralisation. Anaerobic wetlands are deeper with permeable substrates of organic carbon-based materials, often underlain or mixed with limestone, which facilitate bacterial sulfate reduction to form insoluble metal precipitates. Sorption onto organic materials can also remove metals from AMD.

Typically, water flows horizontally through the wetland with depths varying between 15 and 45 cm. Variations in water depth within the wetland cell may be beneficial for performance and longevity.

The key benefits of wetlands are:

- Proven technology that is easy to construct.
- Relatively inexpensive.
- Aesthetically pleasing.
- Serves as a good solution for precipitate storage until replacement of the substrate is required (~every 20 years or so).

The main limitations of wetlands are:

- Residence times of two days or more are required for effective sulfate reduction, which, when combined with typical wetland depths of 15 - 45 cm, may result in spatially prohibitive system sizes under BPC conditions.
- Hydrogen sulfide (H₂S) can be a secondary by-product of anaerobic systems, which is also toxic to aquatic organisms and can generate gas-risks.
- Overloading with metals is possible, which can exhaust sorption sites on organic material and lower permeability due to sulfide precipitation.
- Mono-sulfides, such as FeS (pyrite) or PbS (galena), that have formed within the substrate can oxidise and release acidity if exposed to air, which requires consideration for appropriate disposal (~20 years).
- Organic material may need to be supplemented over time (~ every 20 years or so).

Slag Leaching Beds (SLBs) – Potentially Suitable Option

Slag leaching beds use industrial steel-making slag as a reactive medium for passive treatment. The slag typically contains free lime and silicate minerals that dissolve and increase pH, facilitating metal precipitation. Some slag types may also support sorption or co-precipitation of trace metals such as Zn and Ni.

The key benefits of SLBs include:

- High alkalinity potential and effective removal of acidity and Fe.
- Potential sorption of trace metals.
- Utilisation of industrial by-product materials.

The limitations of SLBs include:

- Limited data on long-term performance in field-scale applications.
- Slag composition can vary significantly between sources, affecting consistency.
- Risk of leaching unwanted trace elements (e.g., vanadium, chromium).
- Disposal and regulatory approval may be more complex depending on the source material.
- SLBs may be appropriate in situations where reliable, consistent slag materials are available and where regulatory constraints can be addressed.
- Very high discharge pH may require acid trimming prior to discharge.
- Anoxic effluent may necessitate an aeration or polishing pond step to ensure compatibility with receiving water quality objectives.
- SLBs may be appropriate in situations where reliable, consistent slag materials are available and where regulatory constraints can be addressed.

Vertical Flow Reactors (VFR) – Potentially Suitable Option

Vertical flow reactors (VFRs) are a passive treatment system that remove acidity and dissolved metals through vertical percolation of AMD through layered reactive media. These systems typically include organic material, limestone, and drainage layers, promoting metal sulfide precipitation, hydroxide formation, and alkalinity generation through microbial sulfate reduction and limestone dissolution.

VFRs are particularly useful in space-constrained sites or where vertical head is available. Their layered configuration supports sequential aerobic and anaerobic zones, enabling multi-step treatment processes in a compact footprint. Depending on design, VFRs can treat a range of neutral metalliferous and acidic drainage types.

The key benefits of VFRs include:

- Suitable for small or irregularly shaped sites with limited horizontal space.
- Vertical flow improves contact time and redox control for the removal of Fe, Al, Zn, Ni, and Mn.
- Can be adapted for different flow volumes and chemical loads.
- Functions passively without external power input; minimal mechanical components.
- Promotes both aerobic and anaerobic treatment stages within a single unit.

The limitations of VFRs include:

- Fewer installations compared to MSRs or wetlands may limit familiarity and confidence in design/application.

- Systems relying on anaerobic treatment processes may require longer residence times to achieve sufficient contaminant removal.
- Effluent may have elevated pH and low dissolved oxygen; therefore, in the BPCP context, a downstream polishing pond may be required to re-oxygenate the discharge and avoid releasing anoxic, high-pH waters to the receiving environment.

Mussel Shell Reactors (MSRs) – Potentially Suitable Option

Mussel shell reactors (MSRs) are passive treatment systems that use waste mussel shells as an alkaline media to neutralise acidity and support metal removal. The shells' high calcium carbonate content provides sustained alkalinity, while associated organic material supports microbial activity, including sulfate reduction, enabling both chemical and biological treatment processes.

Research in New Zealand since 2007 has demonstrated the suitability of MSRs for AMD treatment, with full-scale systems operating successfully at several BRL-managed sites. MSRs are also effective in treating neutral mine drainage, where they provide additional alkalinity and promote the removal of residual metals.

The key benefits of MSRs include:

- Effective removal of acidity, Fe, Al.
- Removal of trace metals
- Local, low-cost media with lower clogging risk than limestone.
- Proven long-term performance in pilot and full-scale systems.
- Suitable for both acidic and neutral mine drainage conditions.

The limitations of MSRs include:

- Generation of secondary contaminants (e.g., hydrogen sulfide, ammoniacal nitrogen) where microbial activity is high.
- Sludge removal required as part of regular maintenance
- Shell sourcing, stockpiling, and transport may present logistical challenges.
- Aged shells may exhibit lower dissolved organic carbon and reduced biological performance compared to fresh shells, though fresh shells can introduce additional environmental risks (e.g., odour, ammoniacal nitrogen, pathogens, arsenic) that must be considered in long-term use near public access areas. Further assessment is recommended to balance performance benefits with potential environmental and social impacts.
- High residence times are often required for sustained anaerobic treatment and sulfate-reducing bacteria activity.
- High discharge pH and alkalinity may occur and could require pH adjustment.
- Anoxic effluent is likely, requiring a downstream aeration or polishing pond in the BPCP context to meet discharge expectations.

- MSR treatment performance is site-specific, and design must be tailored to AMD chemistry and flow rate, particularly where Fe and Al loads differ from reference systems like Whirlwind and BV ELF.
- Generation of secondary contaminants (e.g., hydrogen sulfide, ammoniacal nitrogen) where microbial activity is high.

MSRs are recommended for further evaluation as the preferred passive treatment option due to their strong contaminant removal performance, compatibility with site conditions, and extensive operational precedent in New Zealand.

APPENDIX E LIMITATIONS

This Document has been provided by Mine Waste Management Ltd (MWM) subject to the following limitations:

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In addition, it is recognised that the passage of time affects the information and assessment provided in this Document. MWM's opinions are based upon information that existed at the time of the production of this Document. It is understood that the services provided allowed MWM to form no more than an opinion of the actual conditions of the site at the time the site was reviewed and cannot be used to assess the effect of any subsequent changes in the quality of the site, or its surroundings, or any laws or regulations.

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MWM acknowledges that this report will be relied on by a Panel appointed under the Fast-track Approvals Act 2024 and these disclaimers do not prevent that reliance.



MINE WASTE MANAGEMENT

GREENROAD GROUP

APPENDIX C ESCARPMENT MINE - MSR PERFORMANCE REVIEW

Mussel Shell Reactor Performance Review

Buller Plateaux Continuation Project

20 July 2026

J-NZ0349-003-R-FINAL



**MINE WASTE
MANAGEMENT**
GREENROAD GROUP



BATHURST
RESOURCES LIMITED

Mussel Shell Reactor Performance Review

Buller Plateaux Continuation Project

Document Number: J-NZ0349-003-R-FINAL

Document Date: 20 July 2026

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EXECUTIVE SUMMARY

Bathurst Resources Limited (BRL) is seeking to obtain authorisation through the Fast-track Approvals Act 2024 (FTAA) to progress development and mining of the coal resources across the wider Buller Plateaux. This Project is referred to as the Buller Plateaux Continuation Project (BPCP or Project). Mine Waste Management Limited (MWM) has developed this memorandum to support BRL with the assessment of environmental effects for the BPCP.

Objectives

The objectives of this report are to understand the performance of mussel shell bioreactors (MSR) to treat waters impacted by acid and metalliferous drainage (AMD). The following tasks were undertaken:

- Review water quality data for the MSR that treats acid and metalliferous drainage (AMD) from the Barren Valley Engineered Landform (BV-ELF) at the existing Escarpment Mine and assess design criteria and performance against other MSR.
- Review nickel (Ni) and zinc (Zn) removal efficiencies for the Whirlwind MSR (Stockton Coal Mine), the Tara MSR (Canterbury Coal Mine) and the Barren Valley MSR (BV-MSR) to determine the contributing factors for Ni and Zn removal, which have been identified as lower in the BV-MSR.
- Review the adsorption experiments undertaken by Process Flow Limited (Process Flow) to evaluate the role of adsorption in Ni and Zn removal under varying pH conditions using ferric chloride and alum dosing (Appendix C).
- Summarise performance and recommend design improvements for the BPCP.

Review

BV-ELF, Tara, and Whirlwind MSRs have demonstrated effective removal of Al and Fe through acid neutralisation and subsequent hydroxide formation. However, differences are observed in Ni and Zn removal performance:

- The Tara MSR exhibited the highest removal efficiencies for Ni and Zn (94.5% and 99.5%, respectively), likely due to circumneutral pH conditions, elevated Fe:Zn ratios, and higher total Fe concentrations, which support enhanced adsorption.
- The Whirlwind MSR achieved relatively high removal of Ni and Zn (71.0% and 83.4% respectively) despite lower pH influent. This is attributed to a higher Al:Zn ratio (~57:1), which is assumed to promote higher adsorption compared to the BV-MSR (Al:Zn ~14:1). This mechanism was validated in the Whirlwind MSR by DiLoreto (2013).
- The BV-MSR reported the lowest removal rates for Ni and Zn (40.2% and 56.2% respectively), which may reflect lower Al availability (~14:1 Al:Zn ratio), higher influent Zn concentrations, and lower influent pH leading to potentially lesser Al- and Fe- hydroxide adsorption of Zn and Ni.

These results suggest that pH and influent water chemistry, particularly Fe and Al availability relative to target metals are key drivers of MSR performance for the removal of Ni and Zn.

Data suggest that Zn removal has decreased with time (after 6 years of MSR operation):

- For the first 6 years of operation the removal efficiency was 63.7%
- The average treatment efficiency for Zn after 6 years decreased to 20.1%.

This decrease occurred before desludging and may be due to acid remobilisation of Zn from the $\text{Al}(\text{OH})_3$ layer as the acid neutralisation capacity of the upper shell layers is exhausted and acid waters enter deeper into the MSR before being neutralised redissolving Zn.

Analysis

Three factors were assessed that could influence Ni and Zn removal efficiencies within the MSR. This includes:

- The hydraulic residence time (HRT).
- Adsorption of Ni and Zn onto Al- and Fe- hydroxides.
- Biogeochemical processes due to sulfate reducing bacteria (SRB).

HRT:

MSR water quality data suggest that residence time can influence metal removal. Data suggests that higher HRT might have benefits for Ni and Zn treatment. A residence time of 24 hours was selected for the BPCP.

Geochemical Conditions and pH Dependency:

Studies indicate that the following geochemical processes could be influencing adsorption of trace metals such as Ni and Zn within MSR and the associated treatment efficiency:

- Precipitation of $\text{Fe}(\text{OH})_3$ under oxic circum-neutral conditions to form the upper Fe-sludge layer at suitable concentrations.
- Precipitate of higher quantities of $\text{Al}(\text{OH})_3$ under oxic / sub-oxic conditions.

Trials were undertaken by Process Flow (Appendix C). Results indicate that the addition of Al and Fe to MSR effluent (circum-neutral pH) removed >50% of the Zn in solution. This helps demonstrate the mechanism of adsorption of Zn onto Al- and Fe- hydroxides. Data shows that an additional treatment step after the MSR may be necessary (e.g., an aerated polishing pond with Fe addition) to remove Fe and Zn.

Biogeochemical Processes:

SRB generated alkalinity ranged from 4.71 to 5.76 kg CaCO_3 per m^3 of shells per year across the three MSRs, indicating a consistent rate of alkalinity production (based on sulfate differences in MSR influent and effluent). This also implies that sulfide generation rates are comparable, suggesting that sulfide production is not the primary factor influencing the observed differences in Ni and Zn removal efficiencies. Hence, it is likely that other factors are influencing biogeochemical activity. This has been assessed by obtaining data on dissolved organic carbon (DOC) and sulfide concentrations in MSR effluent.

Further work is required to understand the bioavailable labile carbon availability in MSR, the mechanics of SRB alkalinity generation, quantification of metal removal by sulfides, and whether this can be optimised to improve the MSR treatment efficiency. Optimising the process will lead to improved water treatment performance and the potential for small MSR with lesser HRT.

Sludge Management

Field work was undertaken coincidental with the desludging program for the BV-MSR. Laboratory results indicate that careful management of the MSR sludge is required to avoid the release of acidity and potential constituents of concern (PCOC).

Summary

For the BPCP the following process could be utilised to facilitate better Zn (and Ni) removal/treatment of ELF seepage for the BPCP:

- More frequent removal of the Fe and Al sludge layers (desludging) and replacement of these shells with fresh shells every ~5 years would be beneficial as part of the MSR maintenance program. Performance monitoring of MSR effluent for trace metals (e.g., Zn) would help confirm when shells need replacing.
- Establishment of a polishing pond after the MSR to either oxidise any remnant Fe(II) passing through the MSR (due to sub-oxic ELF seepage elevated in Fe) and/or enable FeCl₃ dosing and its subsequent hydrolysis/precipitation. This is likely to improve Zn removal efficiencies whereby Zn is adsorbed to the iron hydroxides that form.
- Noting: a polishing pond is required to remove secondary contaminants such as HS⁻ and ammoniacal nitrogen (see MWM, 2026c) in the MSR effluent and the same facility could be utilised for Fe and Zn removal.

MSRs will be assessed during the early stages of the BPCP by operational trials with ongoing literature review of new technologies to confirm that MSRs remain the best practicable option. Early construction of the MSR during operations will enable site-specific testing and validation, helping to address uncertainties and demonstrate the system's effectiveness.

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1 **INTRODUCTION**

Bathurst Resources Limited (BRL) is seeking to obtain authorisation through the Fast-track Approvals Act (FTA) to progress development and mining of the coal resources across the wider Buller Plateaux. This Project is referred to as the Buller Plateaux Continuation Project (BPCP or Project). Mine Waste Management Limited (MWM) has developed this memorandum to support BRL with the assessment of environmental effects (AEE) for the BPCP.

1.1 **Report Objectives**

The objectives of this report are to understand the performance of mussel shell bioreactors (MSR) to treat waters impacted by acid and metalliferous drainage (AMD). The following tasks were undertaken:

- Review water quality data for the MSR that treats acid and metalliferous drainage (AMD) from the Barren Valley Engineered Landform (BV-ELF) at the existing Escarpment Mine and assess design criteria and performance against other MSR.
- Review nickel (Ni) and zinc (Zn) removal efficiencies for the Whirlwind MSR (Stockton Coal Mine), the Tara MSR (Canterbury Coal Mine) and the Barren Valley MSR (BV-MSR) to determine the contributing factors for Ni and Zn removal, which have been identified as lower in the BV-MSR.
- Review the adsorption experiments undertaken by Process Flow Limited (Process Flow) to evaluate the role of adsorption in Ni and Zn removal under varying pH conditions using ferric chloride and alum dosing (Appendix C).
- Summarise performance and recommend design improvements for the BPCP.

1.2 **Project Background**

The purpose of the BPCP is to re-consent the existing infrastructure and mining operations associated with the existing Stockton Mine and provide access to additional coal mining areas across the Buller Plateaux, as the coal resource in the current Stockton Mine is close to depletion, and further coal resources for blending are required. There are five key Project sub-areas:

- Stockton mining area (Stockton)
- Mount Frederick South (MFS)
- Escarpment Extended (ESE)
- Upper Waimangaroa Haul Road (UWHR)
- Cypress mining area (Cypress)

This report reviews the performance of the BV-MSR (at the existing Escarpment Mine), with comparison to the Whirlwind MSR (at Stockton Mine) and the Tara MSR (at Canterbury Mine), to assess the technology for treatment of AMD impacted waters during the closure phase of the BPCP (once active treatment ceases).

1.3 MSR Background

Research into passive AMD treatment has spanned several decades with many types of systems being developed to treat various potential constituents of concern (PCOC) (e.g., Gusek, 2009). Since 2007, studies have explored the efficacy of waste mussel shells for treating AMD-impacted waters, offering promising alternatives to conventional media and methods (further details are provided in MWM, 2026a). The primary objectives of a MSR are to neutralise acidity by carbonate dissolution, partially remove metals by adsorption, and facilitate bacterial sulfate reduction by sulfate reducing bacteria (SRB) within chemically reducing environments (which also generates alkalinity). SRB provides (DiLoreto et al., 2016):

- Subsequent reactions that generate alkalinity.
- Creation of conditions conducive to the cycling of sulfur ($\text{SO}_4 \leftrightarrow \text{H}_2\text{S}$) coupled with the complexation of reduced metals like Fe, Zn, Mn, and As.
- Reduced sulfur species that can then be converted to elemental sulfur (S^0) given the right redox conditions increasing the potential removal rates of sulfate.

One issue for passive treatment systems is longevity and surety that upfront capex costs will be a favourable use of resources for the treatment of AMD impacted water in the long term. The short-term performance of passive treatment systems is often well quantified; however, their long-term effectiveness is still poorly understood (as many technologies are juvenile and have not operated for multi-decades). Carbon exhaustion and hydraulic malfunctions are often amongst the most frequent reasons for system failure.

1.4 BV-MSR Overview

The BV-MSR at the existing Escarpment Mine was constructed in 2016 and has been used for the passive treatment of AMD impacted waters from the BV-ELF. The BV-ELF has an engineered underdrain that captures net percolation (NP) into the facility (as well other minor sources of seepage) with toe seepage reporting to the BV-ELF toe pond. The majority of the underdrain flow (excluding higher flows during rainfall events) is diverted to the BV-MSR for treatment. Flow measurements indicate that average underdrain outflow is approximately 3.35 L/sec. Effluent from the BV-MSR is discharged to the Pit 3 pit lake, which has a storage capacity of approximately 200,000 m³ and now represents a filled (and overtopping) pit lake that discharges to the nearby water course (V8 Creek) via a further two ponds. A location map of these facilities is provided in Figure 1.

In 2023, it was agreed by BRL that maintenance work on the BV-MSR was required, which involved sampling, geochemical assessment, and removal of the accumulated MSR AMD sludge (desludging). The requirement to carry out maintenance was identified by a decrease in alkalinity concentrations in the Pit 3 Pit Lake, which suggested a decrease in flow through the MSR. It was assumed that this lower flow rate through the MSR was related to the formation of a thick sludge layer on the shell surface that had reduced the permeability of the MSR. Investigations were undertaken in February 2024 and included excavating three test pits into the MSR before the sludge layer was removed. Further details on the MSR desludging process and outcomes are provided in Section 6.

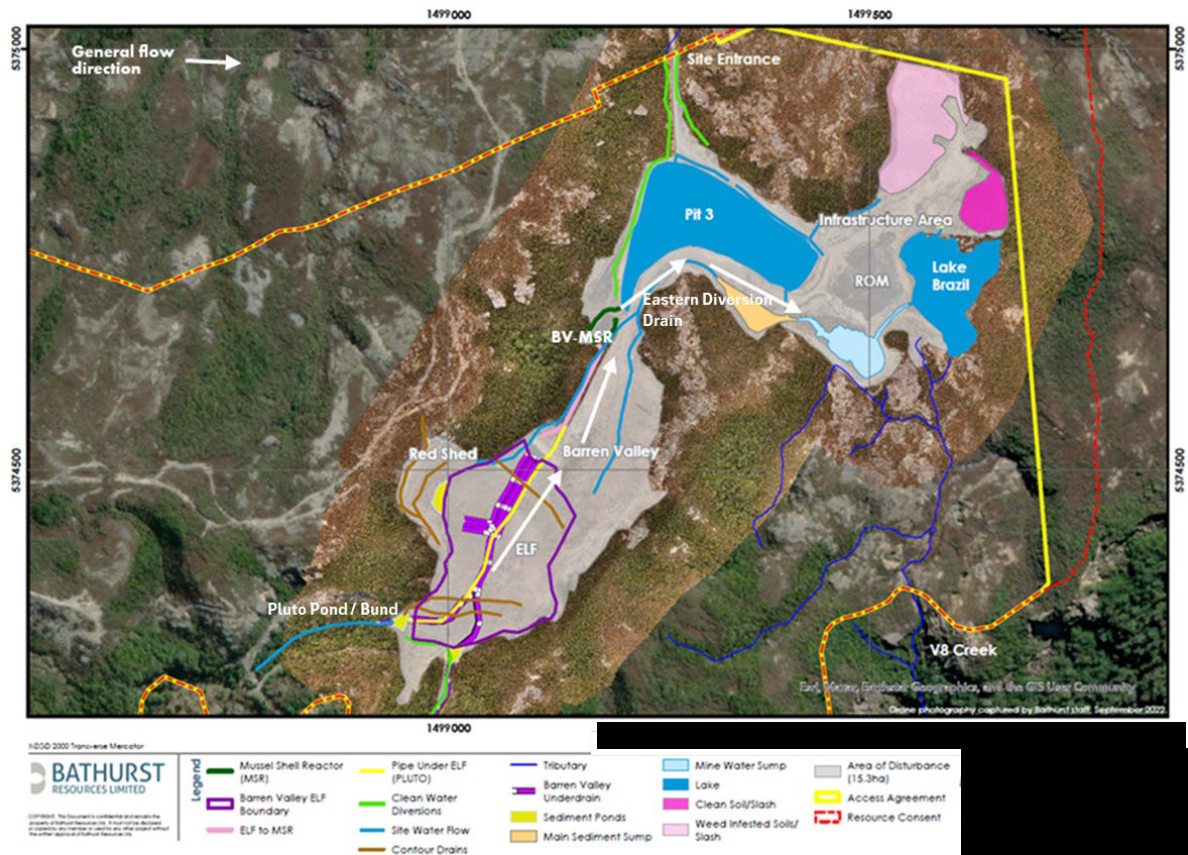


Figure 1: Location of the BV-ELF and BV-MSR at the Escarpment Mine.

2 METHODOLOGY

2.1 Water Treatment Efficiencies

Water quality data were assessed for each MSR. To determine the overall removal efficiencies only data collected on the same day for both influent and effluent samples were used rather than the entire influent/effluent dataset. Influent data and effluent data were then averaged over the sampling period total average difference was used to calculate the removal efficiency:

$$\text{Equation 1: } \frac{(\text{Influent} - \text{Effluent})}{\text{Influent}} \times 100$$

The water quality consent conditions (RC10193) for the existing Escarpment Mine were used as a reference value for determining the general treatment effectiveness of each MSR (Table 1). These water quality consent conditions were developed in 2013 for downstream monitoring site W-M2. They are a useful guide for understanding the treatment efficiencies of the MSR.

Table 1: Median consent limits at monitoring site W-M2 (Escarpment Mine).

PARAMETER	WATER QUALITY REFERENCE VALUES	
pH (pH units)	4.5 - 6.5	
Median Concentrations		
Total suspended solids (mg/L)	15	
Turbidity (NTU)	15	
Iron + manganese (mg/L)	1.1	
Aluminium (mg/L)	0.5	
Median pH	pH > 5.5	pH < 5.5
Cadmium (mg/L)	0.0003	0.0012
Chromium (mg/L)	0.05	0.2
Cobalt (mg/L)	0.044	0.18
Copper (mg/L)	0.002	0.0013
Lead (mg/L)	0.0065	0.026
Nickel (mg/L)	0.017	0.068
Zinc (mg/L)	0.012	0.054

Limits for nickel and zinc are based on a median water hardness of 50 mg CaCO₃/L.

3 **BV-MSR BACKGROUND**

The following section provides the background information relating to the BV-MSR, the treatment efficiencies reported, and the downstream effects in the Pit 3 pit lake that receives the MSR effluent.

3.1 **BV-MSR Water Quality**

Water quality data for the BV-MSR (over an ~8-year period) are provided in Table 2 including average influent and effluent data. Other data are graphed including Fe and Al removal efficiencies (Figure 2), Zn and Ni removal efficiencies (Figure 3), and Zn and Ni effluent concentrations (Figure 4). Full tabulated data for the BV-MSR are provided Appendix B which contains all data (not just data for matching time periods). Results indicated that:

- Influent pH values from the BV_ELF ranged from pH 2.80 to 3.70 with an average pH of 3.40.
- Effluent pH values from the BV-MSR ranged from pH 7.50 to 8.20 with an average pH of 7.87.
- Average influent acidity was 93.0 mg CaCO₃/L; average effluent acidity was 1.62 mg CaCO₃/L.
- Average influent alkalinity was 0 mg CaCO₃/L; average effluent alkalinity was 112.9 mg CaCO₃/L.
- Based on the estimated average influent flow rate of 3.35 L/s, an average influent acidity load of 26.9 kg CaCO₃/day or 9.83 t CaCO₃/yr was calculated.
- Hydraulic residence time (HRT) was calculated, based on the flow rate to be 0.85 days.
- Al and Fe concentrations decrease by close to two orders of magnitude with Al and Fe removal efficiencies being 99.7% over the nine-year monitoring period. Effluent concentrations for Al and Fe were lower than the water quality reference values presented in Table 1.
- No removal efficiency could be determined for Cr as all samples were either at, or below, the limit of reporting (LOR) (0.001 mg/L).
- Cd treatment efficiencies were low (1.89%); however, this is due to the low influent and effluent concentrations. Data are limited.
- Co concentrations decreased from 0.03 mg/L to 0.005 mg/L (82.8%). Data are limited.
- Influent Cu concentrations (average concentration 0.016 mg/L) exceeded the water quality reference value (0.0013 mg/L). Effluent concentrations were reduced to 0.0005 mg/L resulting in a removal efficiency of 96.6%. Data are limited.
- Ni and Zn removal efficiencies were 40.2% and 56.2% respectively and were higher than the water quality reference values presented in Table 1.
- The average treatment efficiency of Zn is also presented for the first ~6 years of operation of the MSR (December 2016 - November 2022), which was 63.7%.
- The average treatment efficiency for Zn after 6 years decreased to 20.1%. This decrease occurred before desludging and may be due to acid remobilisation of Zn from the Al(OH)₃ layer as the acid neutralisation capacity of the upper shell layers is exhausted and acid waters enter deeper into the MSR before being neutralised redissolving Zn.

Table 2: BV-MSR water quality summary (December 2016 – March 2025).

PARAMETER	AVERAGE INFLUENT	AVERAGE EFFLUENT	REMOVAL EFFICIENCIES (%) ¹
pH (pH units)	3.40	7.87	-
Acidity (mg CaCO ₃ /L)	93.0	1.62	-
Alkalinity (mg CaCO ₃ /L)	-	112.9	-
Hardness (mg CaCO ₃ /L)	89.2	276.0	-
Al (n=70)	10.6	0.028	99.7
Cd (n=9)	0.00059	0.00058	1.89
Co (n=8)	0.031	0.005	82.8
Cr ² (n=5)	0.001	0.001	-
Cu (n=6)	0.016	0.0005	96.6
Fe (n=74)	5.77	0.014	99.7
Mn ³ (n=66)	0.382	0.206	58.6
Pb (n=6)	0.0035	0.0005	85.8
SO ₄ (n=59)	170.0	152.3	10.4
Ni (n=61)	0.123	0.073	40.2
Zn (n=63)	0.718	0.314	56.2 (63.7) ⁴
Flow rate (L/s)		3.35	
Calculated HRT (days)		0.85	

Influent and effluent concentrations are presented in mg/L unless otherwise specified.

Average pH presented is based on H⁺ content

A hyphen (-) indicates no value is provided.

Red text indicates values exceeding the Escarpment Mine resource consent values (Table 1) – no hardness modification considered.

1. - Removal efficiencies were derived when both influent and effluent data were available (i.e., on the same day). The removal efficiencies were then averaged (based on the total average influent and total average effluent concentrations).
2. - No removal efficiency could be determined for Cr as all samples were either at, or below, the LOR (0.001 mg/L).
3. - Reported Mn concentrations were at times higher in the effluent than influent, likely due to remobilisation within the systems and sampling timing under longer residence times (0.85 days).
4. – The Zn removal efficiencies presented in brackets is for the first 6 years of operations (December 2016- November 2022).

3.2 BV-MSR Treatment Efficiencies

Data presented in Figure 2 indicates a slight decrease in Al treatment (< 0.5%) after desludging of the MSR. Although noticeable in the graphed data, the effect is minor, but continued monitoring will assess ongoing performance.

Figure 3 suggests that removal rates of Ni and Zn are generally higher immediately after construction of the MSR, lasting for approximately two years. Data between ~2019 – 2023 suggests performance was relatively stable.

Figure 4 presents the effluent concentrations of Ni and Zn from the BV-MSR over time. A 7-point rolling average has been applied to show the long-term trends and remove visual bias of outlier data. Results shows that Ni effluent concentrations are decreasing slightly with time. This may represent the general trend of decreasing Ni concentration in MSR influent (MWM, 2026d).

In contrast, MSR effluent Zn concentrations and the 7-point rolling average have increased indicating that the treatment of Zn has decreased with time (Table 2).

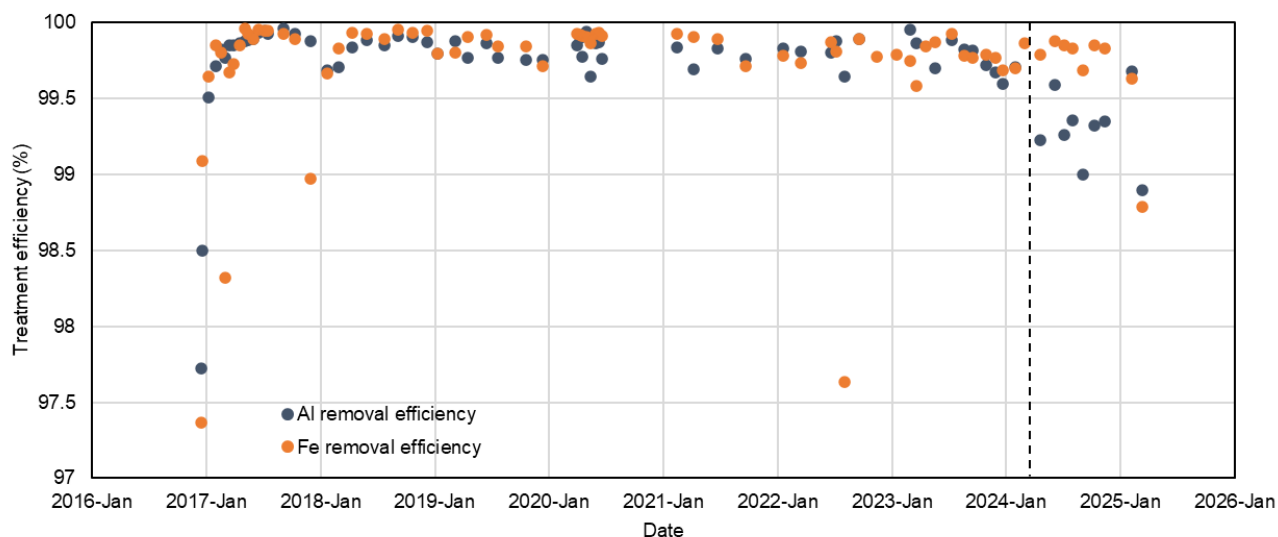


Figure 2: BV-MSR Al and Fe removal efficiencies.

Source: BRL 51279_RPT_Water (water quality excel database).

The dashed black line represents the date that the BV-MSR was desludged (15 February 2024).

Note data are based on daily influent and effluent concentrations where available using Equation 1 to derive the efficiency.

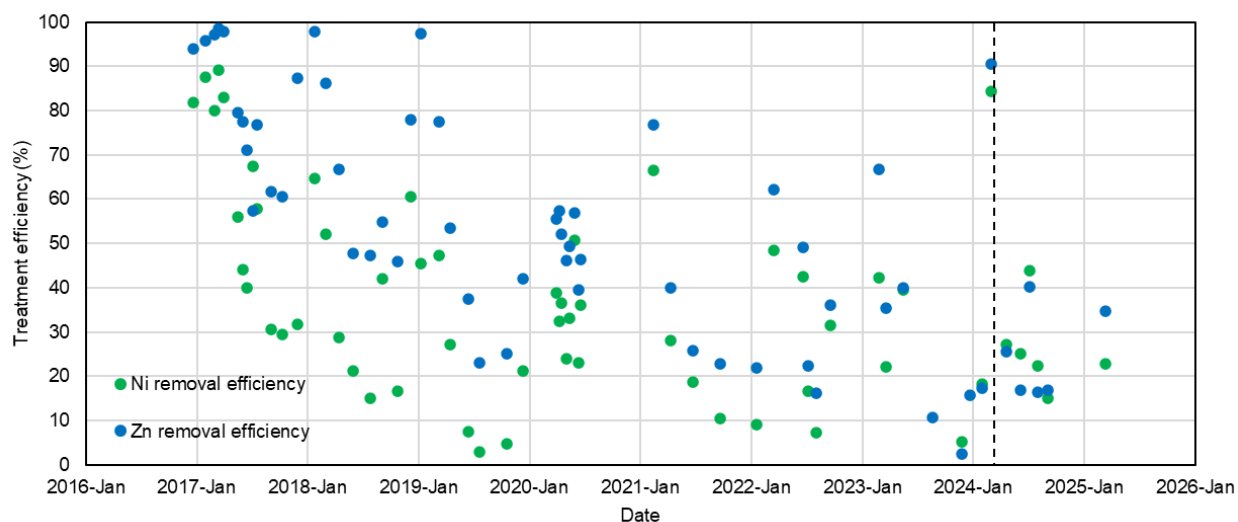


Figure 3: BV-MSR Ni and Zn removal efficiencies.

Source: BRL 51279_RPT_Water (water quality excel database).

The dashed black line represents the date that the BV-MSR was desludged (15 February 2024).

Note data are based on daily influent and effluent concentrations where available using Equation 1 to derive the efficiency.

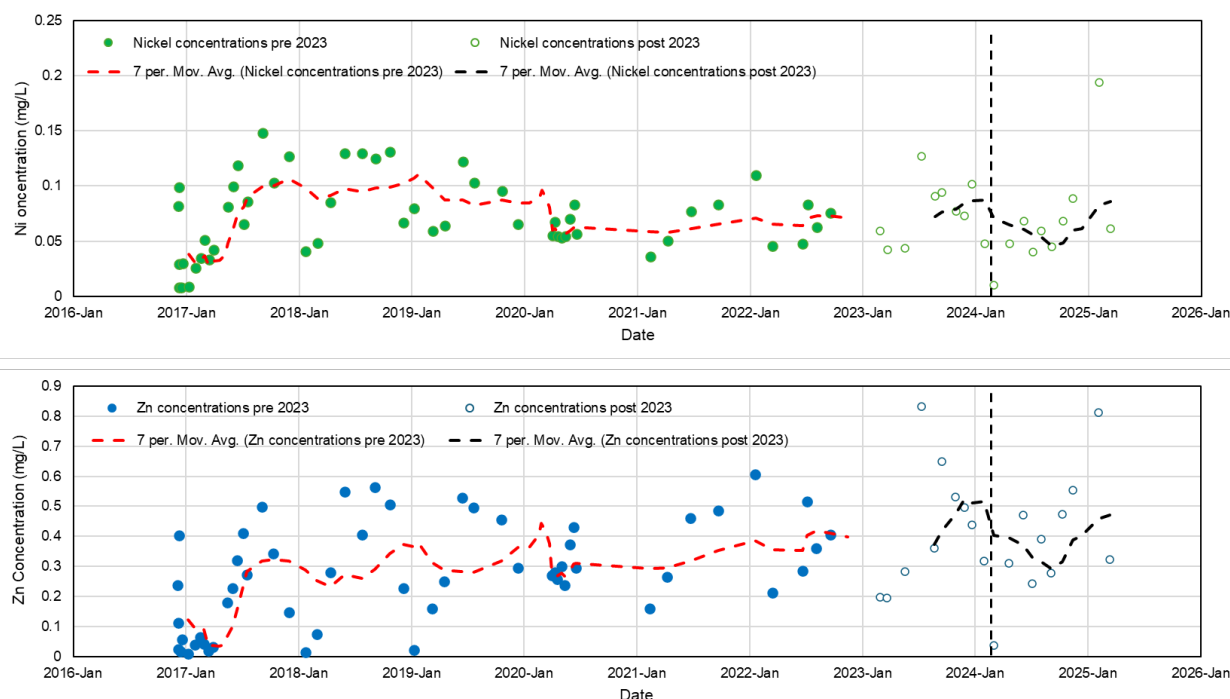


Figure 4: Ni and Zn concentrations for the BV-MSR effluent.

The dashed black line represents the date that the BV-MSR was desludged (15 February 2024).

3.3 BV-MSR Effluent Alkalinity and Pit 3

The BV-MSR effluent discharge to Pit 3 has had a positive effect on Pit 3 water quality (Figure 5). Since the construction of the BV-MSR, approximately, on average, 112.9 mg CaCO₃/L of alkalinity has been introduced into the Pit 3 from BV-MSR effluent flows. The BV-MSR effluent provides an alkalinity load of 11.9 t/yr based on a constant flow rate of 3.35 L/s into Pit 3.

Results show that pH in Pit 3 remained low from February 2016 to November 2016 due to AMD effects from pit walls and recently blasted materials. From December 2016 onwards an increase in pH can be observed from 4.0 to 7.9 due to the introduction of alkalinity from the MSR. Alkalinity concentrations have decreased in Pit 3 after a high of 40 mg CaCO₃/L in February 2021. The only source of alkalinity in the catchment is the BV-MSR effluent. Hence, the observed decline in alkalinity could be attributed to a reduced alkalinity load from the BV-MSR. This could be due to a lower permeability in the BV-MSR caused by sludge buildup, leading to untreated AMD spilling into the main sediment sump (i.e., bypassing Pit 3; Figure 1), reduced flows of treated alkalinity-rich water discharging to Pit 3, and hence a reduced alkalinity load to Pit 3.

Following desludging in early 2024, alkalinity concentrations in Pit 3 remained similar rather than rebounding. Alkalinity concentrations in the MSR effluent have remained stable suggesting the biochemical reactions have not changed, although flows (and load) may have. Further work is needed to understand this slight decrease. Generally, the MSR has continued to perform well, with no maintenance required. Desludging was undertaken at 7 years.

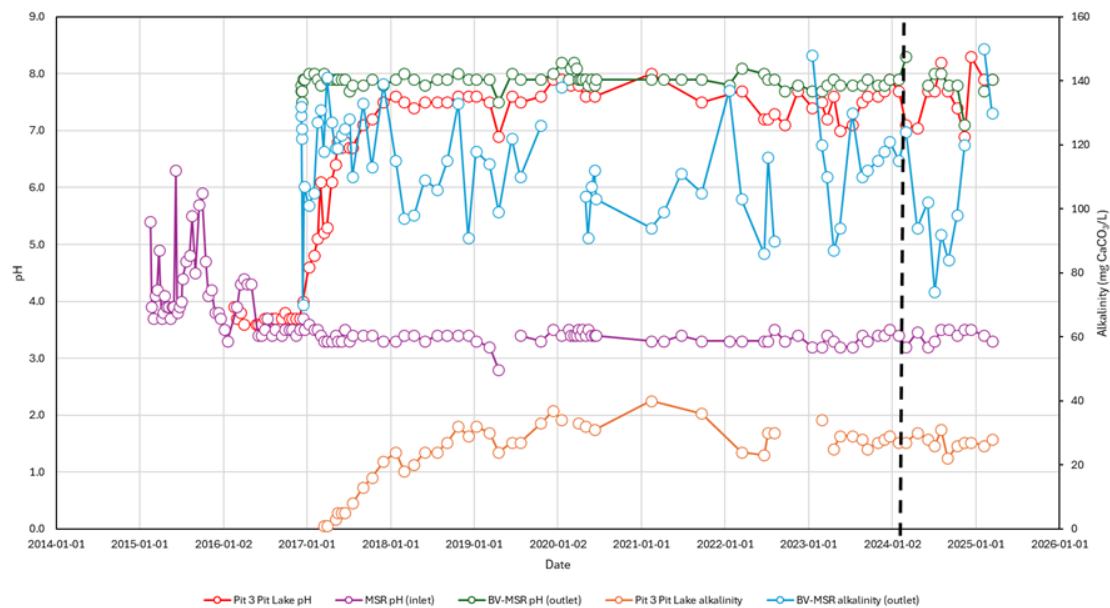


Figure 5: pH and alkalinity values from the MSR to Pit 3.

Source: BRL 51279_RPT_Water (water quality excel database).

The dashed black line represents the date that the BV-MSR was desludged (15 February 2024).

3.4 Summary

Since the construction of the BV-MSR, water quality has improved markedly within the Pit 3 pit lake. Key observations include:

- An increase in Pit 3 pH from acidic conditions to circum-neutral conditions.
- Despite the BV-MSR having removal efficiencies for Al and Fe of 99.7%, sub-optimal Ni and Zn removal efficiencies (40.2% and 56.2% respectively) were identified. This was higher for the first 6 years (63.7%) decreasing to 20.1%.
- The BV-MSR effluent, assuming a constant flow rate of 3.35 L/s and flow weighted mean alkalinity concentration of 112.9 mg CaCO₃/L, contributes 11.9 t/yr of alkalinity load.
- Desludging of the MSR has not markedly changed the alkalinity of Pit 3, suggesting that the alkalinity load from the MSR has remained similar. Overall, the alkalinity in Pit 3 has been reasonably constant, although it was higher in 2020-2022.
- Data suggest that Zn removal has decreased with time (after 6 years of MSR operation). More frequent removal of the Fe and Al sludge layers (desludging) and replacement of these shells with fresh shells every ~5 years would be beneficial as part of the MSR maintenance programme. Performance monitoring of MSR effluent for metals would help confirm when shells need replacing.
- For MSRs associated with the BPCP, systems should be designed without by-pass to ensure all ELF seepage water is treated. If reduced permeability leads to overflow and increasing downstream impacts, maintenance should be initiated in line with adaptive management processes.

4 MUSSEL SHELL REACTOR PERFORMANCE ASSESSMENT

The following section reviews the physical characteristics and the treatment efficiencies of three active MSR: Tara MSR, Whirlwind MSR, and the BV-MSR (previously discussed):

- The Whirlwind MSR has been in operation since September 2012 and treats AMD that flows into the AMD impacted Whirlwind Stream located towards the southern end of the Stockton Mine. The Whirlwind MSR had a design flow rate of 1 L/sec (Weber et al., 2015). The observed flow rates being treated were up to 6 L/s although this was only shortly after construction, when sludge accumulation was minimal. Flow data from 2013 – 2016 for the Whirlwind MSR suggests average flow was ~2.8 L/s.
- The Tara MSR (at the Canterbury Coal Mine, New Zealand) has been in operation since May 2021 and was designed to treat AMD impacted drainage sourced from the Green ELF underdrain after closure of the mine in 2021 (Sinclair and Weber, 2022). Average flow rates for the Tara MSR were 0.06 L/s.

4.1 Review: Physical Characteristics

The Tara MSR used weathered shells and fresh shells (direct from the seafood processing factory) for its reactive treatment media, whereas the Whirlwind MSR and BV-MSR used weathered shells that had been stockpiled for 10+ years prior to placement in the reactor. It was assumed both fresh and weathered materials had sufficient carbon to facilitate SRB activity.

Data (Table 3) indicates that despite its smaller average plan area of 94 m², the Tara MSR has the longest residence time at 5.57 days due to low flow rates. Conversely, the Whirlwind MSR exhibits the shortest residence time at 0.79 days, while the BV-MSR falls intermediary with a residence time of 1.14 days. The total pore volume of the mussel shells within each MSR varies with the Whirlwind MSR at 190 m³, the Tara MSR at 74 m³, and the BV-MSR at 275 m³. Table 3 presents a summary of key MSR design characteristics for each system.

Table 3: MSR design comparisons.

PARAMETER	WHIRLWIND MSR	TARA MSR	BV-MSR
Average plan dimensions (m) (shell layer)	14.0 x 21.5	5 x 24	10 x 35
Average plan area (m ²) (shell layer)	302	94	350
Average shell depth (m)	1.2	1.5	1.5
Ponding depth on top of MSR (m)	0.2 – 0.6	1.0	0.2 – 0.4
Freeboard (m)	0.8 – 0.4	0.5	0.2
Volume of shells (m ³)	366.0	55.0	470.0
Average Flow rate (L/s)	2.80	0.06	3.35
Assumed porosity	0.52	0.52	0.52
Volume of shells (m ³ /m ²)	1.23	1.29	0.99
Shells pore volume (m ³ /m ²)	0.63	0.79	0.79
Total shells pore volume (m ³)	190.1	74.0	275.4
Calculated HRT (days)	0.79	5.57	0.85

4.2 Review: Water Treatment Efficiencies

Table 4 provides the average influent and effluent concentrations for PCOC and their respective removal efficiencies.

Removal efficiencies were derived when both influent and effluent data were available (i.e., on the same day). The removal efficiencies were then averaged (based on the total average influent and total average effluent concentrations). Figure 6 and Figure 7 present comparisons for average Ni and Zn influent and effluent concentrations between each of the MSR. Although other parameters were presented for the BV-MSR, for the purposes of this report, only Fe, Al, Ni, and Zn are examined in further detail.

4.2.1 Whirlwind MSR

Data assessed were from April 2013 – December 2016. Over this three-year monitoring period, the Whirlwind MSR had an approximate mean flow rate of 2.8 L/s, and a HRT of 0.79 days. There is an increase in average pH values from 3.47 (influent) to 7.85 (effluent), reflecting neutralisation of the influent acidity load. Al and Fe removal capacities are between 99.8% and 98.2% over this three-year period and effluent Al and Fe concentrations were lower than the water quality reference values (Table 1).

In comparison to the other MSRs, the Whirlwind MSR exhibited moderate removal efficiencies for Ni and Zn (71.0% and 83.4% respectively). Sulfate concentrations decreased slightly (12.2% removal efficiency).

4.2.2 Tara MSR

The Tara MSR was assessed over a two-year monitoring period (January 2022 – January 2024). Operating at a mean flow rate of 0.06 L/s, it has a HRT of 5.57 days. The average pH values range from pH 6.55 (influent) to 7.21 (effluent). Despite relatively lower removal efficiency for Al, likely due to initially low influent concentrations, there is a noticeable decrease in effluent average metal concentrations, with removal efficiencies for Al and Fe ranging between 91.4% and 96.3%. Importantly, influent concentrations of Fe are reduced via the MSR to levels below water quality reference values (Table 1).

Average effluent Ni and Zn removal efficiencies in the Tara MSR were the highest measured for the MSRs, averaging at 99.5% and 94.5% respectively. When compared to the water quality reference values (Table 1), both the effluent concentrations for Ni and Zn were below the reference values. Sulfate concentrations decreased from a mean of 629.2 mg/L to a mean of 486.6 mg/L (mean removal efficiency 22.7%).

4.2.3 BV-MSR

With an estimated mean influent flow rate of 3.35 L/s, the BV-MSR has a HRT of 0.85 days. Over the eight years of monitoring, a significant decrease in average metal concentrations is observed, with removal capacities for Al and Fe ranging between 99.7% and 99.7%. This leads to influent concentrations of Al and Fe being reduced to concentrations below the water quality reference values.

The BV-MSR had the lowest removal efficiencies for Ni and Zn, measured at 40.2% and 56.2% respectively. When compared to the water quality reference values, both the effluent concentrations for Ni and Zn exceeded the respective values. Sulfate concentrations decrease from 170.0 mg/L to 152.3 mg/L (10.4% removal efficiency).

Table 4: Average influent and effluent concentrations for each MSR.

PARAMETER	WHIRLWIND MSR (APRIL 2013 – DECEMBER 2016)			TARA MSR (JANUARY 2022 – JANUARY 2024)			BV-MSR (OCTOBER 2016 – MARCH 2025)		
	AVERAGE INFLUENT	AVERAGE EFFLUENT	REMOVAL EFFICIENCIES (%) ¹	AVERAGE INFLUENT	AVERAGE EFFLUENT	REMOVAL EFFICIENCIES (%) ¹	AVERAGE INFLUENT	AVERAGE EFFLUENT	REMOVAL EFFICIENCIES (%) ¹
pH (pH units)	3.47	7.85		6.55	7.21	-	3.36	7.90	-
Laboratory acidity (mg CaCO ₃ /L)	64.15	0.26		185.5	1.55	-	93.0	1.62	-
Hardness (mg CaCO ₃ /L)	68.5	273.2		592.7	753.2	-	10.7	0.027	-
Al	14.3	0.03	99.8	0.029	0.003	91.4	10.6	0.028	99.7
Fe	1.60	0.03	98.2	18.5	0.69	96.3	5.77	0.014	99.7
SO ₄	185.5	162.9	12.2	629.2	486.6	22.7	170.0	152.3	10.4
Ni	0.074	0.021	71.0	0.03	0.002	94.5	0.123	0.073	40.2
Zn	0.253	0.042	83.4	1.28	0.007	99.5	0.718	0.314	56.2
Flow rate (L/s)		2.80			0.06			3.35	
Calculated HRT (days)		0.79			5.57			0.85	

Influent and effluent concentrations are presented in mg/L unless otherwise specified.

Average pH presented is based on H⁺ content.

A hyphen (-) indicates no value is given.

1- Removal efficiencies shown for each parameter were derived from influent and effluent samples taken concurrently. The removal efficiencies were then averaged (as shown).

Red text indicates values exceeding the Escarpment Mine consent values (Table 1) which have been used in this assessment as reference values for comparative purposes only.

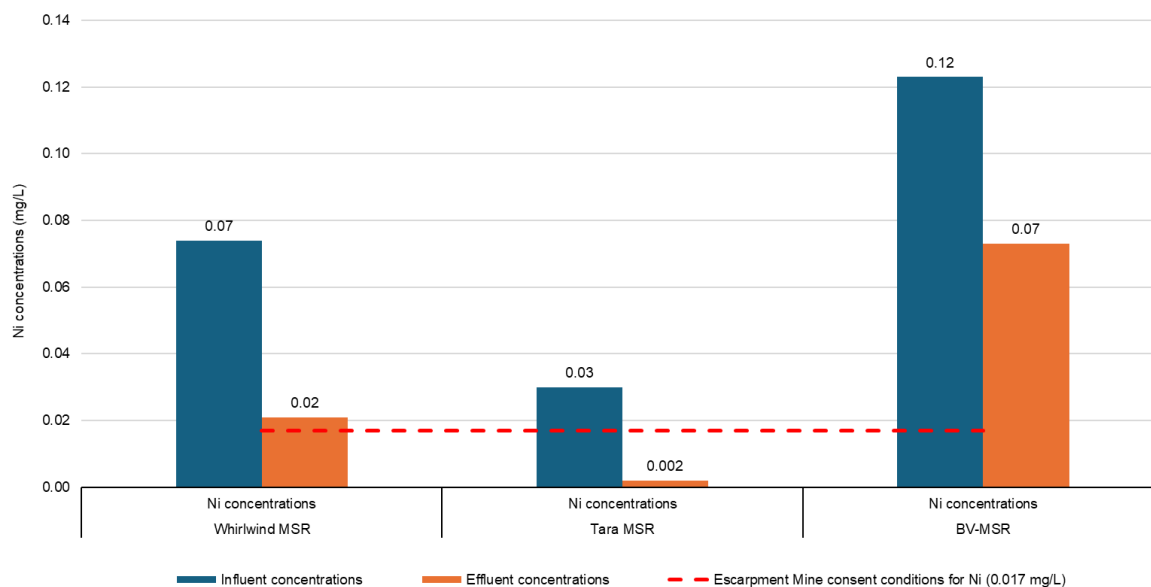


Figure 6: Average Ni influent and effluent concentrations for each MSR.

The consent limit does not consider hardness modifications for Ni.

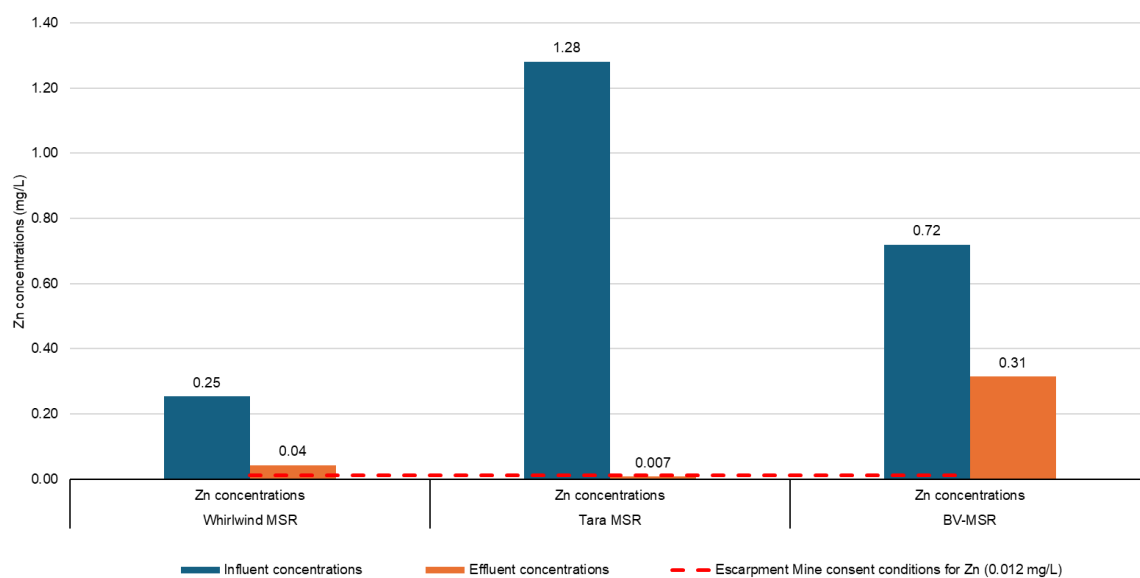


Figure 7: Average Zn influent and effluent concentrations for each MSR.

The consent limit does not consider hardness modifications for Zn.

5 FACTORS INFLUENCING Ni AND Zn REMOVAL EFFICIENCIES

The following section examines three factors that could influence Ni and Zn removal efficiencies within the MSR. This includes:

- HRT
- Adsorption
- Biogeochemical processes

5.1 HRT

Data for Ni and Zn removal rates versus HRT are provided in Figure 8 for the MSR that have been studied. HRT for Whirlwind and BV ELF MSRs are < 1 day. HRT for Tara MSR is ~ 5 days.

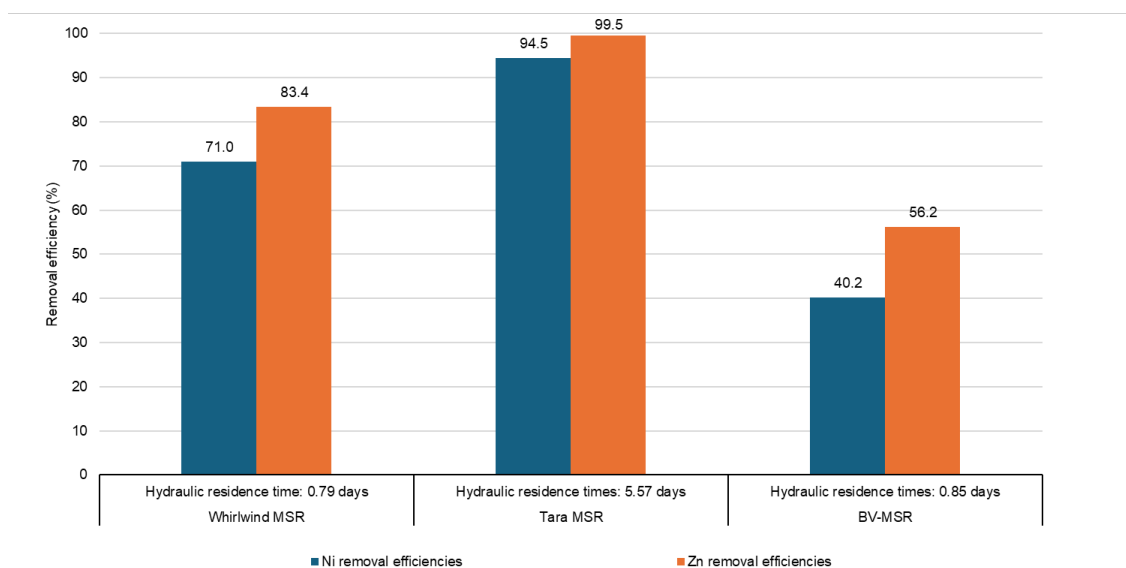


Figure 8: Ni and Zn removal efficiencies for each MSR.

Other MSR data were reviewed (Trumm et al., 2024), which suggests that HRT for an up-flow MSR (median of 10 days HRT) can still be elevated in Zn (Figure 9), although above 12 days there appears to be an overall improvement (but this may be due to a smaller dataset). Construction of MSR to have 12 days HRT is unlikely to be feasible due to spatial requirements and capital costs for the BPCP. A residence time of 24 hours was selected for the BPCP, which has been shown to be adequate, but an additional treatment step is required (i.e., a polishing pond).

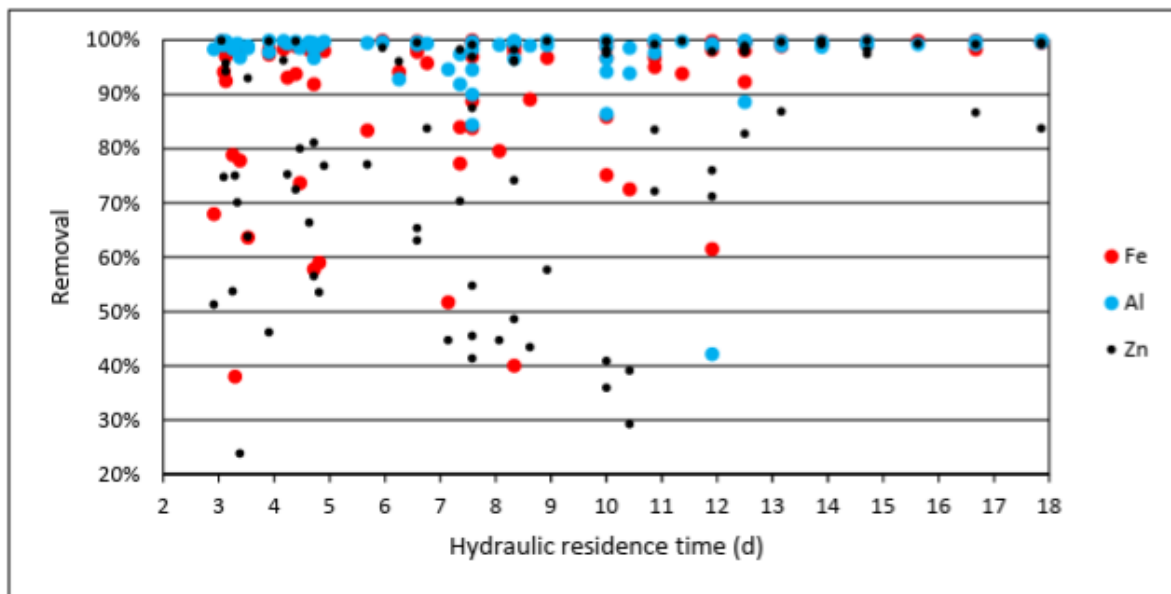


Figure 9: Echo Mine up-flow MSR treatment efficiencies

Source: Trumm et al. (2024)

5.2 Geochemical Conditions and pH Dependency

This section reviews the hydrolysis of Fe and Al and the effects of pH on Ni and Zn removal efficiencies through a MSR.

5.2.1 Review

The data provided in this report suggests one difference between a MSR performing well for Ni and Zn removal where removal efficiencies >90% and one that performs to a lesser degree (e.g., BV-ELF, Whirlwind, Echo) is that the Tara MSR influent was circum-neutral pH. pH is a master geochemical variable that controls the hydrolysis of Fe and Al.

Studies indicate that Ni and Zn removal in the Whirlwind MSR is strongly correlated within the Al layers, due to complexation with newly formed metal hydroxides (DiLoreto, 2013). Al hydroxides typically form at pH 4.5–5.5, creating potential sorption sites for metals.

Fe hydroxides begin forming at around pH values >3.5 (oxic conditions). However, as shown in Figure 10, pH 3.5 may be too low for effective adsorption of metals such as Ni and Zn, which typically require higher pH values. This was confirmed by available Whirlwind MSR data (Diloreto, 2013).

Other studies (MWM, 2026b) where AMD sludge from the BV-MSR was mixed with Pit 3 pit water to determine whether metals would be mobilised showed a reduction in Zn and Ni by approximately an order of magnitude, most likely due to adsorption to Al/Fe hydroxides. This was at circum-neutral pH values and supports the hypothesis of adsorption.

These data suggest that higher pH conditions maximise metal adsorption efficiency onto Fe and Al hydroxides, particularly for Ni and Zn:

- Tara MSR influent is elevated in Fe due to sub-oxic seepage from the Green ELF and is circum-neutral pH (Table 4) with Ni and Zn removal rates of 94.5% and 99.5% respectively. Conceptually:

- Low oxygen circum-neutral seepage elevated in Fe(II) mostly oxidises in the MSR Pond at circum-neutral pH with coincidental adsorption of Ni and Zn.
- No adsorption to Al hydroxides occurs as significant Al is not present within circum-neutral pH influent waters.
- Not all Fe is oxidised. Tara MSR effluent has a higher Fe concentrations compared to the other MSR (by ~one order of magnitude (Table 4)). This is likely due to sub-oxic seepage where Fe(II) is elevated.
- The BV-MSR had the lowest removal efficiencies for Ni and Zn, measured at 40.2% and 56.2% respectively but similar pH conditions (acidic) compared to Whirlwind MSR, yet Whirlwind MSR had Ni and Zn removal efficiencies of 71.0% and 83.4% respectively. Conceptually:
 - $\text{Fe}(\text{OH})_3$ is of limited value due to low pH so would not be a driver for the difference (and is higher in BV-MSR).
 - The difference is most likely related to lower concentrations of Al and lesser adsorption capacity. As shown in Table 4 the lower influent Al:Zn ratio (mg/L) into the BV-MSR (~14:1) compared to in the Whirlwind influent (~57:1) may also be contributing to the difference (lesser ability for adsorption).

Figure 10 demonstrates how metal adsorption is strongly pH-dependent whereby Zn and Ni adsorption increases above pH 5. Hence, why the Tara MSR (influent pH of 6.5) may be performing better in regards to Ni and Zn removal efficiencies with Fe hydrolysis at circum-neutral pH.

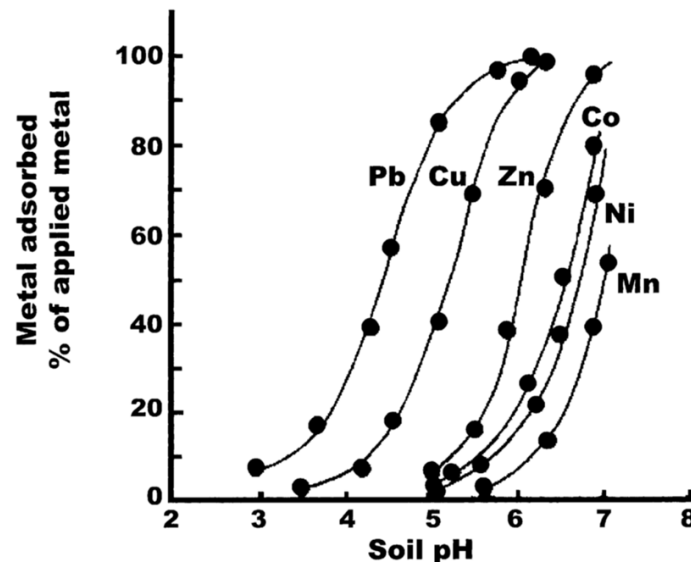


Figure 10: Metal adsorption profiles based on pH.

Source: Basta et al. (2005).

In summary, the following geochemical processes could be influencing adsorption of trace metals such as Ni and Zn within MSR and the associated treatment efficiency:

- Precipitation of $\text{Fe}(\text{OH})_3$ under oxic circum-neutral conditions to form the upper Fe-sludge layer at suitable concentrations.
- Precipitate of higher quantities of $\text{Al}(\text{OH})_3$ under oxic/sub-oxic conditions.

5.2.2 Adsorption Experiments

To further investigate contaminant removal mechanisms, BRL engaged Process Flow to conduct a series of experiments to evaluate the role of adsorption of Ni and Zn at circum-neutral pH with the addition of ferric chloride (FeCl_3) to provide Fe(III) and Alum¹. The study had the following objectives:

- Determine Ni and Zn adsorption onto Fe- and Al- hydroxides at different pH levels using MSR effluent, providing insights into field adsorption mechanisms.
- Assess metal removal efficiency via adsorption at circumneutral pH.

A number of tests were undertaken with addition of Fe and Al up to 10 mg/L equivalence, which also resulted in a decrease in pH from a starting pH of 7.75 due to the hydrolysis of Al and Fe (Table 5).

Table 5: Ni and Zn concentrations after ferric chloride and alum dosage (February 2025 results).

FERRIC CHLORIDE AND ALUM DOSAGE mg/L	Fe DOSE			Al DOSE		
	pH (pH units)	Ni (mg/L)	Zn (mg/L)	pH (pH units)	Ni (mg/L)	Zn (mg/L)
Starting concentration	7.75	0.072 ¹	0.55	7.75	0.072 ¹	0.55
1	7.53	0.065	0.21	7.76	0.072	0.33
2	7.43	0.062	0.186	7.71	0.072	0.27
3	7.33	0.061	0.197	7.65	0.07	0.23
4	7.29	0.062	0.187	7.62	0.071	0.22
5	7.01	0.063	0.23	7.23	0.071	0.24
10	6.91	0.07	0.33	7.13	0.073	0.25
Average (dosage 2 – 10 mg/L)	7.19	0.064	0.223	7.44	0.071	0.257
Treatment efficiency (%)	-	2.2%	59.4%	-	0.93%	53.3%

A hyphen (-) indicates that no data are available.

¹ No starting concentration for Ni was provided by Process Flow. Therefore the 0.0721 mg/L dose concentration was used as the starting concentration (as observed for the 1 mg/L Dose for Aluminium). Further work is required to assess Ni removal rates.

Results indicate that the addition of Al and Fe removed >50% of the Zn remaining in solution. This helps support the mechanism of adsorption of Zn onto Al- and Fe- hydroxides. Initial Ni concentration data at the commencement of the trial were not available. Ni has greater adsorption capacities at higher pH values (e.g., Figure 10) so this may not be a fair dataset to assess its removal efficiency. Further work is required.

For the BPCP the following process could be utilised to facilitate better Zn (and Ni) removal/treatment of ELF seepage:

- Establishment of a polishing pond after the MSR to either oxidise any remnant Fe(II) passing through the MSR (due to sub-oxic ELF seepage elevated in Fe) and/or enable FeCl_3 dosing and its subsequent hydrolysis/precipitation.

¹ $\text{XAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$, where X can be a monovalent cation like potassium (K), sodium (Na), or ammonium (NH_4)

- A polishing pond is already required to remove secondary contaminants such as HS⁻ and ammoniacal nitrogen (see MWM, 2026c) within the MSR effluent and the same facility could be utilised.

5.3 Biogeochemical Processes

Higher labile carbon (often identified by higher dissolved organic carbon (DOC)) can facilitate higher SRB activity and increased HS⁻ concentrations in the MSR. Such data are available for the three MSRs studied (MWM, 2026c) and the Tara MSR has higher DOC and HS⁻ compared to BV-MSR and Whirlwind MSR.

The SRB alkalinity was assessed to determine if sulfide generation rates were a factor for the difference in Ni and Zn removal rates between the three MSR. For instance, a higher SRB alkalinity would indicate a higher source of HS⁻ and potential metal removal.

The difference in sulfate concentrations (influent versus effluent) for the MSR data indicated that sulfate loss through the reactor ranged from 10.4 – 22.7% (Table 4). It was assumed that the loss in sulfate was due to SRB activity whereby H₂S was generated and 2 mole HCO₃⁻ was produced by this process. Based on the flow rate for each MSR, the SRB alkalinity generated was 2.11 t CaCO₃/yr for the Whirlwind MSR; 0.28 t CaCO₃/yr for the Tara MSR; and 2.21 t CaCO₃/yr for the BV-MSR. For the BV-MSR this is ~17% of the total alkalinity exported from the MSR to Pit 3.

When normalised to the mussel shell volume, SRB-generated alkalinity ranged from 4.71 to 5.76 kg CaCO₃ per m³ of shells per year across the three MSRs, indicating a consistent rate of alkalinity production. This also implies that sulfide generation rates are comparable, suggesting that sulfide production is not the primary factor influencing the observed differences in Ni and Zn removal efficiencies.

Further work is required to understand the bioavailable labile carbon availability in MSR, the mechanics of SRB alkalinity generation, quantification of metal removal by sulfides, and whether this can be optimised to improve the MSR treatment efficiency.

6 FIELD WORK

This section summarises the fieldwork that was undertaken during the desludging of the BV-MSR.

6.1 Summary

A site visit to the existing Escarpment Mine was undertaken by MWM on the 15 February 2024 while the MSR was being desludged to assess the BV-MSR. The following activities were completed:

1. Hydraulic testing to determine the infiltration rate and permeability of the MSR sludge that had accumulated.
2. Excavation of three test pits (Figure 11) to examine the depth profiles of the Fe-precipitate zone, the Al-precipitate zone, and the black precipitate zone. These geochemical zones were sampled from each of the three test pits and were submitted for laboratory analysis. The test pits were backfilled once the sampling had been completed.
3. The soft Fe-sludge zone was also measured by spade depth (3 transects) to determine the thickness of this layer above the harder shell layer. Average depth was 104 mm (based on 76 measurements with depth ranging from 60 – 155 mm).
4. The sludge layer was scraped out by an excavator and disposed of into a dry holding cell for subsequent water quality monitoring.



Figure 11: Escarpment Mine MSR samples.

Figure only shows approximate locations of test pits.

6.2 BV-MSR Sludge Hydraulic Properties

A key limitation for the longevity and treatment capacity of down-flow MSRs is their infiltration capacity. Formation of lower permeability sludge can reduce infiltration capacity over time.

Weather and soil conditions on the day of the field work were relatively wet. Periods of heavy showers and wind gusts occurred throughout the day, with an average air temperature of 17 °C. The MSR had been drained 2 days prior to field work, exposing the sludge layer atop the mussel shells ~110 mm thick. Green filamentous algae, present within the MSR pond settled onto the sludge surface (black organic material shown in Figure 12). This sludge layer formed over 7 years of MSR operation.

Infiltration capacity and sludge permeability at the BV-MSR were investigated with a dual ring infiltrometer (Figure 12), but only the inner ring was used for testing (i.e., a single ring infiltrometer test). The internal ring used has a height of 383 mm and a diameter of 298 mm. A single falling head test (FHT) was performed. The testing arrangement was as follows:

- The infiltrometer was driven in approximately 100 mm into the sludge layer.
- The test was initiated by filling the inner ring to a height of 345 mm above the sludge surface.
- The falling water level inside the ring was measured incrementally for 120 minutes.



Figure 12: Infiltrimeter on BV-MSR sludge layer.

6.2.1 Infiltration Rate

The falling head test data is presented in Figure 13. Using the data between 60 minutes and 12 minutes, an infiltration rate of 1.7×10^{-5} m/s is calculated. This value is consistent with the recorded MSR effluent outflow rate (3.35 L/s) normalised by the MSR area (312 m²): 1.1×10^{-5} m/s. Overall the results suggest the sludge layer can sustain flow in the region of 1 to 2 L/s per 100 m².

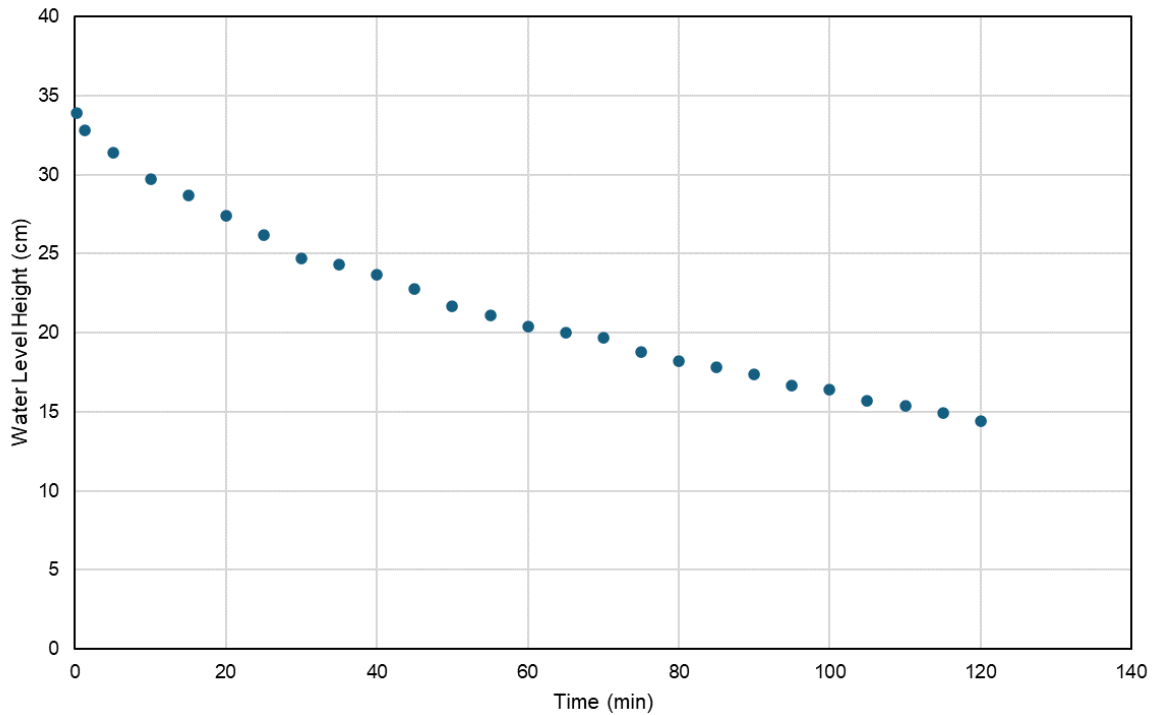


Figure 13: Change in water level over time.

6.2.2 Permeability Calculation

The approach described in Nimmo et al. (2009) was used to estimate sludge permeability (or field saturated hydraulic conductivity, K_{fs}) from the FHT data. The calculation was as follows:

$$K_{fs} = \ln \frac{L_G + \lambda + D_0}{L_G + \lambda + D}$$

$$L_G = C_1 d + C_2 b$$

Where:

- K_{fs} : Field-saturated hydraulic conductivity (m/s).
- λ : macroscopic capillary length² (mm); 250 mm was used given the fine texture of the sludge.
- L_G is the infiltration ring-installation scaling length (mm).
- D_0 is the starting ponding height (mm); 345 mm was used.
- C_1 empirically determined constant 0.993.
- C_2 empirically determined constant 0.578.
- d is the ring insertion depth (mm), 100 mm was used.
- D is the measured water level height (mm), recorded as part of the FHT.
- b is the infiltration ring radius (mm), 149 mm was used.

² Values typically range between 30 to 250 for unstructured soils (Reynolds, 2008 and Reynolds et al., 2015). Values are higher for finer textured material.

Figure 14 shows the period of the FHT where the water level fall rate became relative consistent, from about 60 minutes onwards. From this period, a K_{fs} value of 5.2×10^{-6} m/s was estimated.

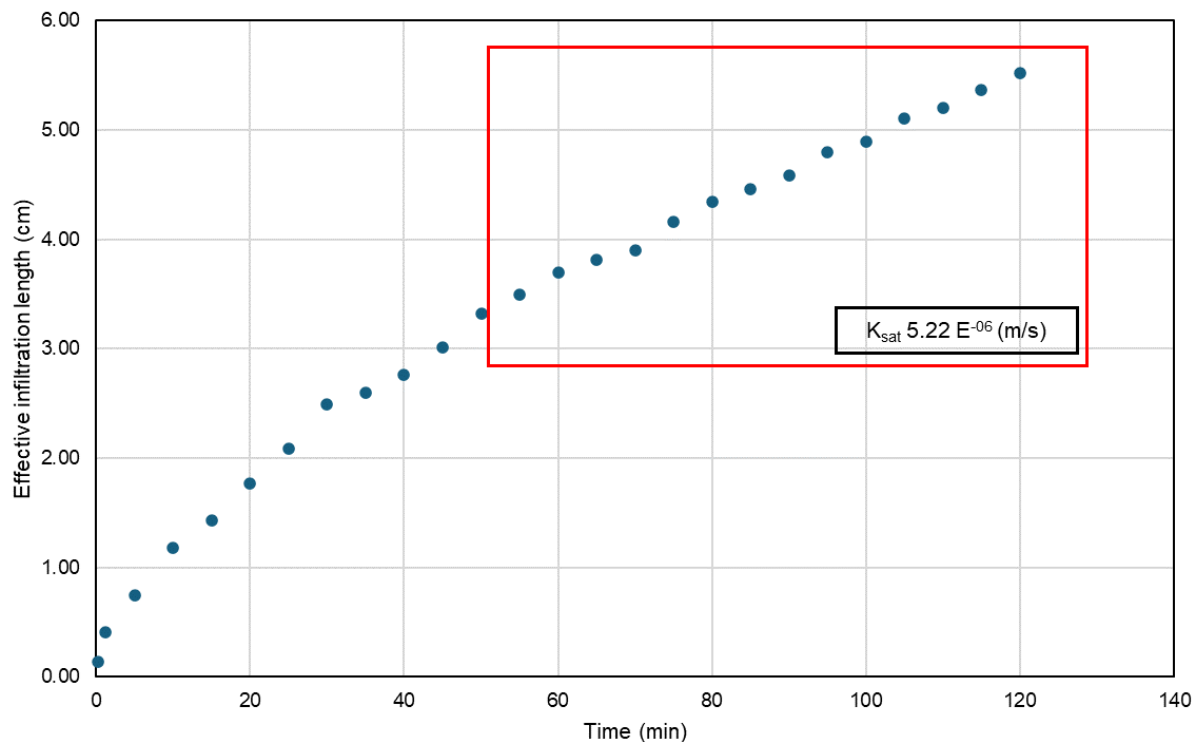


Figure 14: Permeability calculation.

6.3 BV-MSR Test Pit Samples and Analysis

Three test pits were hand excavated into the BV-MSR (approximately 200 mm x 400 mm). The reactive layers (Figure 15) in each test pit were sampled providing nine samples for laboratory testing. Depth and sample profiles for each reactive layer are shown in Table 6; these included:

- Fe-rich zone (orange zone).
- Al-rich zone (white zone) but often including an overlapping orange Fe layer.
- Sulfide-rich zone (black zone).

After the test pit samples were collected the BV-MSR was desludged. This involved the use of a Hitachi four-tonne excavator with a spade bucket (i.e., without teeth) removing the Fe and Al-precipitate zones. These precipitate zones were carefully removed and placed into an unlined holding cell.

All nine sludge samples from the test pits were sent to SGS Laboratories for the following analyses:

- Acid neutralising capacity (ANC), sulfate, pH, electrical conductivity, acidity (to pH 8.3), and synthetic precipitation leaching procedure (SPLP) for dissolved metal content (Al, Fe, Pb, Mn, Ni, Zn, Ca, Mg, Cd, and Cu).

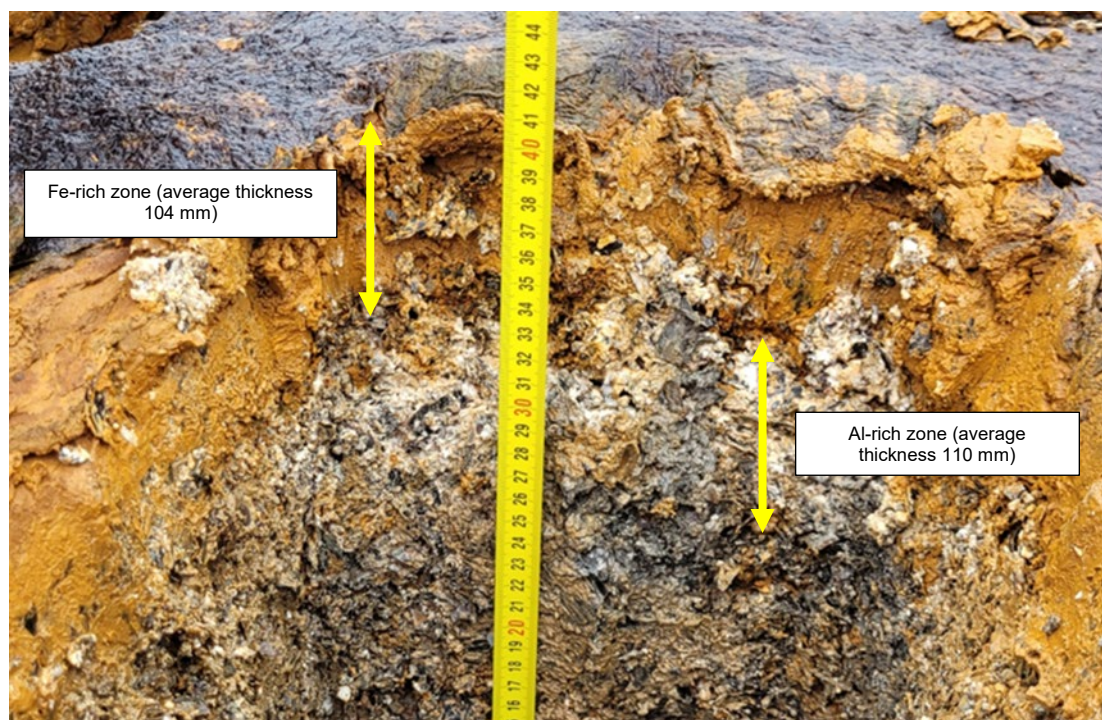


Figure 15: Sludge and Fe + Al precipitation zones within the BV-MSR.

Note: Draining the MSR resulted in the filamentous algae drying out as a thin black layer on the sludge surface (pictured).

Table 6: BV-MSR sample descriptions.

TEST PIT	SAMPLE NAME	PRECIPITATE LAYER DEPTH (mm below surface level)	SAMPLE COLLECTION (mm below surface level)
Test Pit 1	ESC_MSR_TP1_Fe	0 – 90	20 – 80
	ESC_MSR_TP1_Al	90 – 150	110 – 150
	ESC_MSR_TP1_Sulfide	150 – 420	300 – 420
Test Pit 2	ESC_MSR_TP2_Fe	0 – 110	20 – 100
	ESC_MSR_TP2_Al	110 – 265	110 – 250
	ESC_MSR_TP2_Sulfide	265 – 370	280 – 370
Test Pit 3	ESC_MSR_TP3_Fe	0 – 125	20 – 120
	ESC_MSR_TP3_Al	125 – 265	140 – 250
	ESC_MSR_TP3_Sulfide	265 – 410	300 – 410

Note: The precipitate zone depths are only approximate as they generally graded into each other.

Results from the sludge analyses are shown in Table 7. All laboratory reports are provided in Appendix D. For the purposes of this report, the reported analyses were compared to the Escarpment Mine resource consent reference values (Table 1).

Assessment of the acid base accounting data indicates that:

- ANC data for the Fe-rich zone are negative ranging from -33 to -40 kg H₂SO₄/t equivalent, which is also supported by paste pH values ranging from pH 2.6 – 2.8 demonstrating significant stored acidity within the materials. These paste pH values are lower than the average MSR influent pH of 3.36, suggesting the formation of reactive acidic salts that have contributed to stored acidity. This has implications for sludge management, as the drying out of this material could

generate significant acidity (e.g., 33 – 40 kg H₂SO₄/t). However, this stored acidity will be offset by the residual ANC in sludge removed from the Al-rich zone where shells are present.

- ANC data for the Al-rich zone indicated it ranged from 20 to 129 kg H₂SO₄/t, suggesting significant depletion of the ANC (e.g., dissolution of the shells) within this zone, yet some ANC remained. This suggests that removal of the Al-rich layer during desludging is also beneficial to enhance the performance of the MSR. Paste pH data ranged from 6-7, indicating no significant acidic salts were present in this zone.
- ANC data for the sulfide-rich zone indicated it ranged from 195 to 560 kg H₂SO₄/t and that paste pH ranged from 7.3 – 7.9. Data suggests no significant acidic salts were present and that a reasonable reservoir of ANC remains at the depths tested. Variability in ANC at depth suggests preferential flow paths where some areas have treated more acidity than others.
- The Fe-rich zone had a moisture content that ranged from 75.1 - 78.5 wt% with an average of 76.6 wt%. The Al-rich and sulfide-rich zones had lower moisture content (66.0 wt% and 49.1 wt% respectively).

SPLP test data indicated the following:

- High acidities for the samples from the Fe-rich zone ranging from 560 to 690 mg CaCO₃/L, which are much greater than average influent acidity of 119 mg CaCO₃/L. Such data confirms the results obtained from the paste pH and ANC testing, e.g., stored acidic salts are present in this zone.
- Compared to the Fe-rich zone, measured acidities are significantly lower in the Al-rich zone and the sulfide-rich zone by an order of magnitude, which also agrees with paste pH and ANC data for these zones.
- Al remains high (38 – 51 mg/L) in all samples obtained from the Fe-rich zone Al is slightly elevated in the sulfide-rich zone for two samples; the mechanism for this is unclear and may be an artifact of the test process as Al is low in MSR effluent.
- Cd, Cu, and Mn concentrations remain variable across all depths and test pits.
- Pb, Ni, and Zn generally decrease with depth suggesting lesser contaminants at depth.

Such data provide guidance on the geochemical risks for the sludge as well as the longevity of the MSR. Although the Fe-rich and Al-/H₂S-rich materials were not blended during testing, if co-disposal is planned, a blended SPLP test would be required to assess potential cumulative leachability risks and better inform sludge management strategies:

- MSR Fe-rich sludge needs to be managed to avoid the release of acidity and metals.
- MSR Al-rich sludge and sulfide-rich sludge needs to be managed for the release of metals. Furthermore, oxidation of these materials could lead to the release of acidity and other contaminants due to the oxidation of newly formed sulfide minerals.

Table 7: BV-MSR sludge sample SPLP test results.

PARAMETER	TEST PIT 1			TEST PIT 2			TEST PIT 3		
	TP1_Fe	TP1_Al	TP1_sulfide	TP2_Fe	TP2_Al	TP2_sulfide	TP3_Fe	TP3_Al	TP3_sulfide
ANC (kg H ₂ SO ₄ /t) ¹	-33	20	560	-40	77	535	-40	129	194
ANC (kg H ₂ SO ₄ /t) ²	-	-	563	-	-	539	-	-	227
ANC (kg H ₂ SO ₄ /t) ³	-	-	562	-	-	551	-	-	231
Paste pH (1:2 ratio)	2.80	6.00	7.90	2.60	6.90	7.70	2.70	7.00	7.30
BV-MSR sludge moisture content (wt%)	78.5	65.9	29.7	75.1	65.7	53.4	76.3	66.5	64.2
SPLP Data									
pH (pH units)	3.10	6.60	8.30	2.80	7.30	8.00	2.90	7.40	7.50
EC (mS/m)	99	111.6	59.6	134.7	158.9	101.4	132.2	168.8	222
Acidity to pH 8.3 (mg CaCO ₃ /L)	560.0	27.0	<1.0	700.0	33.0	10.0	690.0	31.0	25.0
Al	38	0.004	1.32	44	0.033	0.54	51	0.044	0.062
Cd	0.00013	0.00028	<0.00005	0.00017	0.00005	<0.00005	0.00014	0.0001	0.00012
Ca	10.9	260	96	15.9	410	200	8.4	430	590
Cu	0.039	0.024	0.076	0.066	0.048	0.116	0.051	0.072	0.057
Fe	75	< 0.02	<0.02	96	<0.02	<0.02	93	< 0.02	<0.02
Pb	0.0076	0.00103	<0.00010	0.0084	0.00011	<0.00010	0.007	<0.00010	<0.00010
Mg	1.66	0.48	0.48	1.1	0.25	0.38	1.03	0.33	0.45
Mn	0.28	4.8	0.021	0.23	0.051	0.079	0.162	0.54	0.47
Ni	0.037	0.028	0.021	0.047	0.0083	0.03	0.04	0.021	0.026
Zn	0.22	0.068	<0.001	0.34	0.0033	0.0029	0.26	0.02	0.0122
SO ₄	390	580	220	520	850	480	540	920	1,410

1- Indicates the first round of ANC testing.

2- Indicates the second round of ANC testing which was conducted for Quality assurance and quality control (QA/QC) purposes within the sulfide layer.

3- Indicates the third round of ANC testing which was conducted for QA/QC purposes within the sulfide layer.

Units are presented in mg/L unless otherwise specified. A hyphen (-) indicates no value is given. Red text indicates values exceeding the Escarpment Mine consent values (Table 1) which have been used in this assessment as reference values for comparative purposes only.

7 **SUMMARY**

The following provides a high-level summary of MSR performance:

7.1 **Review**

MSR are now well recognised as a suitable passive treatment system for AMD impacted waters providing effective means for the removal of metals. This includes the effective removal of Al, Fe and lesser Ni, and Zn removal from coal mine AMD impacted drainage. Three MSR were assessed. Results indicate that:

- The Tara MSR exhibited the highest removal efficiencies for Ni and Zn (94.5% and 99.5%, respectively), likely due to circumneutral pH conditions, elevated Fe:Zn ratios, and higher total Fe concentrations, which support enhanced adsorption.
- The Whirlwind MSR achieved relatively high removal of Ni and Zn (71.0% and 83.4% respectively) despite lower pH influent. This is attributed to a higher Al:Zn ratio (~57:1), which is assumed to promote higher adsorption compared to the BV-MSR (Al:Zn ~14:1). This mechanism was validated in the Whirlwind MSR by Diloreto (2013).
- The BV-MSR reported the lowest removal rates for Ni and Zn (40.2% and 56.2% respectively), which may reflect lower Al availability (~14:1 Al:Zn ratio), higher influent Zn concentrations, and lower influent pH leading to potentially lesser Al- and Fe- hydroxide adsorption of Zn and Ni.

These results suggest that pH and influent water chemistry, particularly Fe and Al availability relative to target metals are key drivers of MSR performance for the removal of Ni and Zn.

Data suggest that Zn removal has decreased with time (after 6 years of MSR operation). More frequent removal of the Fe and Al sludge layers (desludging) and replacement of these shells with fresh shells every ~5 years would be beneficial as part of the MSR maintenance program. Performance monitoring of MSR effluent for metals would help confirm when shells need replacing.

7.2 **Removal Mechanisms for Ni and Zn**

Study indicated three possible mechanisms for the removal of Ni and Zn within MSR:

7.2.1 *HRT*

MSR water quality data suggest that residence time can influence metal removal. Data suggests that higher HRT might have benefits for Ni and Zn treatment. However, further work is required to confirm the benefits and whether this can be optimised to improve the MSR treatment efficiency.

7.2.2 *Geochemical Conditions and pH Dependency*

Studies indicate that the following geochemical processes could be influencing adsorption of trace metals such as Ni and Zn within MSR and the associated treatment efficiency:

- Precipitation of $\text{Fe}(\text{OH})_3$ under oxic circum-neutral conditions to form the upper Fe-sludge layer at suitable concentrations.
- Precipitate of higher quantities of $\text{Al}(\text{OH})_3$ under oxic/sub-oxic conditions.

Trials were undertaken by Process Flow. Results indicate that the addition of Al and Fe to MSR effluent (circum-neutral pH) removed >50% of the Zn remaining in solution. This helps support the mechanism of adsorption of Zn onto Al- and Fe- hydroxides. Ni removal was less obvious but starting Ni concentration data at the commencement of the trial were not available.

7.2.3 Biogeochemical Processes

SRB generated alkalinity ranged from 4.71 to 5.76 kg CaCO₃ per m³ of shells per year across the three MSRs, indicating a consistent rate of alkalinity production (based on sulfate differences in MSR influent and effluent). This also implies that sulfide generation rates are comparable, suggesting that sulfide production is not the primary factor influencing the observed differences in Ni and Zn removal efficiencies.

Further work is required to understand the bioavailable labile carbon availability in MSR, the mechanics of SRB alkalinity generation, quantification of metal removal by sulfides, and whether this can be optimised to improve the MSR treatment efficiency.

7.3 Sludge Management

Field work was undertaken coincidental with the desludging program for the BV-MSR. Laboratory results indicate that careful management of the MSR sludge is required to avoid the release of acidity and PCOC.

7.4 Summary

For the BPCP the following process could be utilised to facilitate better Zn (and Ni) removal/treatment of ELF seepage for the BPCP:

- More frequent removal of the Fe and Al sludge layers (desludging) and replacement of these shells with fresh shells every ~5 years would be beneficial as part of the MSR maintenance program. Performance monitoring of MSR effluent for metals would help confirm when shells need replacing.
- Establishment of a polishing pond after the MSR to either oxidise any remnant Fe(II) passing through the MSR (due to sub-oxic ELF seepage elevated in Fe) and/or enable FeCl₃ dosing and its subsequent hydrolysis/precipitation. This is likely to improve Zn removal efficiencies whereby Zn is adsorbed to the iron hydroxides that form.
- Noting: a polishing pond is already required to remove secondary contaminants such as HS- and ammoniacal nitrogen (see MWM, 2026c) within the MSR effluent and the same facility could be utilised.

MSRs will be assessed during the early stages of the BPCP by operational trials with ongoing literature review of new technologies to confirm that MSRs remain the best practicable option. Early construction of the MSR during operations will enable site-specific testing and validation to demonstrate the system's effectiveness.

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9 LIMITATIONS

Attention is drawn to the document “Limitations”, which is included in Appendix E of this report. The statements presented in this document are intended to provide advice on what the realistic expectations of this report should be, and to present recommendations on how to minimise the risks associated with this project. The document is not intended to reduce the level of responsibility accepted by Mine Waste Management, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in doing so.

APPENDIX A ABBREVIATIONS

ABBREVIATION	DEFINITION
AEE	Assessment of environmental effects
AMD	Acid and Metalliferous Drainage
ANC	Acid neutralising capacity
BPCP	Buller Plateaux Continuation Project
BV-ELF	Barren Valley Engineered Landform
BV-MSR	BV-ELF mussel shell bioreactor
BRL	Bathurst Resources Limited
PCOC	Potential Constituents of Concern
DOC	Dissolved organic carbon
ELF	Engineered Landform
ESE	Escarpment Extended
FHT	Falling head test
FTA	Fast-track Approvals Act 2024
HRT	Hydraulic residence time
LOR	Limit of reporting
MFS	Mount Fred South
MWM	Mine Waste Management Ltd
MSR	Mussel shell bioreactor
NP	Net Percolation
PCOC	Potential Constituents of Concern
QA/QC	Quality assurance and quality control
SPLP	Synthetic precipitation leaching procedure
SRB	Sulfate reducing bacteria
UWHR	Upper Waimangaroa Haul Road

APPENDIX B BV-ELF MSR WATER QUALITY DATA

Parameter	Units	Count	Average	Median	Min	Max
pH	pH units	82	7.87	7.90	7.10	8.30
Conductivity	mS/m	74	89.5	57.7	37.5	830.0
Acidity to pH 8.3	mg CaCO ₃ /L	81	3.96	3.00	1.00	15.0
Total Alkalinity	mg CaCO ₃ /L	73	112.9	114.0	70.0	150.0
Calculated hardness	mg CaCO ₃ /L	74	283.5	283.8	155.5	449.5
Sulfate	mg/L	76	161.8	158.0	90.7	310.0
Dissolved (NP) Organic Carbon	mg/L	14	0.357	0.300	0.100	0.800
Suspended Solids	mg/L	10	4.50	3.00	3.00	9.00
Total Dissolved Solids	mg/L	8	273.5	269.5	219.0	335.0
Turbidity	NTU	10	0.472	0.325	0.140	1.50
Ammonia Nitrogen	mg/L	10	0.409	0.010	0.010	2.00
Nitrate-N	mg/L	9	0.541	0.350	0.040	1.10
Nitrite-N	mg/L	9	0.023	0.010	0.0066	0.130
Nitrate-N	mg/L	17	0.432	0.350	0.030	1.10
Total Nitrogen	mg/L	10	0.517	0.286	0.220	2.35
Sulfide	mg/L	1	0.200	0.200	0.200	0.200
Hydrogen Sulfide	mg/L	5	0.110	0.050	0.050	0.350
Total Sulfide Screen	mg/L	1	0.002	0.002	0.002	0.002
Dissolved Aluminium	mg/L	75	0.051	0.020	0.004	0.715
Dissolved Antimony	mg/L	9	0.0014	0.001	0.001	0.005
Dissolved Arsenic	mg/L	8	0.001	0.001	0.001	0.001
Dissolved Boron	mg/L	8	0.027	0.030	0.005	0.030
Dissolved Cadmium	mg/L	7	0.00026	0.0002	0.0002	0.0004
Dissolved Calcium	mg/L	84	106.2	106.0	59.7	170.0
Chloride	mg/L	9	2.95	2.84	2.30	3.50
Dissolved Chromium	mg/L	8	0.001	0.001	0.001	0.001
Dissolved Cobalt	mg/L	12	0.0055	0.00585	0.0007	0.0077
Dissolved Copper	mg/L	12	0.0006	0.0005	0.0005	0.001
Dissolved Iron	mg/L	75	0.022	0.005	0.005	0.580
Dissolved Lead	mg/L	7	0.0005	0.0005	0.0005	0.0005
Dissolved Magnesium	mg/L	74	3.48	3.16	1.57	7.25
Dissolved Manganese	mg/L	64	0.365	0.005	0.0005	13.4
Dissolved Mercury	mg/L	9	0.0005	0.0005	0.0005	0.0005
Dissolved Nickel	mg/L	73	0.072	0.067	0.0079	0.194
Dissolved Potassium	mg/L	7	1.17	1.16	1.00	1.34
Dissolved Selenium	mg/L	9	0.005	0.005	0.005	0.005
Dissolved Silica	mg/L	9	5.51	6.14	3.10	7.94
Dissolved Sodium	mg/L	7	1.88	2.33	0.0005	3.37
Dissolved Tin	mg/L	5	0.0005	0.0005	0.0005	0.0005
Dissolved Thallium	mg/L	9	0.0016	0.0016	0.0006	0.0024
Dissolved Zinc	mg/L	73	0.311	0.295	0.010	0.832

APPENDIX C PROCESS FLOW MEMORANDUM: MSR EFFLUENT TESTING

MEMO – BVMSR Bench Scale Water Treatment Testing Report

BVMSR Effluent Testing December 2024 to March 2025 For Concept Design of Active Water Treatment Plants

Prepared For:	BT Mining/Bathurst Resources
Prepared By:	Process Flow
Date:	1/04/2026
Document Number:	PFL-2408-PRJ-RPT-000104

Re

Revision	Status	Description	Date
A	DRAFT MEMO	Issued for Client Review	20/01/2024
B	DRAFT MEMO	Issued after further testing	12/02/2025
C	DRAFT MEMO	Issued for Client Review after further testing	18/03/2025
0	Memo	Revised for Use – Minor Comments	1/04/2026

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1 REFERENCES

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2 BACKGROUND

Bench scale testing has been carried out in December 2024 by Process Flow Ltd.

As outlined in email Dec 2024 from Paul Weber to Gary Smith and Emma Manhart, tests were carried out using BVMSR effluent collected by William Olds on the 18th of November.

The purpose of the testing was:

1. To confirm if dissolved Zinc or Nickel adsorption to Fe and Al hydroxides is occurring at different pHs with MSR effluent. This is a first step to simulating a process that may be occurring in the field in the Mussel Shell Reactors (MSRs).
2. To understand metal removal via adsorption at circum-neutral pH
3. To understand metal removal via adsorption at lower pHs.

Further testing was performed on the 3rd of February, (on the same BVMSR sample water) with additional Alum (Aluminium Sulphate) and Ferric Chloride Dose points to test a wider range and determine the Zinc and Nickel adsorption at these.

3 METHOD PROVIDED

3.1 December 2024 Testing Method

The following method was provided to Process [REDACTED]

1. Use 1L of MSR effluent from BV-ELF MSR and add 50 mg/L equivalent Fe (e.g., FeCl₃). Mix for 60 minutes (slow mixing) and then let stand for 24 hours to settle floc. Measure supernatant for trace metals etc.
2. Use 1L of MSR effluent from BV-ELF MSR and add 50 mg/L equivalent Al (e.g., floc). Mix for 60 minutes (slow mixing) and then let stand for 24 hours to settle floc. Measure supernatant for trace metals etc.
3. Repeat steps 1-2 using 20 mg/L of Fe and Al again.
This will help understand metal removal at circum neutral pH
4. Repeat steps 1-3 using MSR effluent adjusted to pH 3.5 with H₂SO₄. Note Al unlikely to hydrolyse (Fe should)
5. Repeat steps 1-3 using MSR effluent adjusted to pH 5 with H₂SO₄. Both Al and Fe should hydrolyse
6. Replicate tests were done with no Fe or Al addition at all three pH values, with jar stirring only and settling to compare to the tests with Fe and Al addition.

3.2 February 2025 Testing method

Further dosing trials on 3rd February were done with the following dose rates:

1mg/l, 2mg/l, 3mg/l, 4mg/l, 5mg/l and 10 mg/l Fe and Al (using Ferric Chloride and Alum respectively)

The method was:

1. Use 1L of MSR effluent from BV-ELF MSR and add doses equivalent Fe (e.g., FeCl₃) or Al (Alum)
2. Fast mix for 1 minute during chemical addition
3. Mix for 60 minutes (slow mixing)
4. Let stand for 24 hours to settle floc in cylinders
5. Measure supernatant for trace metals Dissolved Aluminium, Dissolved iron, Dissolved Nickel and Dissolved Zinc. (These were sent to Hills Laboratory for analysis).

3.3 March 2025 Testing Method and Results

In March 2025, further testing was performed on BV-ELF MSR sample from BV-ELF MSR effluent collected by William Olds on the 18th November.

The testing involved the following:

1. Checking the Raw BVMSR water parameters using testing from Hills Laboratory to compare with the in-house Spectrophotometer Raw water test results performed in December for verification of spectrophotometer results.

Raw BV-ELF MSR Testing Results Comparison

pH and Dissolved Metals		In-House Metals Testing Results using Spectrophotometer (November 24)	External Hills Laboratory Testing Results (March 25)
pH		8.05	
Aluminium	mg/l	0.064	0.052
Iron	mg/l	0.002	<0.02
Nickel	mg/l		0.073
Zinc	mg/l	0.55	0.48

2. Supernatant from the Replicate pH 5.3 adjusted sample, saved from the December 2024 test was retested at Hills Laboratory because the in-house metals test had a high zinc result (of 0.78mg/l) . This seemed a result outlier, due to this being higher concentration than the initial Raw BV-ELF MSR value of 0.55mg/l.

pH and Dissolved Metals		In House Metals testing of Replicate no Fe or Al added (pH adjusted to 5.3)	External Hills Lab Testing of same Supernatant sample
pH		5.48	
Aluminium	mg/l	0.056	0.030
Iron	mg/l	0	<0.02
Nickel	mg/l	0.077	0.074
Cobalt	mg/l	0.008	
Zinc	mg/l	0.78	0.51

- Performing titrations with H₂SO₄ acid to change pH to 7.5, 7, 6.5 and 6 on BV-ELF MSR effluent as per the previous testing, to effluent that was not treated with coagulants (equivalent to the replicate testing in December 2024 testing). The purpose of this testing was to provide more data points in the pH 7.5-6 range.

All samples were tested externally for dissolved metals at Hills Laboratory

BV-ELF MSR with pH adjustments with H₂SO₄ Testing 4 March 2025 – Hills Laboratory metals results

pH and Dissolved Metals		BV-ELF MSR adjusted to pH 7.5	BV-ELF MSR adjusted to pH 7.0	BV-ELF MSR adjusted to pH 6.5	BV-ELF MSR adjusted to pH 6.0
pH					
Aluminium	mg/l	0.074	0.068	0.025	0.085
Iron	mg/l	< 0.02	< 0.02	< 0.02	< 0.02
Nickel	mg/l	0.072	0.073	0.072	0.076
Zinc	mg/l	0.39	0.43	0.46	0.50

4 DECEMBER 2024 RESULTS

The following section and Section 5 Graphs show the Supernatant dissolved metals after 1-hour slow mix and 24 hours settling.

Fe 50
mg/l

pH and Dissolved Metals		Raw (pH 8.05)	50mg/l Fe pH adjusted to 5.3	50mg/l Fe (pH unadjusted, is equivalent to pH 2.9 adjusted)
pH (Raw or after slow mix)		8.05	5.65	2.75
Aluminium	mg/l	0.064	0.025	0.42
Iron	mg/l	0.002	0.044	8.51
Nickel	mg/l		0.089	0.105
Cobalt	mg/l		0.011	0.02
Zinc	mg/l	0.55	0.52	0.52

Fe 20
mg/l

		Raw	20mg/l Fe (pH unadjusted)	20mg/l Fe (pH2.9)
pH (Raw or after slow mix)		8.05	5.57	2.93
Aluminium	mg/l	0.064	0.033	0.908
Iron	mg/l	0.002	0.045	10.7
Nickel	mg/l		0.078	0.094
Cobalt	mg/l		0.002	0.017
Zinc	mg/l	0.55	0.49	0.62

Replicate

		Raw	Replicates no Fe or Al added (pH unadjusted)	Replicates no Fe or Al added (pH adjusted to 5.3) (*This supernatant sample has been verified by re-testing at Hills Laboratory on 4 March 25 due to a high Zinc result, with results compared below)	Replicates no Fe or Al added (pH adjusted to 2.9)
pH (Raw or after slow mix)		8.05	8.06	5.48 (In house)	2.9
Aluminium	mg/l	0.064	0.081	0.056 (In house), *0.030 (Hills Lab)	0.062
Iron	mg/l	0.002	0.002	**0 (in house), *<0.02 (Hills Lab)	0.242
Nickel	mg/l		0.072	0.077 (In house), *0.074 (Hills Lab)	
Cobalt	mg/l		0.01	0.008	
Zinc	mg/l	0.55	0.4	0.78 (In House), *0.51 (Hills Lab)	

**Iron +-0.002

Al 50 mg/l

		Raw BVMSR	50mg/l Al (pH unadjusted)	50mg/l Al pH adjusted to 5.3	50mg/l Al pH adjusted to 2.9
pH (Raw or after slow mix)		8.05	4.85	5.18	2.88
Aluminium	mg/l	0.064	1.19	0.191	0.5
Iron	mg/l	0.002	0	0.032	0.23
Nickel	mg/l		0.072	0.076	0.073
Cobalt	mg/l		0.007	0.006	0.008
Zinc	mg/l	0.55	0.56	0.56	0.42

 *Aluminium
 0.5+

Al 20 mg/l

		Raw BVMSR	20mg/l Al (pH unadjusted 6.71)	20mg/l Al pH adjusted to 5.3	20mg/l Al pH adjusted to 2.9
pH (Raw or after slow mix)		8.05	6.71	5.64	2.89
Aluminium	mg/l	0.064	0.108	0.062	0.5
Iron	mg/l	0.002	0.003	0.025	0.2155
Nickel	mg/l		0.055	0.073	0.074
Cobalt	mg/l		0.008	0.003	0.016
Zinc	mg/l	0.55	0.14	0.58	0.51

 *Aluminium
 0.5+

5 FEBRUARY 2025 RESULTS

Fe Doses 1-10mg/l

		Raw BVMSR	1mg/l Fe (ph unadjusted)	2mg/l Fe (ph unadjusted)	3mg/l Fe (ph unadjusted)	4mg/l Fe (ph unadjusted)
pH (Raw or after slow mix)		7.75	7.53	7.43	7.33	7.29
Aluminium	mg/l	0.064	0.008	0.003	0.003	0.003
Iron	mg/l	0.002	0.02	0.02	0.02	0.02
Nickel	mg/l		0.065	0.062	0.061	0.062
Cobalt	mg/l					
Zinc	mg/l	0.55	0.21	0.186	0.197	0.187

		5mg/l Fe (ph unadjusted)	10mg/l Fe (ph unadjusted)	Note: Aluminium and Iron at below Hills detection
pH (Raw or after slow mix)		7.01	6.91	
Aluminium	mg/l	0.003	0.003	* <0.003
Iron	mg/l	0.02	0.02	** <0.02
Nickel	mg/l	0.063	0.07	
Cobalt	mg/l			
Zinc	mg/l	0.23	0.33	

*Aluminium 0.5+

**Iron +0.002

Al Doses 1-10mg/l

		Raw BVMSR	1mg/l Al (ph unadjusted)	2mg/l Al (ph unadjusted)	3mg/l Fe (Al unadjusted)	4mg/l Al (ph unadjusted)
pH (Raw or after slow mix)		7.75	7.76	7.71	7.65	7.62
Aluminium	mg/l	0.064	0.25	0.184	0.16	0.127
Iron	mg/l	0.002	0.02	0.02	0.02	0.02
Nickel	mg/l		0.072	0.072	0.07	0.071
Cobalt	mg/l					
Zinc	mg/l	0.55	0.33	0.27	0.23	0.22

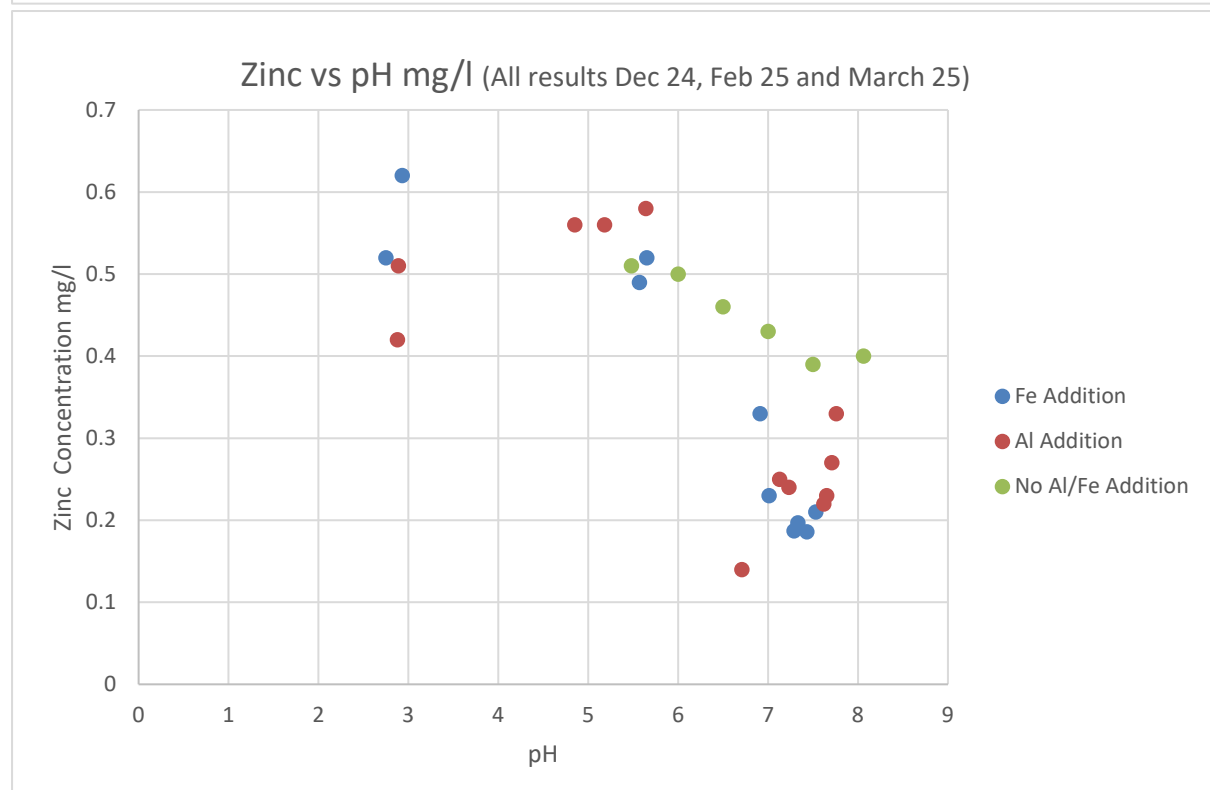
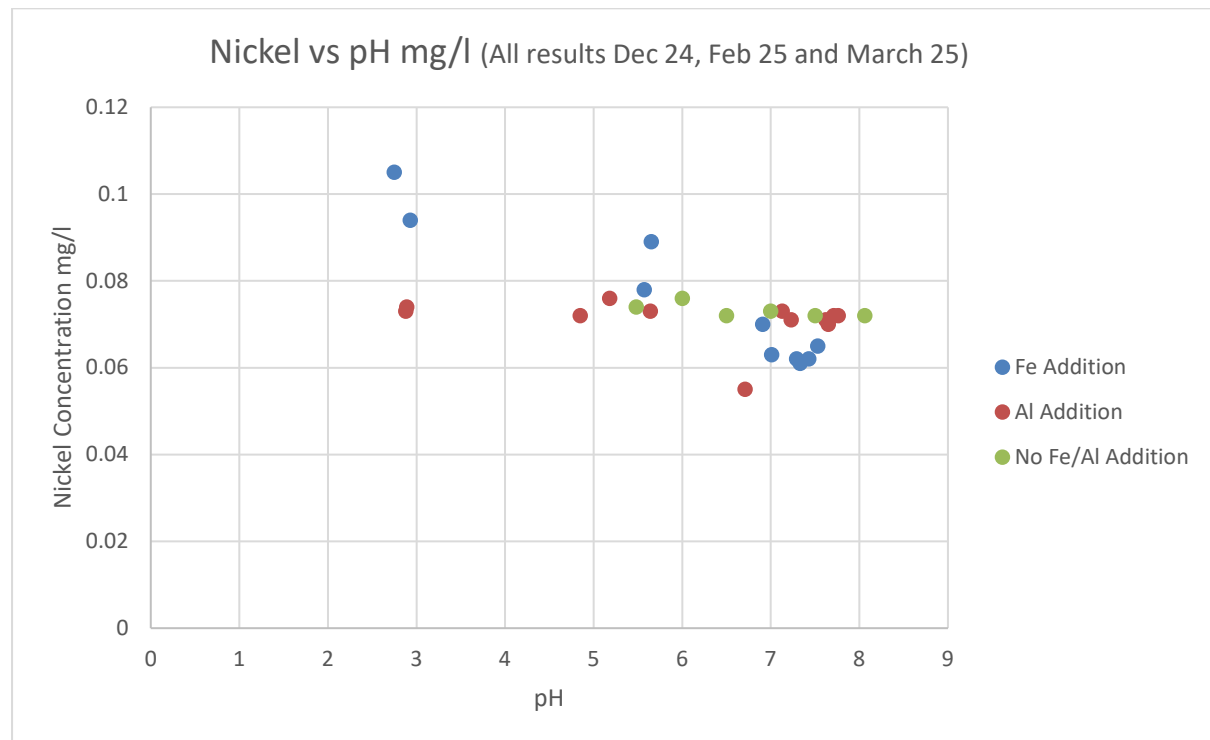
		5mg/l Al (ph unadjusted)	10mg/l Al (ph unadjusted)	Note: Iron at below Hills detection
pH (Raw or after slow mix)		7.23	7.13	
Aluminium	mg/l	0.086	0.054	
Iron	mg/l	0.02	0.02	**<0.02
Nickel	mg/l	0.071	0.073	
Cobalt	mg/l			
Zinc	mg/l	0.24	0.25	

**Iron +0.002

6 GRAPHS

6.1 Nickel and Zinc removal vs pH (Dec 24, Feb 25 and March 25 Testing)

Below the graphs are comparing all the BVMSR Nickel and Zinc test results against pH (for all tests of Iron and Aluminium concentrations done in December 2024, February 2025 and March 2025) and compared to graphs of previous research (by William Olds (2013) on the next page.



Below, graphs of previous research (by William Olds (2013) showing Nickel and Zinc removal vs pH.

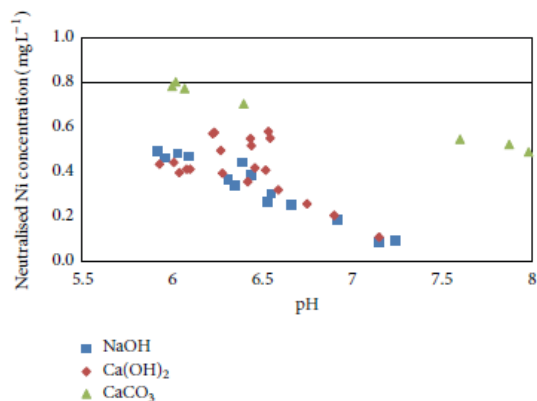


FIGURE 3: Acid mine drainage Ni concentration (initial = 0.8 mg L⁻¹) and concentration after neutralisation by NaOH, Ca(OH)₂, and CaCO₃.

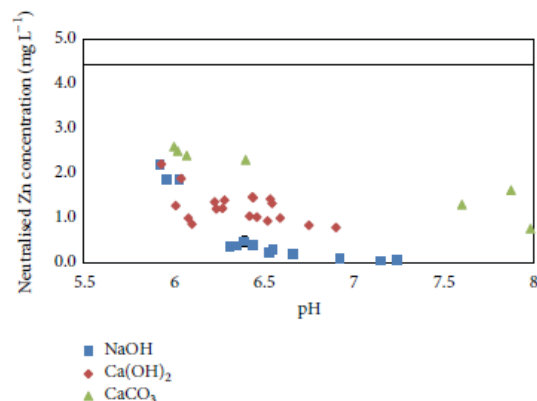


FIGURE 4: Acid mine drainage Zn concentration (initial = 4.42 mg L⁻¹) and concentration after neutralisation by NaOH, Ca(OH)₂, and CaCO₃.

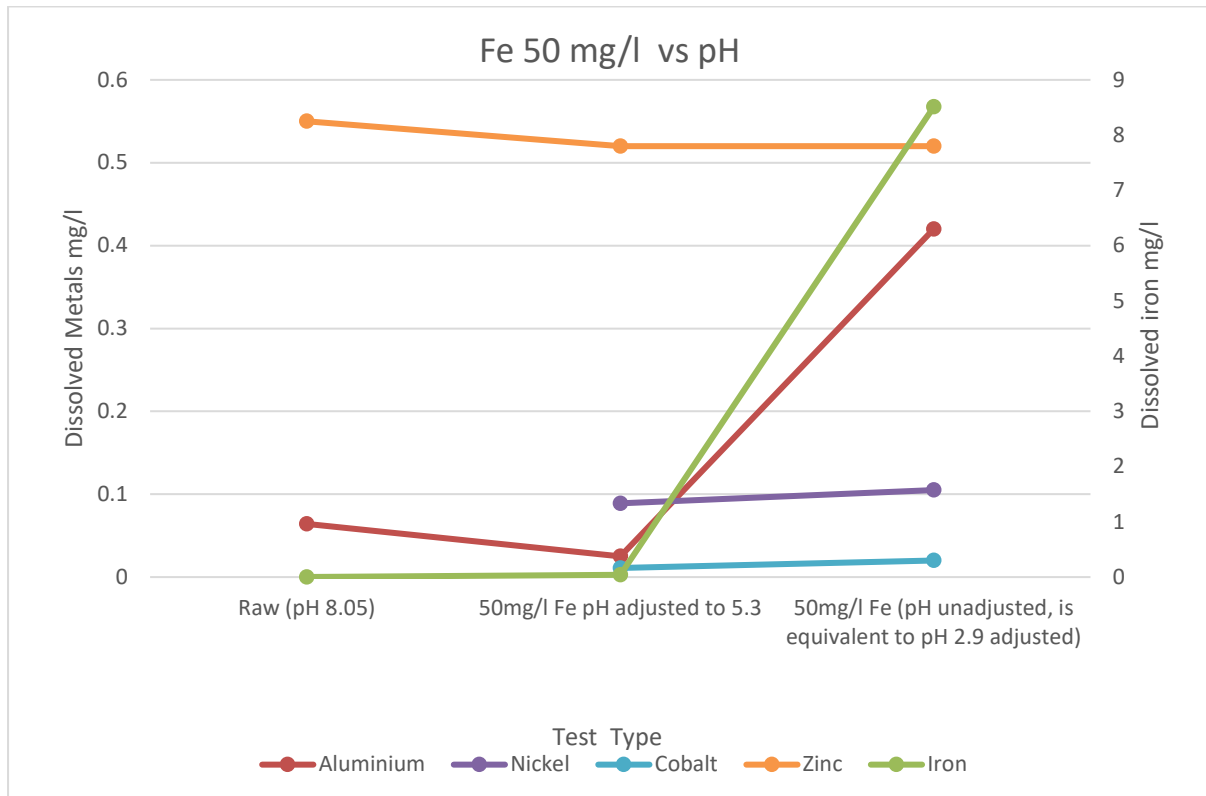
The pH corresponding to the theoretical thermodynamic and minimum solubility of some selected metal hydroxides is shown in Table 7-5 (from INAP GARD guide).

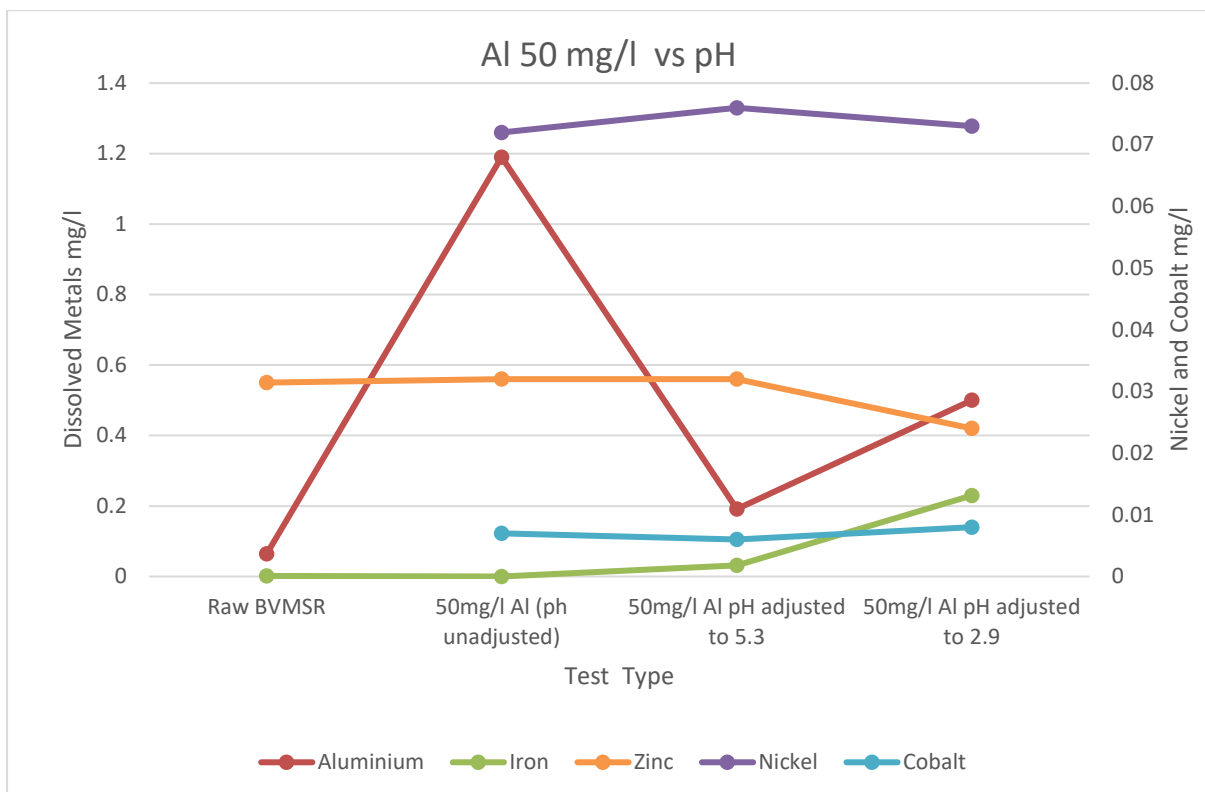
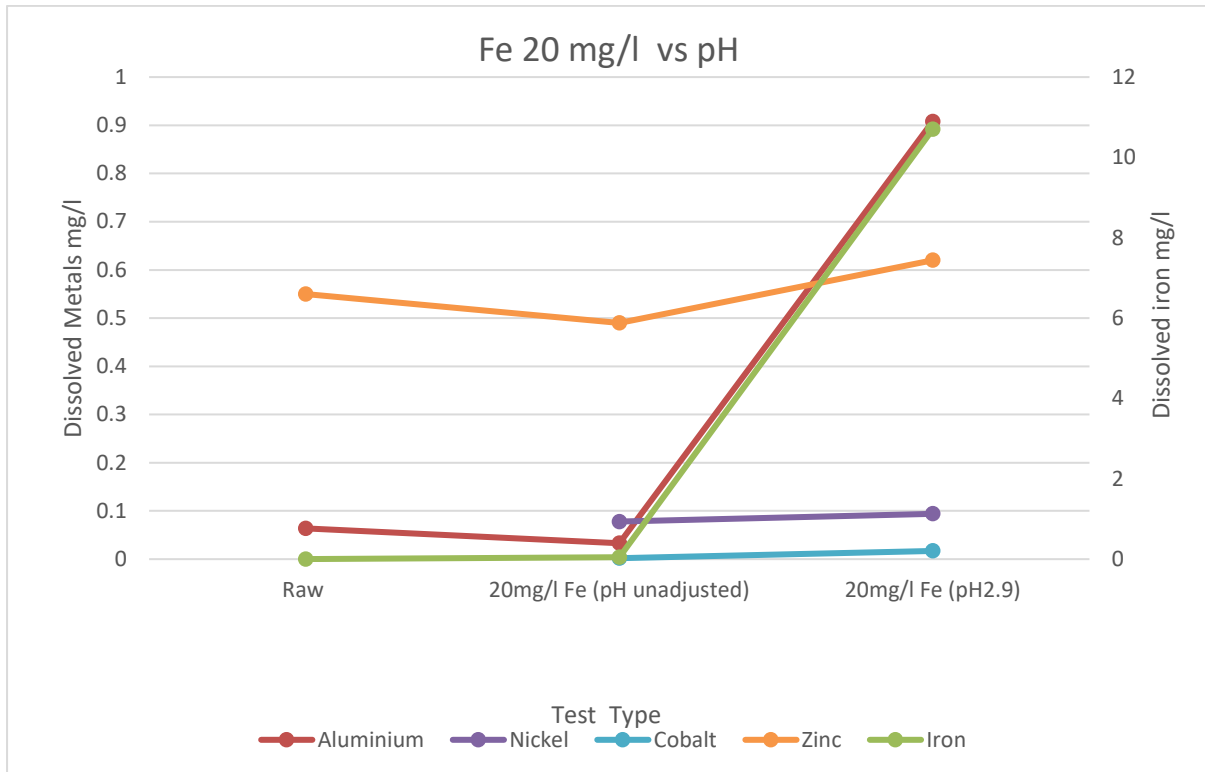
Table 7-5: Theoretical Minimum Metal Hydroxide Solubility pH

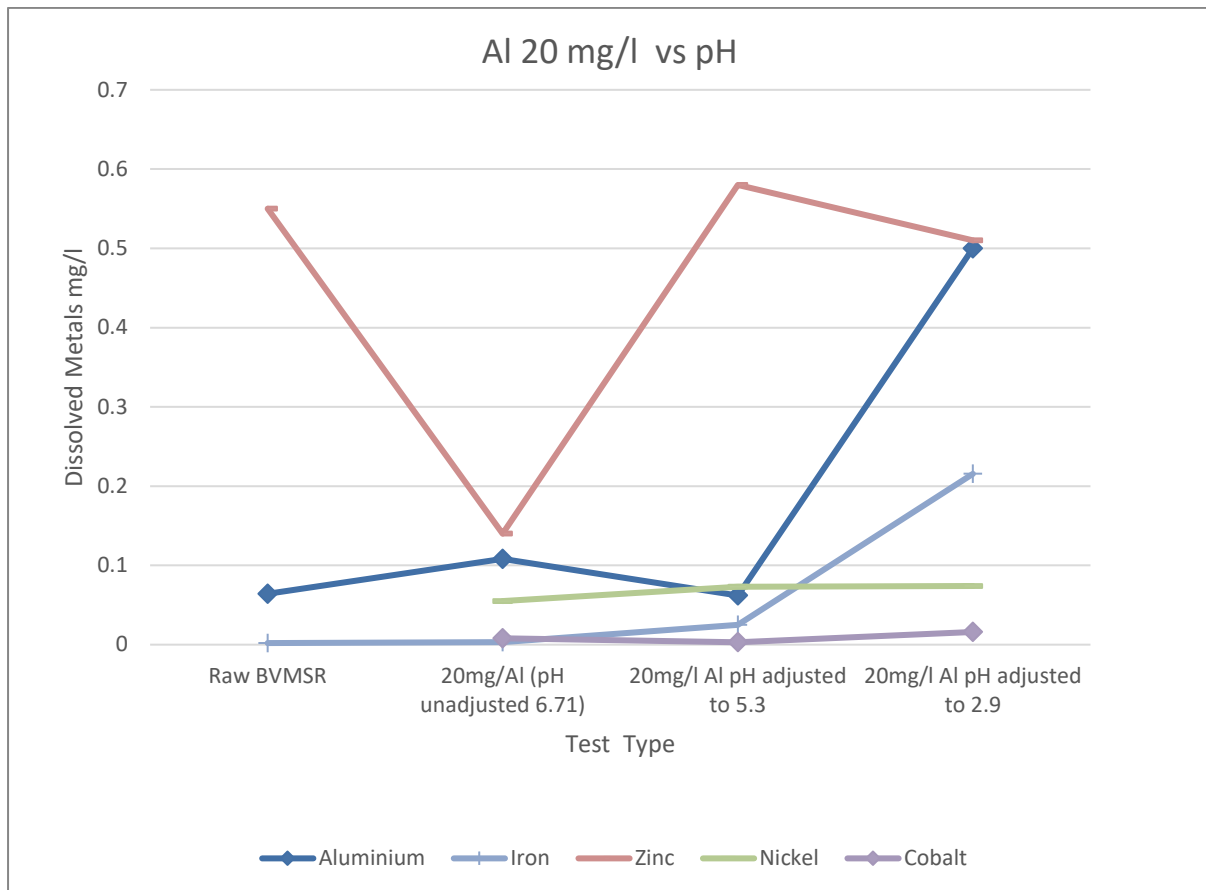
Metal	pH Corresponding to Minimum Metal Hydroxide Solubility/L
Ferric iron, Fe ³⁺	~ 3.5
Antimony, Sb ²⁺	~ 4.2
Aluminum, Al ³⁺	~ 4.5
Lead, Pb ²⁺	~ 6.5
Copper, Cu ²⁺	~ 7.0
Ferrous iron, Fe ²⁺	~ 8.0
Zinc, Zn ²⁺	~ 8.5
Nickel, Ni ²⁺	~ 9.3
Cadmium, Cd ²⁺	~ 10.0
Manganese, Mn ²⁺	~ 10.6

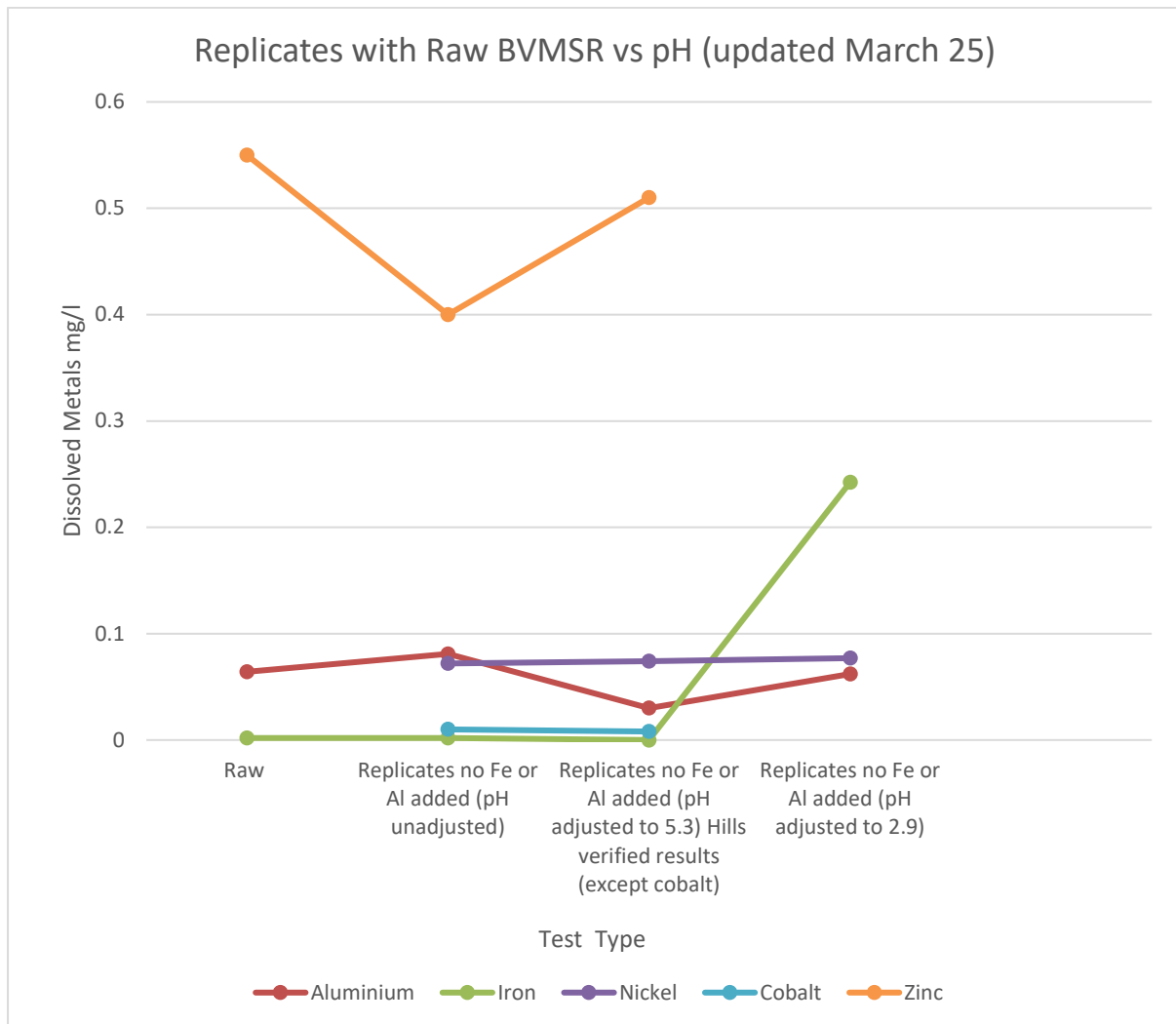
6.2 Metal dose vs pH (Dec 24 Testing)

The following graphs showing Fe and Al dose vs pH are from the December 2024 testing work.









6.2.1 Raw Water Quality

On the 22nd of November 2024 house raw water metals tests were performed on the BVMSR effluent using the Hach DR3900 Spectrophotometer. The pH measurement in house was performed using a Hanna Bench top pH Meter.

On the 4th of March 2025 the same Raw sample water was tested at Hills Laboratory for verification.

Raw water results for the sample can be seen below, compared to the previous sample of another separate MSR water (tested externally at Hills Laboratory).

Table 1 Raw Water Samples Quality

PARAMETER	UNITS	BVMSR RAW (4 MARCH 25, TESTED EXTERNALLY)	BVMSR RAW (22 NOVEMBER 24, TESTED IN HOUSE)	MSR RAW (SAMPLED 22 OCTOBER 24, TESTED EXTERNALLY)
Turbidity	NTU			0.06
pH	pH Units		8.05	8.1
Total Acidity (pH5.5)	g/m3 as CaCO3			< 1.1
Total Acidity (pH 7.0)	g/m3 as CaCO3			< 1.1
Total Acidity (pH 8.3)	g/m3 as CaCO3			2.2
Total Alkalinity	g/m3 as CaCO3			105
Free Carbon Dioxide	g/m3 at 25°C			1.7
Total Hardness	g/m3 as CaCO3			220
Total Suspended Solids	g/m3			< 3
Total Solids (TS)	g/m3			< 300
Dissolved Aluminium	g/m3	0.052	0.064	0.05
Dissolved Cadmium	g/m3			0.00028
Dissolved Calcium	g/m3			83
Dissolved Chromium	g/m3			< 0.0005
Dissolved Cobalt	g/m3			0.0062
Dissolved Copper	g/m3			< 0.0005
Dissolved Iron	g/m3	< 0.02	0.002	< 0.02
Dissolved Lead	g/m3			< 0.00010
Dissolved Magnesium	g/m3			2
Dissolved Manganese	g/m3			0.003
Dissolved Nickel	g/m3	0.073		0.072
Dissolved Zinc	g/m3	0.48	0.55	0.48
Chloride	g/m3			3.2
Nitrite-N	g/m3			< 0.002
Nitrate-N	g/m3			0.24
Nitrate-N + Nitrite-N	g/m3			0.24
Sulphate	g/m3			112
Dissolved Organic Carbon (DOC)	g/m3			< 0.5
Absorbance at 254 nm	AU cm-1			0.007
Transmittance at 254 nm	%T, 1 cm cell			98.3

6.2.2 Process Trials

Methodology:

1. Measure initial (Raw BVMSR) pH
2. Add Iron or Aluminium (Ferric Chloride or Alum) to equivalent amount of 50mg/l or 20m/l Fe or Al.
3. Measure pH after 1-minute rapid mix (350rpm)
4. Add any pH adjustment chemicals (Caustic Soda NaOH, Sulphuric Acid H₂SO₄) and measure pH again
5. When pH adjusted, slow stir at 30rpm for 60 minutes
6. Measure pH at intervals during the 60 minutes
7. After 60 minutes, settling in settling cylinders for 24 hours and decant supernatant.
8. Test Supernatant for pH and dissolved metals Iron, Aluminium, Nickel, Zinc.

DRAFT TEST METHODS	50MG/L FE	50MG/L AL	20MG/L FE	20MG/L AL	REPLICATES NO FE OR AL ADDED
	Test 1	Test 2	Test 3	Test 4	Test 5
PH (UNADJUSTED) APPROX. 8	50 mg/l Iron	50 mg/l Aluminium	20 mg/l Iron	20 mg/l Aluminium	No Iron or Aluminium added
	pH unadjusted	pH unadjusted	pH unadjusted	pH unadjusted	pH unadjusted
	Test 6	Test 7	Test 8	Test 9	Test 14
PH 3.5	50 mg/l Iron	50 mg/l Aluminium	20 mg/l Iron	20 mg/l Aluminium	No Iron or Aluminium added
	pH	pH	pH	pH	pH
	Test 10	Test 11	Test 12	Test 13	Test 15
PH5	50 mg/l Iron	50 mg/l Aluminium	20 mg/l Iron	20 mg/l Aluminium	No Iron or Aluminium added
	pH	pH	pH	pH	pH

7 GENERAL METHODOLOGY

7.1 Bench Scale Process Testing Methods

The following describes the detailed test method used for the bench tests discussed in this report.

Bench Testing Equipment:

- A Boltac Infinity Jar Stirrer and four 1 litres jars were used for rapid and slow mixing process phases.
- Eight x 1 litre glass graduated cylinders were used for bench settling trials.
- Hach DR3900 Spectrophotometer was used for dissolved metals, alkalinity and hardness testing.
- Realtech UVT meter used for UVT₂₅₄ measurement
- Hanna Handheld Turbidimeter used for Turbidity measurement
- Hanna Bench top pH Meter for pH measurement

Figure 1 The Boltac Infinity jar test mixing unit and Graduated Cylinders



7.1.1 Sample handling

BVMSR Effluent was collected on 18th November 2024 from Barren Valley Elf MSR effluent. 10 litre containers of each water sample (BVMSR were collected and stored in darkness at Process Flow in Richmond until testing commenced.) This was to prevent temperature changes and light influence on the water prior to testing. Testing commenced on 2nd December.

All jars were triple rinsed with sample water prior to test water filling.

7.1.2 Contamination prevention

To prevent metals contamination between tests, after testing each run, the jars and cylinders were cleaned with Pyroneg detergent and rinsed with deionised water.

APPENDIX D LABORATORY REPORTS

Certificate of Analysis

Page 1 of 3

Client:	SGS New Zealand Limited C/- SGS New Zealand Limited PO Box 240 Westport 7866	Date Received: Date Reported: Quote No: Order No: Client Reference: Submitted By:	3508014 21-Mar-2024 05-Apr-2024 130029 1171788 SPLP testing Chris Lowe	SPV1
----------------	---	--	--	------

Sample Type: Soil

Sample Name:	ESC_MSR_TP1_ _Fe 16-Feb-2024	ESC_MSR_TP1_ _Al 16-Feb-2024	ESC_MSR_TP1_ _H2S 16-Feb-2024	ESC_MSR_TP2_ _Fe 16-Feb-2024	ESC_MSR_TP2_ _Al 16-Feb-2024	
Lab Number:	3508014.1	3508014.2	3508014.3	3508014.4	3508014.5	
SPLP Sample Weight	g	50	50	50	50	
SPLP Extractant Type*	De-ionised Water, pH 5.8 +/- 0.4	De-ionised Water, pH 5.8 +/- 0.4	De-ionised Water, pH 5.8 +/- 0.4	De-ionised Water, pH 5.8 +/- 0.4	De-ionised Water, pH 5.8 +/- 0.4	
SPLP Final pH	pH Units	3.0	6.5	8.3	2.8	7.3

Sample Name:	ESC_MSR_TP2_H2S 16-Feb-2024	ESC_MSR_TP3_Fe 16-Feb-2024	ESC_MSR_TP3_AI 16-Feb-2024	ESC_MSR_TP3_H2S 16-Feb-2024
Lab Number:	3508014.6	3508014.7	3508014.8	3508014.9
SPLP Sample Weight g	50	50	100	100
SPLP Extractant Type*	De-ionised Water, pH 5.8 +/- 0.4	De-ionised Water, pH 5.8 +/- 0.4	De-ionised Water, pH 5.8 +/- 0.4	De-ionised Water, pH 5.8 +/- 0.4
SPLP Final pH pH Units	8.0	2.8	7.3	7.5

Sample Type: Aqueous

Sample Name:		ESC_MSR_TP1_ _Fe [SPLP Extract] 16-Feb-2024	ESC_MSR_TP1_ _Al [SPLP Extract] 16-Feb-2024	ESC_MSR_TP1_ _H2S [SPLP Extract] 16-Feb-2024	ESC_MSR_TP2_ _Fe [SPLP Extract] 16-Feb-2024	ESC_MSR_TP2_ _Al [SPLP Extract] 16-Feb-2024
Lab Number:		3508014.10	3508014.11	3508014.12	3508014.13	3508014.14
pH	pH Units	3.1	6.6	8.3	2.8	7.3
Electrical Conductivity (EC)*	mS/m	99.0	111.6	59.6	134.7	158.9
Dissolved Aluminium	g/m³	38	0.004	1.32	44	0.033
Dissolved Cadmium	g/m³	0.00013	0.00028	< 0.00005	0.00017	0.00005
Dissolved Calcium	g/m³	10.9	260	96	15.9	410
Dissolved Copper	g/m³	0.039	0.024	0.076	0.066	0.048
Dissolved Iron	g/m³	75	< 0.02	< 0.02	96	< 0.02
Dissolved Lead	g/m³	0.0076	0.00103	< 0.00010	0.0084	0.00011
Dissolved Magnesium	g/m³	1.66	0.48	0.48	1.10	0.25
Dissolved Manganese	g/m³	0.28	4.8	0.021	0.23	0.051
Dissolved Nickel	g/m³	0.037	0.028	0.021	0.047	0.0083
Dissolved Zinc	g/m³	0.22	0.068	< 0.0010	0.34	0.0033
Sulphate*	g/m³	390	580	220	520	850

Sample Name:		ESC_MSR_TP2_H2S [SPLP Extract] 16-Feb-2024	ESC_MSR_TP3_Fe [SPLP Extract] 16-Feb-2024	ESC_MSR_TP3_Al [SPLP Extract] 16-Feb-2024	ESC_MSR_TP3_H2S [SPLP Extract] 16-Feb-2024
Lab Number:		3508014.15	3508014.16	3508014.17	3508014.18
pH	pH Units	8.0	2.9	7.4	7.5
Electrical Conductivity (EC)*	mS/m	101.4	132.2	168.8	222
Dissolved Aluminium	g/m³	0.54	51	0.044	0.062
Dissolved Cadmium	g/m³	< 0.00005	0.00014	0.00010	0.00012
Dissolved Calcium	g/m³	200	8.4	430	590

Sample Type: Aqueous				
Sample Name:		ESC_MSR_TP2_H2S [SPLP Extract] 16-Feb-2024	ESC_MSR_TP3_Fe [SPLP Extract] 16-Feb-2024	ESC_MSR_TP3_AI [SPLP Extract] 16-Feb-2024
Lab Number:		3508014.15	3508014.16	3508014.17
Dissolved Copper	g/m ³	0.116	0.051	0.072
Dissolved Iron	g/m ³	< 0.02	93	< 0.02
Dissolved Lead	g/m ³	< 0.00010	0.0070	< 0.00010
Dissolved Magnesium	g/m ³	0.38	1.03	0.33
Dissolved Manganese	g/m ³	0.079	0.162	0.54
Dissolved Nickel	g/m ³	0.030	0.040	0.021
Dissolved Zinc	g/m ³	0.0029	0.26	0.020
Sulphate*	g/m ³	480	540	920

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Labs, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Soil			
Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
SPLP Profile*	Extraction at 30 +/- 2 rpm for 18 +/- 2 hours, (Ratio 1g sample : 20g extraction fluid). US EPA 1312.	-	1-9
SPLP Profile			
SPLP Sample Weight	Gravimetric. US EPA 1312.	0.1 g	1-9
SPLP Extractant Type*	US EPA 1312 (Modified for New Zealand conditions to use De-ionised Water unless otherwise specified).	-	1-9
SPLP Final pH	pH meter. US EPA 1312.	0.1 pH Units	1-9

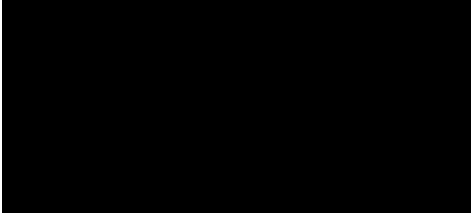
Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	10-18
pH	pH meter. APHA 4500-H ⁺ B (modified) : Online Edition. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	10-18
Electrical Conductivity (EC)*	Conductivity meter, 25°C. APHA 2510 B : Online Edition.	0.1 mS/m	10-18
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B : Online Edition.	-	10-18
Dissolved Aluminium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.003 g/m ³	10-18
Dissolved Cadmium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.00005 g/m ³	10-18
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.05 g/m ³	10-18
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0005 g/m ³	10-18
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.02 g/m ³	10-18
Dissolved Lead	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.00010 g/m ³	10-18
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.02 g/m ³	10-18
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0005 g/m ³	10-18
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0005 g/m ³	10-18
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0010 g/m ³	10-18
Sulphate*	Filtered sample. Ion Chromatography. APHA 4110 B (modified) : Online Edition.	0.5 g/m ³	10-18

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 27-Mar-2024 and 05-Apr-2024. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.



Certificate of Analysis

Page 1 of 3

Client:	SGS New Zealand Limited	Lab No:	3508014	SPV2
Contact:		Date Received:	21-Mar-2024	
	C/- SGS New Zealand Limited	Date Reported:	16-Apr-2024	(Amended)
	PO Box 240	Quote No:	130029	
	Westport 7866	Order No:	1171788	
		Client Reference:	SPLP testing	
		Submitted By:	Chris Lowe	

Sample Type: Soil

Sample Name:	ESC_MSR_TP1_Fe 16-Feb-2024	ESC_MSR_TP1_AI 16-Feb-2024	ESC_MSR_TP1_H2S 16-Feb-2024	ESC_MSR_TP2_Fe 16-Feb-2024	ESC_MSR_TP2_AI 16-Feb-2024
Lab Number:	3508014.1	3508014.2	3508014.3	3508014.4	3508014.5
SPLP Sample Weight	g	50	50	50	50
SPLP Extractant Type*	De-ionised Water, pH 5.8 +/- 0.4	De-ionised Water, pH 5.8 +/- 0.4	De-ionised Water, pH 5.8 +/- 0.4	De-ionised Water, pH 5.8 +/- 0.4	De-ionised Water, pH 5.8 +/- 0.4
SPLP Final pH	pH Units	3.0	6.5	8.3	2.8

Sample Name:	ESC_MSR_TP2_H2S 16-Feb-2024	ESC_MSR_TP3_Fe 16-Feb-2024	ESC_MSR_TP3_AI 16-Feb-2024	ESC_MSR_TP3_H2S 16-Feb-2024
Lab Number:	3508014.6	3508014.7	3508014.8	3508014.9
SPLP Sample Weight	g	50	50	100
SPLP Extractant Type*	De-ionised Water, pH 5.8 +/- 0.4	De-ionised Water, pH 5.8 +/- 0.4	De-ionised Water, pH 5.8 +/- 0.4	De-ionised Water, pH 5.8 +/- 0.4
SPLP Final pH	pH Units	8.0	2.8	7.3

Sample Type: Aqueous

Sample Name:	ESC_MSR_TP1_Fe [SPLP Extract] 16-Feb-2024	ESC_MSR_TP1_AI [SPLP Extract] 16-Feb-2024	ESC_MSR_TP1_H2S [SPLP Extract] 16-Feb-2024	ESC_MSR_TP2_Fe [SPLP Extract] 16-Feb-2024	ESC_MSR_TP2_AI [SPLP Extract] 16-Feb-2024
Lab Number:	3508014.10	3508014.11	3508014.12	3508014.13	3508014.14
pH	pH Units	3.1	6.6	8.3	2.8
Total Acidity (pH 8.3)*	g/m ³ as CaCO ₃	560	27	< 1.0	700
Electrical Conductivity (EC)*	mS/m	99.0	111.6	59.6	134.7
Dissolved Aluminium	g/m ³	38	0.004	1.32	44
Dissolved Cadmium	g/m ³	0.00013	0.00028	< 0.00005	0.00017
Dissolved Calcium	g/m ³	10.9	260	96	15.9
Dissolved Copper	g/m ³	0.039	0.024	0.076	0.066
Dissolved Iron	g/m ³	75	< 0.02	< 0.02	96
Dissolved Lead	g/m ³	0.0076	0.00103	< 0.00010	0.0084
Dissolved Magnesium	g/m ³	1.66	0.48	0.48	1.10
Dissolved Manganese	g/m ³	0.28	4.8	0.021	0.23
Dissolved Nickel	g/m ³	0.037	0.028	0.021	0.047
Dissolved Zinc	g/m ³	0.22	0.068	< 0.0010	0.34
Sulphate*	g/m ³	390	580	220	520

Sample Name:	ESC_MSR_TP2_H2S [SPLP Extract] 16-Feb-2024	ESC_MSR_TP3_Fe [SPLP Extract] 16-Feb-2024	ESC_MSR_TP3_AI [SPLP Extract] 16-Feb-2024	ESC_MSR_TP3_H2S [SPLP Extract] 16-Feb-2024
Lab Number:	3508014.15	3508014.16	3508014.17	3508014.18
pH	pH Units	8.0	2.9	7.4
Total Acidity (pH 8.3)*	g/m ³ as CaCO ₃	10.0	690	31
Electrical Conductivity (EC)*	mS/m	101.4	132.2	168.8
Dissolved Aluminium	g/m ³	0.54	51	0.044



This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised. The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked * or any comments and interpretations, which are not accredited.

Sample Type: Aqueous					
Sample Name:		ESC_MSR_TP2_H2S [SPLP Extract] 16-Feb-2024	ESC_MSR_TP3_Fe [SPLP Extract] 16-Feb-2024	ESC_MSR_TP3_Al [SPLP Extract] 16-Feb-2024	ESC_MSR_TP3_H2S [SPLP Extract] 16-Feb-2024
Lab Number:		3508014.15	3508014.16	3508014.17	3508014.18
Dissolved Cadmium	g/m³	< 0.00005	0.00014	0.00010	0.00012
Dissolved Calcium	g/m³	200	8.4	430	590
Dissolved Copper	g/m³	0.116	0.051	0.072	0.057
Dissolved Iron	g/m³	< 0.02	93	< 0.02	< 0.02
Dissolved Lead	g/m³	< 0.00010	0.0070	< 0.00010	< 0.00010
Dissolved Magnesium	g/m³	0.38	1.03	0.33	0.45
Dissolved Manganese	g/m³	0.079	0.162	0.54	0.47
Dissolved Nickel	g/m³	0.030	0.040	0.021	0.026
Dissolved Zinc	g/m³	0.0029	0.26	0.020	0.0122
Sulphate*	g/m³	480	540	920	1,410

Analyst's Comments

Amended Report: This certificate of analysis replaces report '3508014-SPv1' issued on 05-Apr-2024 at 11:47 am.
Reason for amendment: At the client's request, acidity testing has been added.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Labs, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Soil			
Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
SPLP Profile*	Extraction at 30 +/- 2 rpm for 18 +/- 2 hours, (Ratio 1g sample : 20g extraction fluid). US EPA 1312.	-	1-9
SPLP Profile			
SPLP Sample Weight	Gravimetric. US EPA 1312.	0.1 g	1-9
SPLP Extractant Type*	US EPA 1312 (Modified for New Zealand conditions to use De-ionised Water unless otherwise specified).	-	1-9
SPLP Final pH	pH meter. US EPA 1312.	0.1 pH Units	1-9

Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	10-18
pH	pH meter. APHA 4500-H ⁺ B (modified) : Online Edition. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	10-18
Total Acidity (pH 8.3)*	Titration to pH 8.3 with standard sodium hydroxide solution, phenolphthalein indicator. APHA 2310 B : Online Edition.	1.0 g/m ³ as CaCO ₃	10-18
Electrical Conductivity (EC)*	Conductivity meter, 25°C. APHA 2510 B : Online Edition.	0.1 mS/m	10-18
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B : Online Edition.	-	10-18
Dissolved Aluminium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.003 g/m ³	10-18
Dissolved Cadmium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.00005 g/m ³	10-18
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.05 g/m ³	10-18
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0005 g/m ³	10-18
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.02 g/m ³	10-18
Dissolved Lead	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.00010 g/m ³	10-18
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.02 g/m ³	10-18

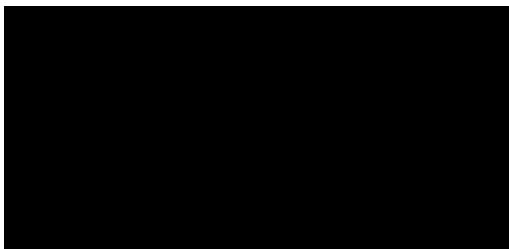
Sample Type: Aqueous			
Test	Method Description	Default Detection Limit	Sample No
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0005 g/m ³	10-18
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0005 g/m ³	10-18
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B : Online Edition.	0.0010 g/m ³	10-18
Sulphate*	Filtered sample. Ion Chromatography. APHA 4110 B (modified) : Online Edition.	0.5 g/m ³	10-18

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 27-Mar-2024 and 16-Apr-2024. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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ANALYSIS REPORT

WP24-13393



Client: BT Mining Ltd
PO Box 79151
Avonhead
Christchurch 8446 NEW ZEALAND
Attention:

Received: 16-Feb-2024
Completed: 10/04/2024
Job Number: WP24-13393
Report Number: 0000027982
Order Reference: PO539196

Sampled By:

		ESOMOIS_NZS4402_2_1 Moisture* %W/W	ESO_CLA48V ANC H2SO4* KGH2SO4/T LOR -1,000.00	ESO_CLA48V ANC CaCO3* % LOR -100.00
Sample ID	Laboratory ID			
ESC_MSR_TP1_Fe	WP24-13393.001	78.5	-33	-3.4
ESC_MSR_TP1_Al	WP24-13393.002	65.9	20	2.0
ESC_MSR_TP1_H2S	WP24-13393.003	29.7	560	57.1
ESC_MSR_TP2_Fe	WP24-13393.004	75.1	-40	-4.0
ESC_MSR_TP2_Al	WP24-13393.005	65.7	77	7.8
ESC_MSR_TP2_H2S	WP24-13393.006	53.4	535	54.6
ESC_MSR_TP3_Fe	WP24-13393.007	76.3	-40	-4.0
ESC_MSR_TP3_Al	WP24-13393.008	66.5	129	13.2
ESC_MSR_TP3_H2S	WP24-13393.009	64.2	194	19.8



ANALYSIS REPORT

WP24-13393



Client: BT Mining Ltd
PO Box 79151
Avonhead
Christchurch 8446 NEW ZEALAND
Attention:

Received: 16-Feb-2024
Completed: 10/04/2024
Job Number: WP24-13393
Report Number: 0000027982
Order Reference: PO539196

Date Start/End Analysis (19/3/2024 - 10/4/2024)

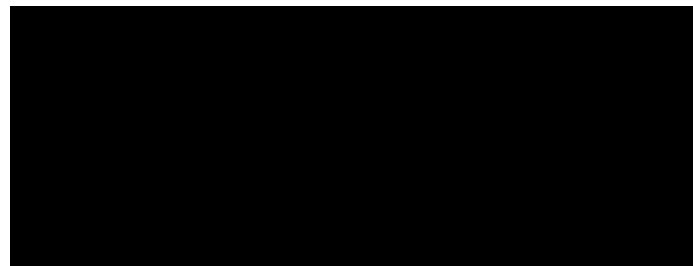
* - Denotes non accredited tests

APPLIED METHODS:

ESOMOIS_NZS4402_2_1: Moisture content soils
NZS4402:1986 Test 2.1: NZS4402:1986 Test 2.1

ESO_CLA48V: Determination of ANC, TAP and NAPP of
Soils/Rocks: SGS inhouse method

Signed and dated on 10-Apr-2024



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ANALYSIS REPORT

WP24-13695



Client: BT Mining Ltd
PO Box 79151
Avonhead
Christchurch 8446 NEW ZEALAND
Attention: Christine McLachlan

Received: 01-May-2024
Completed: 08/05/2024
Job Number: WP24-13695
Report Number: 0000028252
Order Reference: PO539196

Sampled By:

Sample ID	Laboratory ID	ESO_CLA48V ANC H2SO4* KGH2SO4/T LOR -1,000.00	ESO_CLA48V ANC CaCO3* % LOR -100.00	ESO_NEPM103_1_2 pH 1:2 aged* pH unit LOR 2.00
ESC_MSR_TP1_Fe	WP24-13695.001	-	-	2.8
ESC_MSR_TP1_Al	WP24-13695.002	-	-	6.0
ESC_MSR_TP1_H2S #1	WP24-13695.003	563	57.5	7.9
ESC_MSR_TP1_H2S #2	WP24-13695.004	562	57.3	-
ESC_MSR_TP2_Fe	WP24-13695.005	-	-	2.6
ESC_MSR_TP2_Al	WP24-13695.006	-	-	6.9
ESC_MSR_TP2_H2S #1	WP24-13695.007	539	55.0	7.7
ESC_MSR_TP2_H2S #2	WP24-13695.008	551	56.2	-
ESC_MSR_TP3_Fe	WP24-13695.009	-	-	2.7



ANALYSIS REPORT

WP24-13695



Client: BT Mining Ltd
PO Box 79151
Avonhead
Christchurch 8446 NEW ZEALAND
Attention: Christine McLachlan

Received: 01-May-2024
Completed: 08/05/2024
Job Number: WP24-13695
Report Number: 0000028252
Order Reference: PO539196

		ESO_CLA48V ANC H2SO4* KGH2SO4/T LOR -1,000.00	ESO_CLA48V ANC CaCO3* % LOR -100.00	ESO_NEPM103_1_2 pH 1:2 aged* pH unit LOR 2.00
ESC_MSR_TP3_AI	WP24-13695.010	-	-	7.0
ESC_MSR_TP3_H2S #1	WP24-13695.011	227	23.1	7.3
ESC_MSR_TP3_H2S #2	WP24-13695.012	231	23.6	-

Date Start/End Analysis (3/5/2024 - 8/5/2024)

* - Denotes non accredited tests

REMARKS:

The samples ESC_MRS_TP3_H2S#1 and ESC_MRS_TP3_H2S#2 have a volume of 15 ml's for H2s04 compared to 50 ml's of H3s04 in report WP24-13393 which could cause variance in the two batches of results.

APPLIED METHODS:

ESO_CLA48V: Determination of ANC, TAP and NAPP of
Soils/Rocks: SGS inhouse method

ESO_NEPM103_1_2: Paste pH in soil: NEPM103 1:2 extraction



ANALYSIS REPORT

WP24-13695



Client: BT Mining Ltd
PO Box 79151
Avonhead
Christchurch 8446 NEW ZEALAND
Attention: Christine McLachlan

Received: 01-May-2024
Completed: 08/05/2024
Job Number: WP24-13695
Report Number: 0000028252
Order Reference: PO539196

Signed and dated on 08-May-2024

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advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's transaction

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MINE WASTE MANAGEMENT

GREENROAD GROUP

APPENDIX D MSR Mn TREATMENT EFFICIENCIES

MEMORANDUM

Recipient: [REDACTED]

From: [REDACTED]

Date: 20 July 2026

Cc: [REDACTED]

Document Number: J-NZ0349-012-M-FINAL

Document Title: Escarpment Mine – Mussel Shell Reactor Manganese Treatment Efficiencies

Bathurst Resource Limited (BRL) is seeking to obtain authorisation through the Fast-track Approvals Act (FTAA) to progress development and mining of the coal resources across the wider Buller Plateaux. This project is referred to as the Buller Plateaux Continuation Project (BPCP or Project).

Since issuing the MWM (2026a) report, additional water quality data from the Tara MSR scrubber has been made available for the assessment of manganese (Mn) treatment efficiencies by MSR. These new data are compared to the existing available data from the BV-ELF MSR, the Tara MSR, and the Whirlwind MSR to provide further insight on Mn treatment efficiencies. Treatment efficiencies are required for forecasting water quality in MSR effluent for the proposed BPCP with Mn being considered a potential constituent of concern (PCOC).

OBJECTIVES

The objectives of this memorandum are to:

- Understand Mn treatment efficiencies based on data obtained from the Tara MSR (including the Tara MSR scrubber data), the BV-ELF MSR, and the Whirlwind MSR.
- Consider these Mn treatment efficiencies as part of the assessment of environmental effects for the BPCP.

MSR PERFORMANCE ASSESSMENT

Mn water quality data were assessed for each MSR. To determine the overall removal efficiencies only data collected on the same day for both influent and effluent samples were used rather than the entire influent/effluent dataset. This was to ensure effluent data matched as closely as possible to influent data (noting that the residence time of the MSR ~ 1 day), which means that the data are not exact. Influent data and effluent data were then averaged over the sampling period total average difference was used to calculate the removal efficiency for Mn¹.

¹ where efficiency was determined by Equation 1:

The removal of Mn using MSRs is largely dependent on adsorption (co-precipitation with Fe), bacterial activity, and oxidation potential of the water. Table 1 presents the average Mn concentrations for each of the MSRs and their respective treatment efficiencies. The provided Mn concentrations for each MSR and their respective removal efficiencies are provided in the Attachment A. It should be noted that some effluent readings were reported as higher than the influent, which produced a negative removal efficiency for Mn. This anomaly was observed across all MSRs and is likely to be attributed to the re-mobilisation of Mn within the MSRs or minor temporal differences in sampling of influent versus effluent water quality (and the hydraulic residence time in the MSR).

Based on the available data, the following observations were made:

- The Whirlwind MSR had the lowest average Mn removal efficiency (-6.68%), followed by the Tara MSR (19.7%), and then the BV MSR (58.6%).
- At the Tara site, the addition of the scrubber system² improved overall Mn removal. When considering both the Tara MSR and the scrubber, the average treatment efficiency increased to 49%, with the scrubber alone contributing an additional 29.3 percent removal relative to the Tara MSR effluent.

Table 1: Average manganese treatment efficiencies.

SITE	AVERAGE INFLUENT (mg/L)	AVERAGE EFFLUENT (mg/L)	REMOVAL EFFICIENCY (%)
Tara MSR (March 2023 – July 2024)	1.34	1.08	19.7
BV-ELF MSR (February 2017 – March 2025)	0.365	0.151	58.6
Whirlwind MSR (April 2013 – April 2018)	0.95	1.02	-6.68
TARA MSR EFFLUENT AND SCRUBBER SYSTEM			
SITE	AVERAGE TARA MSR EFFLUENT (mg/L)	AVERAGE SCRUBBER EFFLUENT (mg/L)	AVERAGE TREATMENT EFFICIENCY (%)
Tara MSR Scrubber (March 2023 – July 2024)	1.05	0.74	29.3

DISCUSSION

The data indicates a significant variation in Mn removal efficiencies for the MSRs studied. Further work is required to confirm the exact biogeochemical processes occurring and what processes are contributing to higher removal efficiencies.

Equation 1:

$$\frac{(Influent - Effluent)}{Influent} \times 100$$

² A series of oxidizing 1,000L IBCs were installed as the water quality polishing step (scrubber) after the Tara MSR to increase dissolved oxygen content and remove ammoniacal nitrogen and dissolved sulfide.

Mn Treatment Studies

Other New Zealand projects have evaluated passive treatment of Mn (e.g., Trumm et al., 2017) for the OceanaGold Waihi Operation. Small-scale trials were installed at two locations (TU and L-10) at Waihi with different water chemistries and operated for five months. At the TU site, the water had a pH of 6.0 – 6.4 and contained an average of 20 mg/L of dissolved Fe and 8.5 mg/L of dissolved Mn. One system consisted of a vertical flow reactor (VFR) for Fe removal, followed by a steel slag leaching bed (SLB) for trace element removal, while another system used a VFR followed by a limestone leaching bed (LLB). The VFRs were able to remove up to 98% of the Fe. At the TU site, the SLBs did not raise pH sufficiently for effective Mn removal. Maximum removal was 12% at the TU site and 17% at L-10, with only L-10 showing consistent performance. Limited removal may be due to factors such as microbial Mn oxidisers, autocatalytic oxidation, or Mn oxidation states in the influent.

In contrast, the LLBs outperformed the SLBs made with Melter slag, achieving average Mn removals of 38% (TU) and 26% (L-10). At L-10, where Mn concentrations were high, removal likely occurred via microbial and autocatalytic oxidation, followed by Mn oxide precipitation.

Due to its high solubility, Mn sulfide is not expected to form under the conditions presented in the MSRs but rather as oxides, hydroxides (Stumm & Morgan, 1996), or carbonates (Bamforth et al., 2006). However, these mechanisms are less likely under current conditions. The most plausible Mn removal mechanism is adsorption to Fe hydroxides.

BV-ELF Seepage Manganese Data

Manganese water quality data from the BV ELF are presented in Figure 1 and show a steady decrease in concentrations with time after a maximum of ~0.8 mg Mn/L. A Mn concentration of 0.8 mg/L is lower than the ANZG³ (2018) 95% default guideline value (DVG) of 1.9 mg/L and treatment of this PCOC is not required at these concentrations. However, the current consent condition for the existing Escarpment Mine (RC10193) for Mn (water quality monitoring location W-M2) is coupled with Fe and both PCOC combined cannot exceed 1.1 mg/L.

BPCP Engineered Landform (ELF) Water Quality

Other studies (MWM, 2026b) suggest that ELF (e.g., the WWH catchment) being proposed as part of the BPCP could be 59.7 m high (average height) with a sulfur content of 0.38 wt%. Based on the toolkit developed to estimate ELF seepage water quality (MWM, 2026b) and scaling to address height and sulfur content differences, the Mn concentration in seepage from the WWH ELF catchment could be:

- 4.32 mg/L as a peak decreasing to 2.84 mg/L after 10 years (based on a 7% decay rate); and
- 1.17 mg/L after MSR treatment 10 years after rehabilitation activities are complete.

This suggests active treatment may be required for a period of ~10 years after ELF construction is completed to comply with ANZG (2018) 95% ANZG guidelines for Mn.

³ Australia & New Zealand guidelines for fresh & marine water quality (<https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/search>).

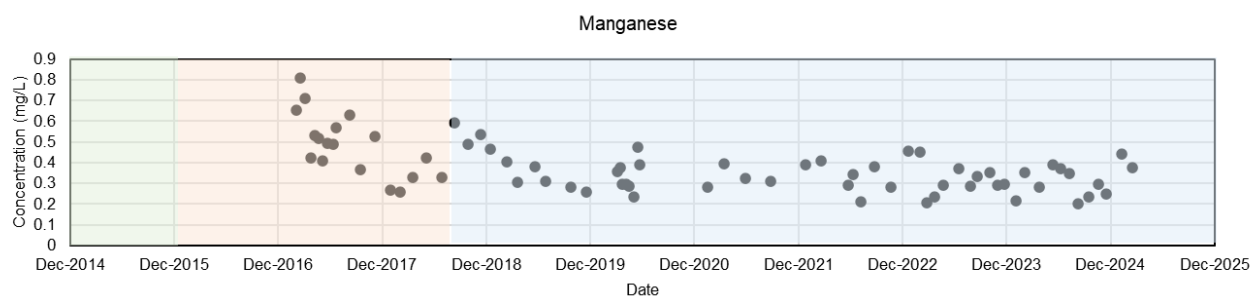


Figure 1: BV-ELF seepage manganese concentrations.

Green shading indicates Phase 1: Construction Phase.

Yellow shading indicates Phase 2: Stabilisation Phase.

Blue shading indicates Phase 3: Decay Phase.

Further details on these phases are provided in MWM (2026b).

Recommendations

The following recommendations are proposed:

- A manganese removal efficiency of 58.6%, based on performance monitoring of the BV-ELF MSR, is proposed as the design basis for MSRs at ESE and MFS under the BPCP. This rate reflects sustained treatment of low to moderate Mn concentrations under site-specific conditions and is considered an appropriate benchmark given the similarities in treatment configuration and long-term operation.
- Further studies may be required to confirm that 58.6% Mn removal efficiencies are reasonable for MSRs planned at ESE and MFS as part of the BPCP. It is recommended this uncertainty is managed by performance monitoring and adaptive management, which will be outlined within the AMD Management Plan.
- Maximum Mn concentrations in seepage from the proposed ESE and MFS engineered landforms are modelled to be up to 4.32 mg/L; even after MSR treatment this could still be higher than the ANZG (2018) 95% DGV of 1.9 mg/L. Active treatment may be required for at least 10 years until Mn concentrations decrease (or other management options are considered). However, other data suggests this PCOC is unlikely to be the limiting factor for transition from active to passive treatment.

CLOSING REMARKS

Please do not hesitate to contact Paul Weber at +64 3 242 0221 or paul.weber@minewaste.com.au should you wish to discuss this matter in greater detail.

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Attachment A - MANGANESE REMOVAL EFFICIENCIES

Barren Valley Mussel Shell Reactor

Sample Date	Manganese Concentrations - Influent (mg/L)	Manganese Concentrations - Effluent (mg/L)	Treatment Efficiency (%)
15/12/2016	-	-	-
20/12/2016	-	-	-
9/01/2017	-	-	-
31/01/2017	-	-	-
17/02/2017	0.529	0.129	75.6
1/03/2017	0.519	0.087	83.2
15/03/2017	0.41	0.06	85.4
30/03/2017	0.494	0.093	81.2
19/04/2017	0.491	0.063	87.2
5/05/2017	0.569	0.039	93.1
16/05/2017	0.628	0.014	97.8
1/06/2017	0.367	0.005	98.6
16/06/2017	0.527	3.42	-549.0
6/07/2017	0.269	0.383	-42.4
18/07/2017	0.257	0.02	92.2
4/09/2017	0.327	0.013	96.0
11/10/2017	0.422	0.005	98.8
30/11/2017	0.328	0.005	98.5
23/01/2018	0.593	0.005	99.2
1/03/2018	0.488	0.078	84.0
13/04/2018	0.537	0.386	28.1
30/05/2018	0.465	0.85	-82.8
5/09/2018	0.304	0.005	98.4
23/10/2018	0.379	0.005	98.7
6/12/2018	0.308	0.005	98.4
9/01/2019	0.28	0.005	98.2
9/03/2019	0.256	0.0079	96.9
17/04/2019	-	-	-
15/06/2019	-	-	-
22/07/2019	-	-	-
20/10/2019	-	-	-
12/12/2019	-	-	-
17/01/2020	-	-	-
24/01/2020	0.355	0.005	98.6
19/02/2020	0.375	0.061	83.7
27/02/2020	0.298	0.005	98.3
12/03/2020	0.298	0.005	98.3
23/03/2020	0.288	0.005	98.3
31/03/2020	0.234	0.005	97.9
9/04/2020	0.474	0.005	98.9
17/04/2020	0.392	0.005	98.7
1/05/2020	0.282	0.047	83.3
12/05/2020	0.393	0.005	98.7
28/05/2020	0.324	0.005	98.5
10/06/2020	0.311	0.0005	99.8
17/06/2020	-	-	-
12/02/2021	0.409	0.428	-4.6
9/04/2021	0.291	0.005	98.3
23/06/2021	0.344	0.006	98.3
20/09/2021	0.21	0.0018	99.1
19/01/2022	0.38	0.005	98.7
15/03/2022	0.28	0.005	98.2
21/06/2022	0.454	1.88	-314.1
7/07/2022	0.449	0.683	-52.1
4/08/2022	0.205	0.011	94.6
19/09/2022	0.233	0.005	97.9
15/11/2022	0.291	0.005	98.3
17/01/2023	0.372	0.005	98.7
27/02/2023	0.288	0.0005	99.8
22/03/2023	0.332	0.0008	99.8
20/04/2023	0.352	0.0007	99.8
18/05/2023	0.291	0.0022	99.2
11/07/2023	0.296	0.0008	99.7
22/08/2023	0.217	0.0015	99.3
15/09/2023	0.353	0.0025	99.3
30/10/2023	0.283	0.006	97.9
27/11/2023	-	-	-
21/12/2023	-	-	-
30/01/2024	0.205	0.0015	99.3
1/03/2024	0.808	0.0025	99.7
20/04/2024	0.385	0.006	98.4
5/06/2024	0.392	0.0062	98.4
4/07/2024	0.372	0.0058	98.4
2/08/2024	0.35	0.007	98.0
4/09/2024	0.2	0.002	99.0
11/10/2024	0.234	0.0031	98.7
12/11/2024	0.296	0.004	98.6
11/12/2024	-	-	-
5/02/2025	-	-	-
13/03/2025	0.375	0.881	-134.9
Average	0.365	0.151	58.6

A hyphen (-) indicates that no data available

Whirlwind Mussel Shell Reactor

Date	Manganese Concentrations - Influent (mg/L)	Manganese Concentrations - Effluent (mg/L)	Treatment Efficiency (%)
1/04/2013	1.55	0.0005	100.0
13/05/2013	1.04	0.053	94.9
27/08/2013	0.9	0.0009	99.9
25/11/2013	1	0.38	62.0
30/01/2014	0.63	0.0021	99.7
29/04/2014	0.66	0.0014	99.8
22/05/2014	0.74	0.0016	99.8
30/06/2014	0.57	0.0024	99.6
28/07/2014	1.07	0.0016	99.9
25/08/2014	0.96	0.0017	99.8
24/11/2014	0.72	0.0008	99.9
25/02/2015	1.45	1.08	25.5
25/05/2015	1.02	0.0039	99.6
31/08/2015	0.9	0.0018	99.8
30/11/2015	0.77	0.0008	99.9
21/01/2016	0.83	0.0016	99.8
22/02/2016	0.74	0.0083	98.9
26/05/2016	0.83	0.0014	99.8
25/08/2016	0.93	0.01	98.9
23/11/2016	1.09	0.0023	99.8
30/05/2017	0.025	0.89	-3460
23/08/2017	2.1	11.6	-452
22/11/2017	1.4	7.2	-414
4/04/2018	0.99	3.2	-223
Average	0.95	1.02	-6.68

A hyphen (-) indicates that no data available

Tara Mussel Shell Reactor

Date	Manganese Concentrations - Influent (mg/L)	Manganese Concentrations - Effluent (mg/L)	Treatment Efficiency (Mussel Shell Reactor Only) (%)
15/03/2023	1.71	0.685	59.9
29/03/2023	1.18	1.01	14.4
17/04/2023	2.38	1.02	57.1
2/05/2023	2.41	1.06	56.0
15/05/2023	1.68	1.53	8.9
17/05/2023	-	-	-
2/06/2023	1.31	1.2	8.4
12/06/2023	1.28	0.947	26.0
3/07/2023	6.25	1.58	74.7
17/07/2023	-	-	-
1/08/2023	1.49	0.92	38.3
15/08/2023	1.47	0.89	39.5
25/08/2023	-	-	-
30/08/2023	0.53	0.94	-77.4
5/09/2023	-	-	-
15/09/2023	0.52	0.82	-57.7
20/09/2023	-	-	-
26/09/2023	0.8	0.9	-12.5
6/10/2023	-	-	-
13/10/2023	1.47	0.79	46.3
20/10/2023	-	-	-
30/10/2023	1	0.88	12.0
15/11/2023	0.86	1.13	-31.4
22/11/2023	-	-	-
29/11/2023	0.8	1.14	-42.5
4/12/2023	-	-	-
15/12/2023	1.46	1.23	15.8
22/12/2023	-	-	-
9/01/2024	1.17	1.50	-28.2
15/01/2024	-	-	-
23/01/2024	-	-	-
1/02/2024	1.13	1.47	-30.1
15/02/2024	0.99	1.38	-39.4
22/02/2024	-	-	-
4/03/2024	0.62	1.34	-116.1
15/03/2024	0.56	1.42	-153.6
21/03/2024	-	-	-
2/04/2024	0.54	1.23	-127.8
8/04/2024	-	-	-
17/04/2024	1.03	1.18	-14.6
22/04/2024	-	-	-
1/05/2024	0.52	1.07	-105.8
8/05/2024	-	-	-
15/05/2024	0.46	0.78	-69.6
22/05/2024	-	-	-
31/05/2024	0.51	0.79	-54.9
7/06/2024	-	-	-
14/06/2024	2.9	0.62	78.6
21/06/2024	-	-	-
2/07/2024	-	-	-
15/07/2024	1.19	0.83	30.3
22/07/2024	-	-	-
Average	1.34	1.08	19.7

A hyphen (-) indicates that no data available

Tara Mussel Shell Reactor Scrubber System

Date	Manganese Concentrations - Effluent (mg/L)	Scrubber System - Effluent (mg/L)	Treatment Efficiency (Mussel Shell Reactor Effluent and Scrubber System Effluent) (%)
15/03/2023	0.685	0.7	-2.2
29/03/2023	1.01	1.05	-4.0
17/04/2023	1.02	1.04	-2.0
2/05/2023	1.06	1.02	3.8
15/05/2023	1.53	1.34	12.4
17/05/2023	-	-	-
2/06/2023	1.2	1.02	15.0
12/06/2023	0.947	1.03	-8.8
3/07/2023	1.58	0.787	50.2
17/07/2023	-	-	-
1/08/2023	0.92	0.95	-3.3
15/08/2023	0.89	0.81	9.0
25/08/2023	0.95	0.84	11.6
30/08/2023	0.94	0.98	-4.3
5/09/2023	0.8	0.77	3.8
15/09/2023	0.82	0.43	47.6
20/09/2023	0.75	0.054	92.8
26/09/2023	0.9	0.031	96.6
6/10/2023	0.65	0.021	96.8
13/10/2023	0.79	0.59	25.3
20/10/2023	0.77	0.137	82.2
30/10/2023	0.88	0.34	61.4
15/11/2023	1.13	0.182	83.9
22/11/2023	1.2	0.17	85.8
29/11/2023	1.14	0.48	57.9
4/12/2023	1.18	0.11	90.7
15/12/2023	1.23	0.31	74.8
22/12/2023	1.2	0.17	85.8
9/01/2024	1.5	4.3	-187
15/01/2024	-	-	-
23/01/2024	1.67	1.48	11.4
1/02/2024	1.47	0.61	58.5
15/02/2024	1.38	0.92	33.3
22/02/2024	1.38	0.87	37.0
4/03/2024	1.34	0.88	34.3
15/03/2024	1.42	0.77	45.8
21/03/2024	1.35	0.66	51.1
2/04/2024	1.23	0.63	48.8
8/04/2024	1.29	0.31	76.0
17/04/2024	1.18	0.47	60.2
22/04/2024	1.19	0.39	67.2
1/05/2024	1.07	0.98	8.4
8/05/2024	0.97	1.13	-16.5
15/05/2024	0.78	0.69	11.5
22/05/2024	0.8	0.9	-12.5
31/05/2024	0.79	0.55	30.4
7/06/2024	0.65	0.75	-15.4
14/06/2024	0.62	0.78	-25.8
21/06/2024	0.6	0.7	-16.7
2/07/2024	-	-	-
15/07/2024	0.83	0.84	-1.2
22/07/2024	0.8	0.73	8.8
Average	1.05	0.74	29.3

A hyphen (-) indicates that no data available

APPENDIX E MSR TREATMENT - SECONDARY CONTAMINANTS

MEMORANDUM

Recipient: [REDACTED]

From: [REDACTED]

Date: 20 July 2026

Cc: [REDACTED]

Document Number: J-NZ0349-010-M-FINAL

Document Title: MSR – Secondary Contaminants

Bathurst Resource Limited (BRL) is seeking to obtain authorisation through the Fast-track Approvals Act 2024 (FTAA) to progress development and mining of the coal resources across the wider Buller Plateaux. This project is referred to as the Buller Plateaux Continuation Project (BPCP or Project). Mine Waste Management Limited (MWM) has developed this memorandum to support BRL with the assessment of environmental effects (AEE) for the BPCP.

OBJECTIVES

The objectives of this memorandum are to:

- Review previous data on mussel shell bioreactor (MSR) treatment and secondary contaminants (i.e., potential constituents of concern [PCOC]).
- Summarise data and potential effects associated with secondary contaminants.

BACKGROUND

The Barren Valley Engineered Landform (BV-ELF) Mussel Shell Reactor (MSR) has been successfully operating at the existing Escarpment Mine for > 7 years (MWM, 2026a).

Additional assessment is required for secondary contaminants generated by the MSR including sulfide (HS⁻), ammoniacal nitrogen (Amm-N), nitrate, biochemical oxygen demand (BOD), and dissolved organic carbon (DOC). These data are compared to the existing available data from the Tara and Whirlwind MSRs to provide insight into secondary contaminants and management methods for these PCOC.

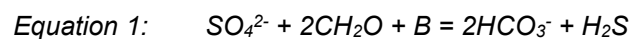
MSR PERFORMANCE ASSESSMENT

Table 1 presents effluent water quality data for secondary contaminants (HS⁻, Amm-N, nitrate, BOD, and DOC) from the BV-ELF MSR and compares it to the existing data from the Tara and Whirlwind MSRs. Inflow concentrations are not reported. Although the available effluent datasets are limited, the key observations were:

- Total Amm-N concentrations were typically orders of magnitude higher in the Tara MSR than in the Whirlwind and the BV-ELF MSR.
- Average nitrate-N and nitrite-N concentrations in discharge from the Whirlwind and BV MSR were similar:
 - **BV MSR:** 0.32 mg/L (nitrate-N) and 0.01 mg/L (nitrite-N).
 - **Whirlwind MSR:** 0.41 mg/L (nitrate-N) and 0.01 mg/L (nitrite-N).
- Total effluent nitrogen concentrations in the Tara MSR were higher than the BV-ELF MSR with average concentrations being 8.57 mg/L and 0.33 mg/L respectively.
- Average effluent DOC concentrations in the BV MSR (0.33 mg/L) were lower than those observed from the Whirlwind (1.10 mg/L) and Tara MSR (7.59 mg/L).
- Similarly to DOC, both average total sulfide screen and H₂S concentrations were orders of magnitude lower in the BV MSR (0.002 mg/L and 0.05 mg/L respectively) than in the Tara MSR (4.86 mg/L and 0.69 mg/L respectively). The Whirlwind MSR had no sulfide data available.

One explanation for the higher efficiencies exhibited in the Tara MSR is that it used both weathered and fresh shells (direct from the seafood processing factory) for its reactive treatment media resulting in higher sulfate reducing bacteria (SRB) activity. The Whirlwind MSR and BV MSR used weathered shells that had been stockpiled for 10+ years prior to placement in the reactor. It was assumed that the weathered materials had sufficient carbon to facilitate SRB activity. However, the data shows that fresh shells (Tara MSR) generate higher DOC concentrations compared to weathered shells (BV MSR).

Therefore, higher DOC will enable higher concentrations of HS⁻, a primary driver for the formation of metal sulfides such as FeS₂ (pyrite) and (Zn,Fe)S (Wurtzite):



SUMMARY

Hydrogen sulfide is a key component of anaerobic passive treatment and facilitates the precipitation of sulfide minerals removing metals such as Fe, Zn, and Ni. Hence, MSR need to ensure labile organic carbon is available to enable Equation 1 to proceed. This can be achieved by two potential processes, amongst others:

1. Use fresh shells to increase organic carbon availability; however, this is unlikely to sustain long-term carbon demand without maintenance or replacement.
2. Add organic carbon (e.g., acetic acid) to the MSR to promote SRB activity (e.g., enhanced passive treatment systems (E-PTS)) to increase the rates of Ni and Zn removal (e.g., Christenson et al., 2018).

However, data presented in Table 1 indicates that sulfide and nitrogenous compounds (nitrate and Amm-N) can be elevated in MSR effluent and could be above proposed consent conditions for the BPCP. Treatment of these secondary contaminants may be required. Further discussion on how these will be managed is provided in MWM, (2026b). Noting: BRL have experience in managing these

secondary contaminants at the Canterbury Coal Mine (i.e., the Tara MSR) and further information and data are available on this process (MWM, 2026c).

Table 1: MSR effluent secondary contaminants.

PARAMETER	TARA MSR (JANUARY 2022 - JANUARY 2024)			BV MSR (MARCH 2024 - JULY 2024) ¹			WHIRLWIND MSR (SEPTEMBER 2012 - JUNE 2023)		
	MIN	AVE	MAX	MIN	AVE	MAX	MIN	AVE	MAX
Total Amm-N	0.680	3.66	13.9	0.01	0.02	0.03	0.01	0.29	7.70 ²
Nitrate-N	0.002	0.08	2.40	0.03	0.32	0.58	0.002	0.41	5.20 ²
Nitrite-N	0.002	0.005	0.01	0.01	0.01	0.01	0.002	0.01	0.09
Nitrate-N + Nitrite-N	0.002	0.025	0.36	0.04	0.33	0.59	0.002	0.41	5.20 ²
Total Nitrogen	4.47	8.57	11.6	0.229	0.33	0.51	-	-	-
DOC	4.90	7.59	10.0	0.10	0.29	0.7	0.20	1.10	8.40 ³
BOD	1.00	2.66	8.00	-	-	-	-	-	-
Total sulfide screen	0.002	4.86	31.0	0.002	0.002	0.002	-	-	-
H ₂ S	0.002	0.69	5.70	0.05	0.05	0.05	-	-	-

All concentrations are shown in mg/L.

The dates shown for each MSR present the date ranges for the parameters shown.

A hyphen (-) indicates no data are available.

1 - The BV MSR uses all available data where applicable. Data for the BV MSR is limited due to a small dataset (data count ranges from 1 – 7 samples).

2 – A period of elevated nitrogen was identified in the dataset. This lasted for ~2 years (2016-2017) and is likely to be related to the temporary storage of biosolids in the catchment. Data were more comparable to BV MSR for the other time periods (i.e., total nitrogen < 0.5 mg/L) demonstrating nitrogenous compounds were low.

3 – Anomalous data identified contributing to spikes in DOC.

Note: laboratory results have not been provided. Data have been downloaded from the BRL database for the Canterbury Coal Mine.

DISCUSSION

The generation of secondary contaminants due to the treatment of AMD by MSR are likely to be variable and a function of labile organic matter, bacterial communities, temperature, nutrients, hydraulic residence time, media age, and MSR management processes. Once operational MSR trials are established a comprehensive monitoring programme needs to be established to understand MSR treatment efficiencies and influent and effluent concentrations for secondary contaminants.

The management of MSR effluent and the treatment of these secondary contaminants will be addressed by oxidation of the MSR effluent in a polishing pond. The details of this system are provided in the Water Management Plan. A standard operating procedure (SOP) will be developed for the operation of MSRs. This SOP will include a trigger action response plan (TARP) for any variance from the expected case to ensure water quality objectives are achieved.

CLOSING REMARKS

Please do not hesitate to contact Paul Weber at +64 3 242 0221 or paul.weber@minewaste.com.au should you wish to discuss this matter in greater detail.

REFERENCES

- Christenson, H., Weber, P., Pope, J., Newman, N., Olds, W., & Trumm, D., 2018. Enhanced passive treatment systems: addition of nutrients to bioreactors. In AusIMM New Zealand Branch Annual Meeting, Tauranga, AusIMM NZ Ltd (pp. 97-104).
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- MWM (Mine Waste Management), 2026b. Passive Treatment System Design Toolkit - Buller Plateaux Continuation Project. Mine Waste Management Report J-NZ0453-005-R-FINAL.
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APPENDIX F ESCARPMENT MINE MSR MAINTENANCE SUMMARY

20 July 2026

J-NZ0349-005-L-FINAL



Escarpment Mine MSR Maintenance Summary

Mine Waste Management Limited (MWM) has prepared this letter to provide Bathurst Resources Limited (BRL) with a summary of the maintenance requirements for the Barren Valley Mussel Shell Reactor (BV-MSR) that is currently operating at the existing Escarpment Coal Mine and consider maintenance requirements for MSR associated with the proposed Buller Plateaux Continuation Project (BPCP or Project) based on these data.

OBJECTIVES

The objectives of this letter are to:

- Review MSR performance.
- Provide recommendations for maintenance (e.g., desludging and shell replacement/top-up).
- Provide guidance on BPCP MSR AMD desludging requirements.

BACKGROUND

The BV-MSR, used for the passive treatment of AMD¹ impacted waters from the Barren Valley engineered landform (BV-ELF) is located on the south-eastern edge of the Dennison Plateau, a historic underground mining area that recently had a small opencast phase of mining (the existing Escarpment mine). The BV-MSR was installed by BRL as an operational trial to confirm the technologies suitability for AMD impacted waters at the site.

The BV-MSR has been in operation since September 2016, which is when the existing Escarpment mine was placed into care and maintenance. The initial design criteria for the BV-MSR were the treatment of influent acidity from the BV-ELF, treatment of the acidity in Pit 3 (low pH) by MSR effluent alkalinity, and minimal ongoing maintenance costs. This required minimising sediment input into the MSR to prevent clogging of pore space leading to decreased permeability and treatment capacity (Robertson et al., 2017).

The BV-ELF has an engineered underdrain that captures net percolation into the facility with discharge to the BV-ELF toe pond that ensures the underdrain remains flooded (thereby limiting oxygen ingress into the BV-ELF). The majority of the underdrain flow (excluding higher rainfall events) is diverted to

¹ Acid and Metalliferous Drainage

the BV-MSR for treatment. Flow measurements indicate that underdrain outflow is approximately 3.35 L/sec. Effluent from the BV-MSR is discharged to Pit 3, which has a storage capacity of approximately 200,000 m³ and now represents a filled (and overflowing) pit lake that discharges to the nearby water course. A location map of these facilities is provided in Figure 1.

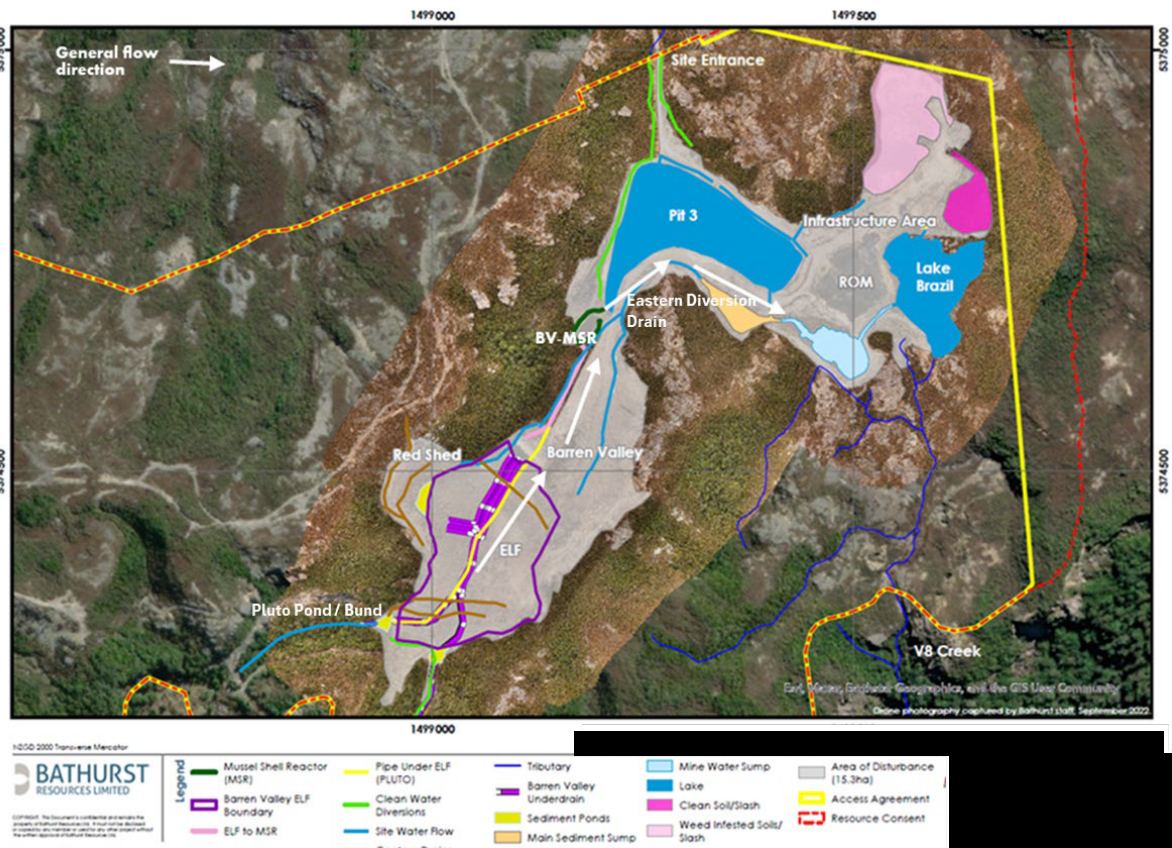


Figure 1: Escarpment Mine conceptual site model.

BV-MSR EFFLUENT ALKALINITY AND PIT 3

The BV MSR effluent discharge to Pit 3 has had a positive effect on Pit 3 water quality (Figure 2). Since the construction of the BV MSR, approximately 112.9 mg CaCO₃/L of alkalinity has been introduced into Pit 3.

Results show that pH remained low due to acidity inputs from the pit void between February 2016 and November 2016. From December 2016 onwards an increase in pH can be observed from 4.0 to 7.9 due to the introduction of alkalinity from the MSR.

The BV MSR effluent provides an alkalinity load of 11.9 t/yr based on a constant flow rate of 3.35 L/s (assumed) and an alkalinity concentration of 112.9 mg CaCO₃/L. This has contributed to an increase in the pH of Pit 3. However, alkalinity concentrations have decreased in Pit 3 after a high of 40 mg CaCO₃/L in February 2021. The only source of alkalinity in the catchment is the BV-MSR effluent. Hence, the observed decline in alkalinity might be attributed to lesser flow through the MSR (due to a decreased permeability due to AMD sludge formation).

To determine if a lower MSR permeability was the cause of a drop in alkalinity in Pit 3, the BV-MSR was desludged (discussed in MWM, 2026a) and monitoring was continued to assess performance. This also provided an opportunity to obtain data on sludge volumes for the BPCP.

RESULTS

Data indicates that since the BV-MSR was desludged on 15 February 2024, alkalinity concentrations in Pit 3 have remained stable but have not returned to the peak levels recorded in 2021 (Figure 2). These data suggest the decrease in alkalinity in Pit 3 is unlikely to be due to the MSR permeability and lesser treated AMD. Other unidentified mechanisms are contributing to this peak in alkalinity.



Figure 2: pH and alkalinity values from the MSR to Pit 3.

Source: BRL 51279_RPT_Water (water quality excel database).

The dashed black line represents the date that the BV MSR was desludged (15 February 2024).

The alkalinity concentrations in Pit 3 could be used as a benchmark or reference point to determine the maintenance frequency needed for the BV-MSR. Data suggests minimal maintenance for the BV ELF MSR with maintenance every 7 years being a reasonable timeframe. However, the fact that Pit 3 remained circum-neutral suggests a longer maintenance period might be applicable if alkalinity was the only performance metric.

MSR MAINTENANCE EXPECTATIONS: BPCP

Understanding maintenance requirements of MSR for the BPCP will be important for understanding operating costs and water treatment efficiencies. All BPCP MSR are designed based on the flow rate, with 1 L/s being treated by 100 m² of MSR surface area and 1 day Hydraulic Residence Time. Differences in concentration (e.g., Fe and Al) will drive desludging frequency with higher concentrations of Fe and Al leading to more regular desludging.

Data indicates that the BV-MSR did not require desludging for 7 years and a longer period may have been suitable to maintain the pH of Pit 3. However, other data suggest that Zn removal was lesser after 6 years (MWM, 2026a). A conservative approach is used to assess maintenance requirements and 5 years is proposed as a reasonable timeframe for MSR AMD sludge removal.

Studies of the BV MSR AMD sludge (MWM, 2026a) indicated that the depth of the Fe sludge layer was 104 mm and the Al layer was 110 mm thick, totalling a depth of 214 mm. Given that Zn can be mobilised from this Al layer it is recommended that both Al and Fe layers are removed during desludging. For the BV MSR (350 m²) this is equivalent to ~75 m³ of sludge after 7 years.

The BV ELF MSR was used as an analogue model to forecast the sludge generation rates for the proposed BPCP MSR (based on an average annual acidity load of ~10 t/yr and 75 m³ of AMD sludge being produced (assumed to be over 5 years²)). These data are presented in Table 1. Analysis indicates that 0.75 m³ of MSR AMD sludge is generated per tonne of acidity. This is significantly less than active treatment AMD sludge that can range from 20-40 m³/t acidity due to a lower sludge density and a large sediment component (e.g., total suspended solids [TSS]).

Table 1: BPCP MSR desludging requirements.

BPCP SUB-AREA	ELF	MSR ACTIVATION DATE	MSR DESIGN ACIDITY (t/yr) ¹	MSR SURFACE AREA (m ²) ¹	SLUDGE QUANTITY AFTER 5 YEARS (m ³)	SLUDGE THICKNESS AFTER 5 YEARS (mm)
-	BV ELF	-	10	350	74.9	214
ESE	BVE	2058	38.2	1,537	286	186
ESE	CON	2058	174.4	8,339	1,308	157
ESE	NSUL	2046	5.1	1,994	39	19
ESE	PPG	2058	0.1	306	1	3
ESE	WWH	2058	299.1	12,991	2,243	173
ESE	ESC	2030	11.9	245	89	363
MFS	MSR1	2045	11.2	512	84	165
MFS	MSR2	2045	2.7	128	20	159
MFS	MSR3	2045	3.8	345	28	82
MFS	MSR4	2045	16.1	345	121	351
MFS	MSR5	2045	24.2	1,582	182	115
MFS	MSR6	2045	5.3	375	39	105
MFS	MSR7	2045	28.5	1,683	214	127
MFS	MDC1	2029	0.1	49	0.7	15
MFS	MDC2	2038	0.1	42	0.4	10
MFS	MSR8	2047	43.3	2,644	325	123
MFS	MSR9	2047	5.1	331	38	115
MFS	MSR10	2047	2.7	204	20	98
MFS	MSR11	2029	8.6	244	65	265
MFS	MSR12	2029	8.9	244	67	274
Total					5,170	

1. Data from MWM (2026b). Acidity loads are based on the activation date of the MSR as per the water and load balance models.

² This generates a conservative value for sludge formation as the system had been operating for 7 years.

Data indicates that the quantity of sludge generated after 5 years is highly variable and is a function of the influent acid load, normalised against the BV ELF MSR. A total of 5,170 m³ of sludge will be generated annually once all MSR are operating (although there will be a decline in loads of at least 0.62% per year) from the start date of the MSR so this is a conservative value.

Results indicate that after 5 years the sludge thicknesses in each MSR are comparable to the BV ELF MSR, hence flow rates are assumed to be reasonable. Performance monitoring is required to validate this desludging interval.

Due to the down-flow configuration of the MSR there is no need to rebuild the MSR. The original capital construction costs do not need to be replicated for ongoing maintenance. It is recommended that during any sludge removal campaign that additional shells are used to replace those removed to minimise equipment mobilisation costs.

DISCUSSION

Although, the data presented in this study are based on one datapoint (i.e., one desludging event). Other MSR desludging activities have been undertaken for the Whirlwind MSR at Stockton Mine that provide confidence that the approach is operationally feasible.

Desludging of MSR will continue until water quality is suitable for release from engineered landforms without treatment. This is anticipated to be many decades after mine closure. Decommissioning of the MSR need to be addressed at this point and could include complete removal and/or conversion into a wetland to provide ecological services. If the MSR is to be converted into a wetland then further studies are required.

The operation of MSR will be addressed by the AMD Water Management Plan (BRL, 2026) and a management process will be developed.

CLOSING REMARKS

Please do not hesitate to contact Paul Weber at +64 3 242 0221 or paul.weber@minewaste.com.au should you wish to discuss this matter in greater detail.

REFERENCES

BRL (Bathurst Resources Limited), 2026. AMD Water Management Plan. Bathurst Resources Limited Document: BPCP-ENV-PLN-010.

MWM (Mine Waste Management), 2026a. Mussel Shell Reactor Performance Review - Buller Plateaux Continuation Project. Mine Waste Management Report: J-NZ0349-003-R-FINAL.

MWM (Mine Waste Management), 2026b. ELF Water Quality and MSR Design Summary - Buller Plateaux Continuation Project. Mine Waste Management Report: J-NZ0453-006-R-FINAL.

Robertson, C., Weber, P., & Olds, W., 2017. AMD Passive Treatment System: A Case Study—Escarpment Mine, Denniston Plateau. In New Zealand Annual AusIMM Branch Conference, The Australasian Institute of Mining and Metallurgy, Melbourne, pp. 243-252.

APPENDIX G MSR SLUDGE TRIALS

MEMORANDUM

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

Date: 20 July 2026

Cc:

[REDACTED]

Document Number: J-NZ0349-019-M-FINAL

Document Title: MSR Sludge Trials

Bathurst Resources Limited (BRL) is seeking to obtain authorisation through the Fast-track Approvals Act 2024 (FTAA) to progress development and mining of the coal resources across the wider Buller Plateaux. This project is referred to as the Buller Plateaux Continuation Project (BPCP or Project). Mine Waste Management Limited (MWM) has been engaged to support BRL with the assessment of environmental effects (AEE) for the BPCP.

This memorandum was developed to understand the potential implications of adding AMD sludge from the Barren Valley ELF Mussel Shell Reactor (BV-MSR) to the Pit 3 Pit Lake. The purpose is to assess feasibility of underwater storage of acid and metalliferous drainage (AMD) sludge, derived from a MSR in this pit lake and consider the viability of underwater sludge storage as an option in future pit voids as part of the BPCP.

OBJECTIVES

The objectives of this memorandum are to:

- Summarise the laboratory results for the BV-MSR sludge and mixing tests with Pit 3 water.
- Evaluate the potential water quality impacts of introducing BV-MSR sludge into Pit 3 Pit Lake to inform the suitability of sludge disposal in future pit voids associated with the proposed BPCP.

BACKGROUND

Treatment of AMD by active treatment technologies (e.g., CaO dosing) and passive treatment technologies (e.g., MSR) generates AMD sludge (often elevated in Fe and Al and other trace metals) that requires disposal. During the operational phase, AMD sludge will be disposed with mine waste as backfill within the proposed engineered landforms (ELFs). This approach is discussed in further details in MWM (2026a). Following closure and rehabilitation of the ELFs, alternate disposal options for AMD sludge are required as these mine domains will not be available.

One disposal option is the placement of AMD sludge within flooded pit voids, which will require an assessment of its potential environmental effects. One identified risk is remobilisation of potential constituents of concern (PCOC) from the AMD sludge. This could occur under oxic conditions

(dissolution) and also sub-oxic conditions (redox sensitive dissolution of metals such as Fe and its adsorbed PCOC) at the bottom of a pit lake due to thermal/density stratification. Remobilisation risks for PCOC can vary depending upon whether the pit lake is permanently or seasonally stratified.

PREVIOUS STUDIES

Previous studies (MWM, 2026b) have been conducted on the water quality of the BV-MSR sludge to understand the environmental risks for disposal. A site visit to the existing Escarpment Mine was undertaken by MWM on the 15 February 2024 to assess the BV MSR. The following activities were completed:

- Three test pits were hand excavated into the BV-MSR (approximately 200 mm x 400 mm). The reactive layers (Figure 1) in each test pit were sampled providing nine samples for laboratory testing. Depth and sample profiles for each reactive layer are shown in Table 1. These included:
 - Fe-rich zone (orange zone).
 - Al-rich zone (white zone) but often including an overlapping orange Fe layer.
 - H₂S-rich zone (black zone).
- Nine sludge samples collected from the test pits were sent to SGS Laboratories for the analysis of acid neutralising capacity (ANC), sulfate, pH, EC, acidity (to pH 8.3), and synthetic precipitation leaching procedure (SPLP) for dissolved metal content (Al, Fe, Pb, Mn, Ni, Zn, Ca, Mg, Cd, and Cu).

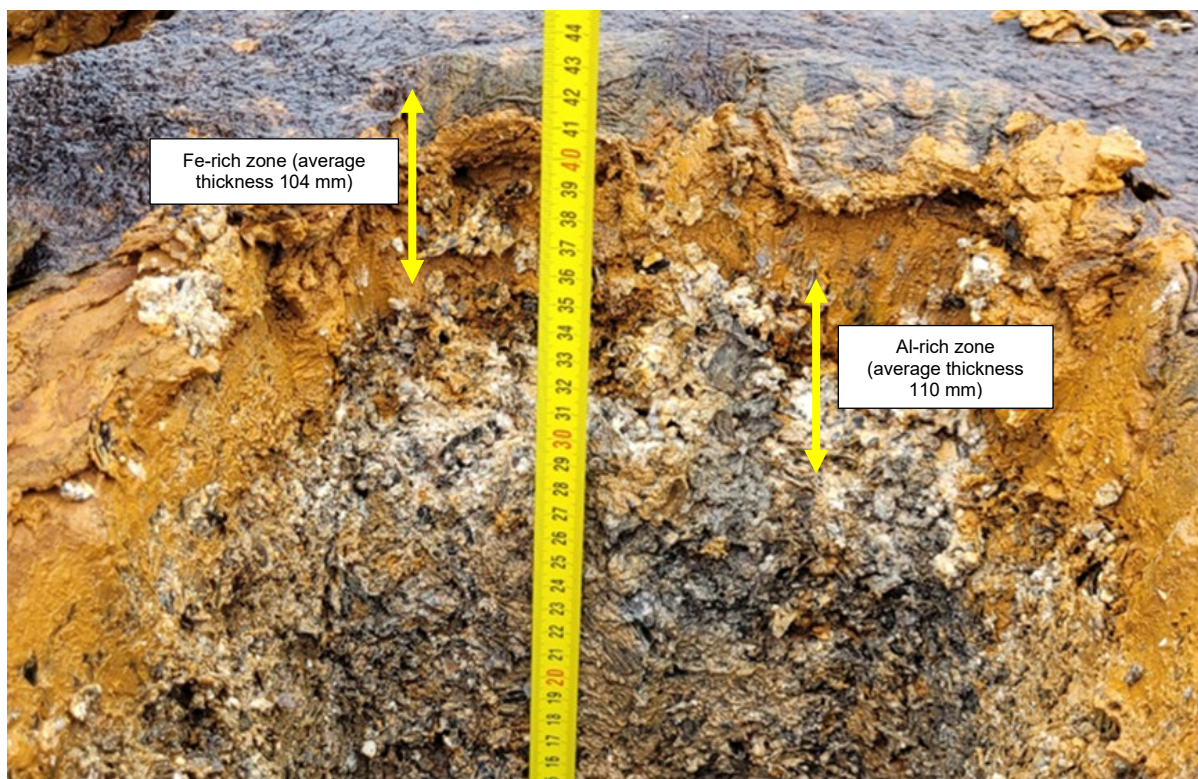


Figure 1: MSR AMD Sludge and Fe + Al precipitation zones within the BV-MSR.

Note: Draining the MSR resulted in the filamentous algae drying out as a thin black layer on the sludge surface (pictured).

Table 1: BV-MSR sample descriptions.

TEST PIT	SAMPLE NAME	PRECIPITATE LAYER DEPTH (mm below surface level)	SAMPLE COLLECTION (mm below surface level)
Test Pit 1	ESC_MSR_TP1_Fe	0 – 90	20 – 80
	ESC_MSR_TP1_Al	90 – 150	110 – 150
	ESC_MSR_TP1_H ₂ S	150 – 420	300 – 420
Test Pit 2	ESC_MSR_TP2_Fe	0 – 110	20 – 100
	ESC_MSR_TP2_Al	110 – 265	110 – 250
	ESC_MSR_TP2_H ₂ S	265 – 370	280 – 370
Test Pit 3	ESC_MSR_TP3_Fe	0 – 125	20 – 120
	ESC_MSR_TP3_Al	125 – 265	140 – 250
	ESC_MSR_TP3_H ₂ S	265 – 410	300 – 410

Note: The precipitate zone depths are only approximate as they generally graded into each other.

The following is a summary of the test results. Full analytical details and results from the sludge analyses are presented in MWM (2026b). Key observations from the laboratory results are summarised below:

- ANC data for the Fe-rich zone are negative ranging from -33 to -40 kg H₂SO₄/t equivalent, which is also supported by paste pH values ranging from pH 2.6 – 2.8 demonstrating significant stored acidity within the materials. These paste pH values are lower than the average MSR influent pH of 3.36, suggesting the formation of reactive acidic salts that have contributed to stored acidity. This has implications for sludge management, as the drying out of this material could generate significant acidity (e.g., 33 – 40 kg H₂SO₄/t). This acidity is likely to be offset by ANC within the Al-rich zone where shells are present.
- ANC data for the Al-rich zone ranged from 20 to 129 kg H₂SO₄/t, suggesting significant depletion of the ANC (e.g., dissolution of the shells) within this zone, yet some ANC remained. This suggests that removal of the Al-rich layer during desludging is also beneficial to enhance the performance of the MSR. Paste pH data ranged from 6-7, indicating no significant acidic salts were present in this zone.
- ANC data for the H₂S-rich zone ranged from 195 to 560 kg H₂SO₄/t and that paste pH ranged from 7.3 – 7.9. Data suggests no significant acidic salts were present and that a reasonable reservoir of ANC remains at the depths tested. Variability in the ANC data at depth suggests preferential flow paths where some areas have treated more acidity than other areas.
- The Fe-rich zone had a moisture content that ranged from 75.1 - 78.5 wt% with an average of 76.6 wt%. The Al-rich and H₂S-rich zones had lower moisture content (66.0 wt% and 49.1 wt% respectively).

SPLP test data indicated the following:

- High acidities for the samples from the Fe-rich zone ranging from 560 to 690 mg CaCO₃/L, which are much greater than average influent acidity of 119 mg CaCO₃/L. Such data confirms

the results obtained from the paste pH and ANC testing, e.g., stored acidic salts are present in this zone.

- Compared to the Fe-rich zone, measured acidities are significantly lower in the Al-rich zone and the H₂S-rich zone by an order of magnitude, which also agrees with paste pH and ANC data for these zones.
- Al remains high (38 – 51 mg/L) in all samples obtained from the Fe-rich zone, which is higher than the influent concentrations of 11 mg/L. This suggests the dissolution of secondary minerals containing Al, most likely a function of the low pH of the SPLP test for these samples. Al is slightly elevated in the H₂S-rich zone for two samples; the mechanism for this is unclear and may be an artifact of the test process as Al is low in BV-MSR effluent.
- Cd, Cu, and Mn concentrations remain variable across all depths and test pits.
- Pb, Ni, and Zn generally decrease with depth suggesting lesser contaminants at depth.

WATER QUALITY ANALYSIS

A metal ecotoxicity quotient (MEQ) was used to identify PCOC that may be elevated with respect to water quality guidelines, compliance limits, or trigger values that manage ecotoxicity risks (Weber and Olds, 2016).

For this memorandum, water quality data were assessed against the water quality consent conditions (RC10193) for the existing Escarpment Mine as reference values (Table 2). These water quality consent conditions were developed in 2013 for downstream monitoring site WM-2, so are not directly applicable. However, they are a good local guide for understanding water quality.

The MEQ value for a PCOC is determined by dividing the measured maximum concentration by the water quality reference values (WQ Ref Value). MEQ values greater than 1 indicate parameters that exceed the relevant reference values. Conversely, MEQ values less than 1 are below the relevant reference values. If any contaminants are within 50% of the reference values (i.e., $1 > \text{MEQ} \geq 0.5$) they are considered potentially elevated (and are noted as being potentially elevated in this report) and ongoing monitoring is recommended to confirm trends and/or potential hazards. This approach is similar to using 50% of maximum acceptable value (MAV) for drinking water where it is used as a screening level for follow up action (Taumata Arowai, 2022).

MEQ data are colour coded for ease of analysis and data interpretation where:

- **Red MEQ** indicates that concentrations exceed the reference values or similar guidelines.
- **Orange MEQ** indicate MEQ between ≤ 1.0 and ≥ 0.5 (i.e., potentially elevated).

No hardness modifications were applied to data as this was a screening assessment. For the purposes of this memorandum, the reference values applied were for a median pH >5.5 .

For this memorandum, the MEQ as calculated using the consent conditions at the existing Escarpment Mine (RC10193) as reference values. This differs from previous reports where the guideline values were used for parameters without consent values.

Table 2: Median consent limits at monitoring site W-M2 (Escarpment Mine) (RC10193).

PARAMETER	WQ REF VALUE (DISSOLVED)	
pH (pH units)	4.5 – 6.5	
	Median Concentrations	
Total suspended solids (mg/L)	15	
Turbidity (NTU)	15	
Iron + manganese (mg/L)	1.1	
Aluminium (mg/L)	0.5	
Median pH	pH > 5.5	pH < 5.5
Cadmium (mg/L)	0.0003	0.0012
Chromium (mg/L)	0.05	0.20
Cobalt (mg/L)	0.044	0.18
Copper (mg/L)	0.002	0.0013
Lead (mg/L)	0.0065	0.026
Nickel (mg/L)	0.017	0.068
Zinc (mg/L)	0.012	0.054

Limits for cadmium, copper, chromium, lead, nickel, and zinc are based on a median water hardness of 50 mg CaCO₃/L.

MUSSEL SHELL REACTOR SLUDGE TRIALS

This section outlines the methodology and setup of sludge trials conducted by Verum Laboratory, using materials supplied by BRL and coordinated by MWM. Further details of the sampling and analysis methodology are provided in the laboratory certificate of analysis provided in Attachment A.

Methodology

On 14 June 2024, the following materials were sent to Verum:

- 4 x 20 L bucket of Pit 3 Pit Lake water.
- 1 x 20 L bucket of BV-MSR sludge.

To ensure representative sub-samples were taken, the 20 L sludge sample was spread onto a flat surface then manually mixed. Large mussel shell fragments were broken down using a plastic tool. Once a consistent colour and particle size were observed, the sludge was evenly spread and divided into a 3 × 3 grid. Prior to mixing with Pit 3 Pit Lake water, the sludge sample was analysed for ANC, SPLP, and solids were combined from the centre of each grid section. The remaining sludge was returned to the original container for use in the leaching trials.

The leaching experiments followed the protocol provided by MWM, with the following procedure:

1. **Water Conditioning:** The four buckets of Pit 3 Pit Lake water were mixed and aerated until stable pH, EC, and saturated dissolved oxygen (DO) levels were recorded. Once stable, sub-samples of the water were collected for baseline analysis.
2. **Sludge-Water Mixing:** Sludge was weighed into separate buckets, and 20 L of the conditioned lake water was added to each, as per the volumes listed in Table 3 .
3. **Settling Period:** Each mixture was stirred vigorously for one minute, then left to settle undisturbed for 24 hours.

4. **Sampling:** After 24 hours, the supernatant water from each bucket (Figure 2) was sampled for and analysed for (metals, metalloids, nutrients and nitrogen species, and other inorganics).

The pit lake water-sludge experiments were designed to assess the short-term mobility of primary PCOC metals and changes in water chemistry. Secondary components, DOC, nitrogen species, and sulfur species were not measured in these initial trials, as they were considered less critical for the oxic surficial MSR sludge materials. As noted in SPLP test results (Table 4) ammoniacal nitrogen and sulfide sulfur were low and would be low in other oxic tests.

Table 3. Sludge weight and water volumes in each experimental bucket.

BUCKET	SLUDGE WEIGHT (g)	WATER VOLUME (L)
1	-	20
2	104	20
3	502	20
4	1,002	20

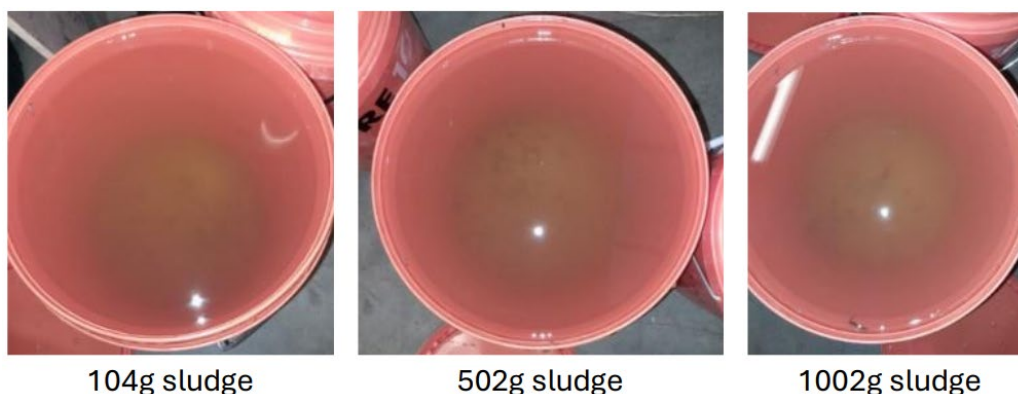


Figure 2: Pit 3 Pit Lake water mixed with different weights of sludge, after 24 hours of settling.

Laboratory Results

This section summarises the laboratory results of the BV-MSR sludge prior to mixing, as well as the results of the sludge and Pit 3 Pit Lake water mixing trials.

BV-MSR Sludge SPLP Leachate:

This section summarises the results of the SPLP conducted on the BV-MSR sludge sample to evaluate the potential leaching of PCOC. The SPLP test followed a modified US EPA Method 1312, using distilled water as the extractant to simulate leaching behaviour. Table 4 presents the SPLP leachate results, comparing the BV-MSR sludge sample to a distilled water blank. The following observations were made:

- Several parameters increased in concentration relative to the blank, suggesting potential mobility. These included:
 - Manganese increased by 0.329 mg/L.
 - Total silica increased by 0.750 mg/L.
 - Nitrate + nitrite-N increased by 0.247 mg/L.
 - Cobalt increased by 0.0056 mg/L.
 - Ni increased by 0.00585 mg/L.

- The following parameters decreased in concentration:
 - Copper decreased by 0.0002 mg/L.
 - Zinc decreased by 0.0019 mg/L.
- Parameters (e.g., As, B, Cd, Cr, Fe, Hg, Pb, Sb, Se, and Sn) showed no measurable difference between the blank and the leachate sample. This is attributed to results being below the laboratory limit of reporting (LOR) or no detectable leaching under the test conditions.
- No parameters were reported as exceeding the WQ REF Value (as explained in Table 2).
- The BV-MSR sludge displayed a moderate ANC (61.5 kg H₂SO₄/t) and a paste pH of 6.06, suggesting some buffering potential. The solids content was measured at 39.3%, which is lower than observed previously and may represent partial drying of the sample during transport and sample preparation.

Table .: BV-MSR sludge SPLP data.

PARAMETERS	BLANK (mg/L)	BV-MSR SLUDGE SAMPLE (mg/L)	DIFFERENCE (mg/L)	MEQ
Aluminium	0.005	0.007	0.002	0.014
Antimony	0.0001	0.0001	-	-
Boron	0.03	0.03	-	-
Cobalt	0.0001	0.0057	0.0056	0.130
Iron	0.01	0.01	-	-
Manganese	0.001	0.330	0.329	-
Mercury	0.00004	0.00004	-	-
Selenium	0.0005	0.0005	-	-
Total Silica	0.280	1.03	0.750	-
Thallium	0.000025	0.00063	0.000605	-
Tin	0.00025	0.00025	-	-
Total Ammoniacal	0.005	0.125	0.12	-
Silicon	0.133	0.480	0.347	-
Sulfide	-	0.0025	-	-
Nitrite-N	0.001	0.001	-	-
Nitrate-N	0.003	0.250	0.247	-
Nitrate + Nitrite	0.003	0.250	0.247	-
Arsenic	0.0005	0.0005	-	-
Cadmium	0.000025	0.000025	-	0.083
Chromium	0.00025	0.00025	-	0.005
Copper	0.0012	0.001	-0.0002	0.500
Lead	0.00005	0.00005	-	0.008
Nickel	0.00025	0.0061	0.00585	0.359
Zinc	0.0035	0.0016	-0.0019	0.133
Iron + manganese	0.011	0.340	0.329	0.299
% Solids	-	39.3	-	-
Paste pH	-	6.06	-	-
ANC (kg H ₂ SO ₄ /t)	-	61.5	-	-

A hyphen (-) indicates no data are available. All units are measured in mg/L unless stated otherwise. Values in purple were recorded as <LOR and have been presented as half LOR. Values in orange indicate MEQ between ≤ 1.0 and ≥ 0.5 (i.e., potentially elevated).

BV-MSR Sludge and Pit 3 Pit Water Mixing Trials

Table 5 presents the summary of the BV-MSR mixing trial results. Figure 3 and Figure 4 summarise the key parameters. Based on the results presented the following was observed:

- pH remained stable with increasing sludge addition.
- Electrical conductivity (EC) increased with increasing sludge additions: from 174.5 $\mu\text{S}/\text{cm}$ (control) to 400.3 $\mu\text{S}/\text{cm}$ (1,000 g), reflecting increased dissolved solids and ion exchange associated with the AMD sludge.
- An increase in sulfate concentrations with an increasing sludge mass in a fixed water volume. Sulfate concentrations increased from 48 mg/L in the control to 155 mg/L with 1,000 g of sludge.
- Iron and Mn concentrations (combined) were low and less than the WQ Ref Value (see Table 2.)
- Total alkalinity remained relatively stable (30 - 34 mg CaCO_3/L), and acidity was <LOR (<1.0 mg CaCO_3/L) across all trials.
- Nickel concentrations decreased with higher sludge additions (0.0103 mg Ni/L - 0.0078 mg Ni/L). The same trend was observed in Zn concentrations (0.024 mg Zn/L - 0.0042 mg Zn/L). This may reflect adsorption to sludge particles or co-precipitation, suggesting the sludge has some capacity to reduce metal concentrations in water. MEQ results indicate the highest MEQ is associated with the Pit 3 pit water before the addition on MSR AMD Sludge.
- Dissolved Co and Mn concentrations increased with added sludge (0.0008 mg Co/L - 0.0056 mg Co/L and 0.00025 mg Mn/L - 0.27 mg Mn/L). Both Co and Mn are typically more mobile and may have desorbed or dissolved from the sludge matrix.
- Aluminium concentrations were observed decreasing slightly. Other parameters (e.g. Cu, Pb, As) remained stable or below LOR.

Table 4: Summary of the MSR sludge trial results.

PARAMETER	PIT 3 PIT LAKE WATER (CONTROL)	PIT WATER + 100 g SLUDGE	PIT WATER + 500 g SLUDGE	PIT WATER + 1,000 g SLUDGE	MEQ (MAX VALUE)
Water volume (L)	20	20	20	20	-
Total sample weight (kg)	-	20.1	20.5	21.0	-
Sludge weight (g)	-	104	502	1,002	-
Temperature ($^{\circ}\text{C}$)	8.30	8.70	8.60	8.90	-
pH (pH unit)	6.84	7.60	7.47	7.32	-
DO (%)	100.6	103.5	103	103.2	-
DO (mg/L)	11.83	12.04	11.98	11.95	-
EC ($\mu\text{S}/\text{cm}$)	174.5	240.3	301.2	400.3	-
ORP* (mV)	219.2	181.7	183.9	191.4	-
Turbidity (NTU)	1.76	3.80	4.00	3.70	0.267
Acidity (pH 7.0) (mg CaCO_3/L)	0.5	0.5	0.5	0.5	-
Total Alkalinity (mg CaCO_3/L)	31.0	30.0	31.0	34.0	-

PARAMETER	PIT 3 PIT LAKE WATER (CONTROL)	PIT WATER + 100 g SLUDGE	PIT WATER + 500 g SLUDGE	PIT WATER + 1,000 g SLUDGE	MEQ (MAX VALUE)
Total Suspended Solids	1.50	5.00	8.00	5.00	0.533
Total Dissolved Solids	96	136	196	240	-
Aluminium	0.02	0.011	0.008	0.006	0.040
Antimony	0.0001	0.0001	0.0001	0.0001	-
Boron	0.015	0.011	0.007	0.009	-
Calcium	30.0	36.0	53.0	75.0	-
Cobalt	0.0008	0.0016	0.0039	0.0056	0.127
Iron	0.01	0.01	0.01	0.01	-
Manganese	0.00025	0.039	0.168	0.27	-
Magnesium	1.14	1.10	1.09	1.03	-
Mercury	0.00004	0.00004	0.00004	0.00004	-
Potassium	0.61	0.67	0.78	0.81	-
Selenium	0.0005	0.0005	0.0005	0.0005	-
Total Silica	2.60	2.40	2.50	2.20	-
Sodium	3.60	3.10	2.80	4.00	-
Thallium	0.00016	0.00022	0.00067	0.00033	-
Tin	0.00025	0.00025	0.00025	0.00025	-
Chloride	2.80	2.80	2.90	3.00	-
Silicon	1.20	1.14	1.15	1.03	-
Sulfate	48.0	59.0	100.0	155.0	-
Arsenic	0.0005	0.0005	0.0005	0.0005	-
Cadmium	0.000025	0.000025	0.000025	0.000025	0.083
Chromium	0.00025	0.00025	0.00025	0.00025	0.005
Copper	0.00025	0.00025	0.00025	0.00025	0.125
Lead	0.00005	0.00005	0.00005	0.00005	0.008
Nickel	0.0103	0.0084	0.0077	0.0078	0.606
Zinc	0.024	0.0031	0.0058	0.0042	2.00

* ORP – oxidation-reduction potential

Analytes are reported as dissolved concentrations unless stated otherwise.

A hyphen (-) indicates no data are available.

All units were report as mg/L unless stated otherwise.

Purple samples are recorded as <LOR. Sample have been presented as half LOR.

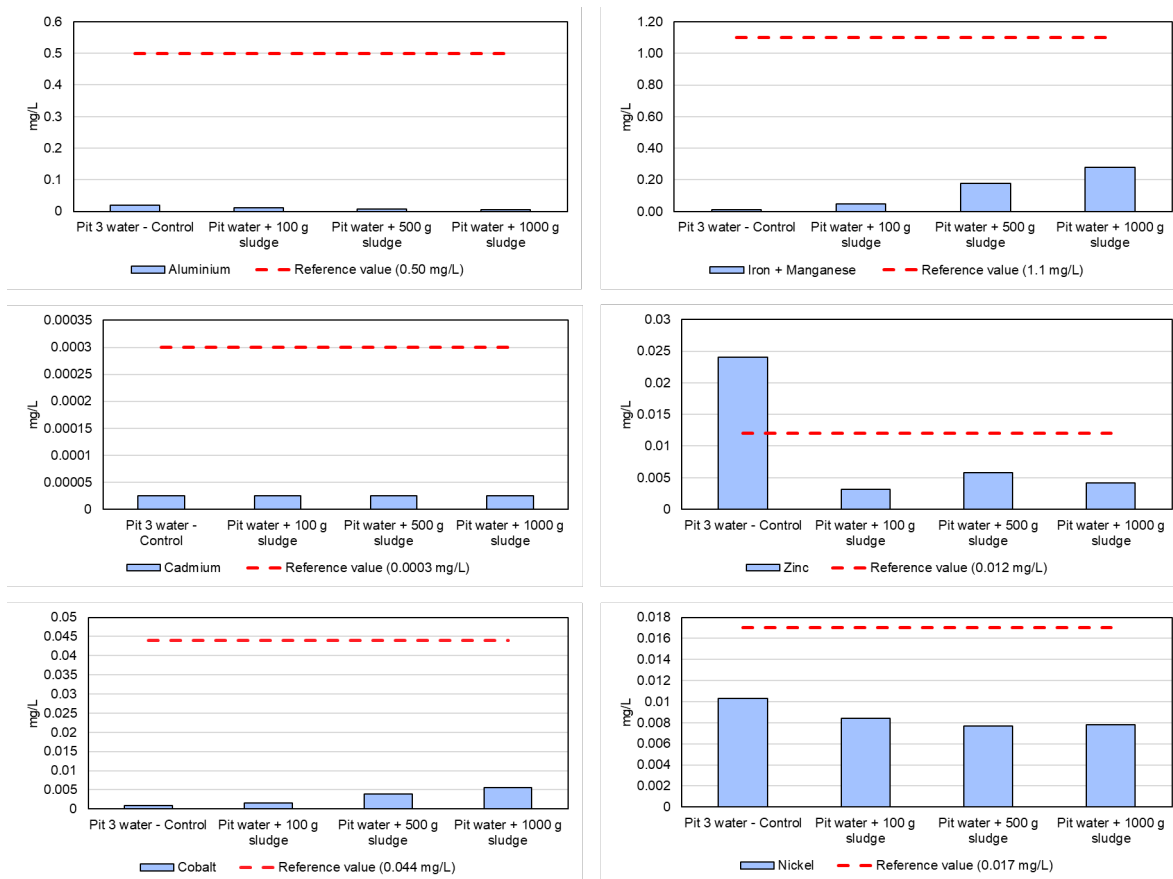


Figure 3: Comparison of PCOC concentrations at varying sludge quantities.

Hardness modifications have not been applied to these data

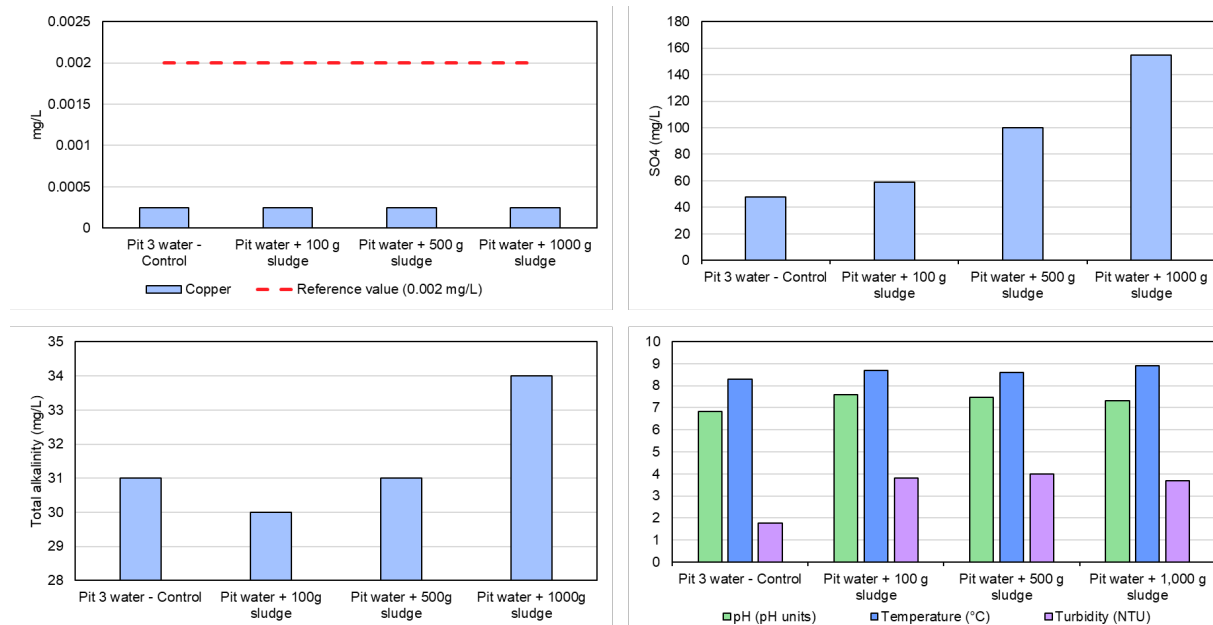


Figure 4: Comparison of PCOC concentrations at varying sludge levels continued.

pH measured in pH units. Temperature measured in degrees Celsius. Turbidity measured in NTU.

Alkalinity and Acidity Loads

Table 6 presents alkalinity and acidity concentrations and loads associated with sludge addition.

- Alkalinity concentrations increased slightly from 30 mg/L (100 g of sludge) to 34 mg/L (1,000 g). The alkalinity load was derived from the 20 L bucket volume and was reported as increasing from 0.60 g to 0.68 g across the sludge additions.
- Acidity concentrations were <LOR for all trials. The acidity load was derived from the 20 L bucket volume and was reported as being 0.01 g across all sludge masses.

The results indicate that BV-MSR sludge addition led to a minor increase in alkalinity concentration and load, while acidity remained below the detection threshold and unchanged across all treatments. The pH remained within the circumneutral range, consistent with the low acidity and moderate alkalinity measured. This suggests the addition of MSR AMD sludge would provide alkalinity to any pit void until shell ANC is exhausted.

Table 5: Acidity and alkalinity concentrations and loads.

PARAMETER	SLUDGE WEIGHT (g)		
	100	500	1,000
pH	7.60	7.47	7.32
Total Alkalinity (mg/L)	30	31	34
Pit 3 Water (L)	20	20	20
Alkalinity Load (mg)	600	620	680
Alkalinity Load (g)	0.6	0.62	0.68
Acidity* (mg/L)	0.5	0.5	0.5
Pit 3 Water (L)	20	20	20
Acidity Load (mg)	10	10	10
Acidity Load (g)	0.01	0.01	0.01

*Titrated to pH 7.0, results were below the 1.0 mg/L LOR and are therefore presented herein as half of the LOR.

SUMMARY

This memorandum evaluated the potential implications of placing sludge from the BV-MSR into the Pit 3 Pit Lake, with the aim of assessing the feasibility of underwater disposal of AMD sludge in future pit voids as part of the BPCP. It is noted that Pit 3 receives residual alkalinity from the BV-MSR effluent, which likely enhances its buffering capacity. Other pit voids within the BPCP, such as quarry sumps or voids without adjacent passive treatment systems, may lack this buffering and may not be suitable for similar sludge disposal without further assessment. Future sludge placement should consider the baseline water chemistry and buffering capacity of each candidate void.

The following observations are provided:

- Sulfate concentrations increased with increasing sludge additions indicating the presence of soluble sulfate salts in the sludge. Electrical conductivity followed a similar trend, consistent with increased dissolved solids.
- pH remained stable and circumneutral across all sludge additions, and total alkalinity increased slightly. Acidity remained <LOR.

- Nickel and Zn concentrations decreased with increasing sludge additions suggesting possible adsorption or co-precipitation under near-neutral conditions. This mechanism is validated by other studies that indicate adsorption of Zn to Fe-hydroxides (MWM, 2026c).
- Cobalt and Mn concentrations increased indicating potential desorption from the sludge matrix.

The laboratory trials were conducted using 20 L of Pit 3 water with sludge additions of 100 g, 500 g, and 1,000 g, corresponding to mass-based dilution ratios of approximately 1:200, 1:40, and 1:20. These test conditions were deliberately conservative to assess potential short-term impacts for low water: sludge ratios. For the BPCP sludge to water qualities are likely to be different and further studies are required if sludge disposal to pit voids is to be considered.

FURTHER WORK

These data presented in this report suggest that the option of MSR AMD sludge disposal into pit voids is viable. However, further work is required to assess the risks of aqueous disposal of MSR AMD sludge within pit voids. This includes:

- At the time of completing this work, final water quality objectives for the BPCP were not defined. Further studies are required to understand if PCOC are mobilised as compared to final water quality objectives.
- Future work should consider the potential for sub-oxic to anoxic conditions in pit voids, as these may influence the redox remobilisation of metals such as Fe and associated PCOC from the sludge.
- Larger scale operational trials should be undertaken, and water samples should be tested for secondary contaminants such as dissolved organic carbon, nitrogenous compounds, and sulfide.
- Further work is required if MSR AMD Sludge is stored under acidic conditions.
- Mixing trials using Pit 3 water and MSR AMD Sludge indicates a reduction in Zn and Ni by approx. an order of magnitude, most likely due to adsorption to Al/Fe hydroxides. These data suggest the process could be beneficial for these PCOC. An increase in Co and Mn indicates that some metals may be mobilised from the MSR AMD Sludge and further work is required to understand these risks including the placement of AMD sludge into acidic waters if this was a proposed management option.

CLOSING REMARKS

Please do not hesitate to contact Paul Weber at +64 3 241 0221 or paul.weber@minewaste.com.au should you wish to discuss this matter in greater detail.

Attachments: Attachment A – Lab Certificates

REFERENCES

MWM, 2026a. AMD Sludge Management – Buller Plateaux Continuation project. Mine Waste Management Report J-NZ0349-015-R-FINAL.

MWM, 2026b. Escarpment Mine – Mussel Shell Reactor Performance Review. Mine Waste Management Report J-NZ0349-003-M-FINAL.

MWM, 2026c. Passive Treatment System Design Toolkit - Buller Plateaux Continuation Project. Mine Waste Management Report J-NZ0453-005-R-FINAL.

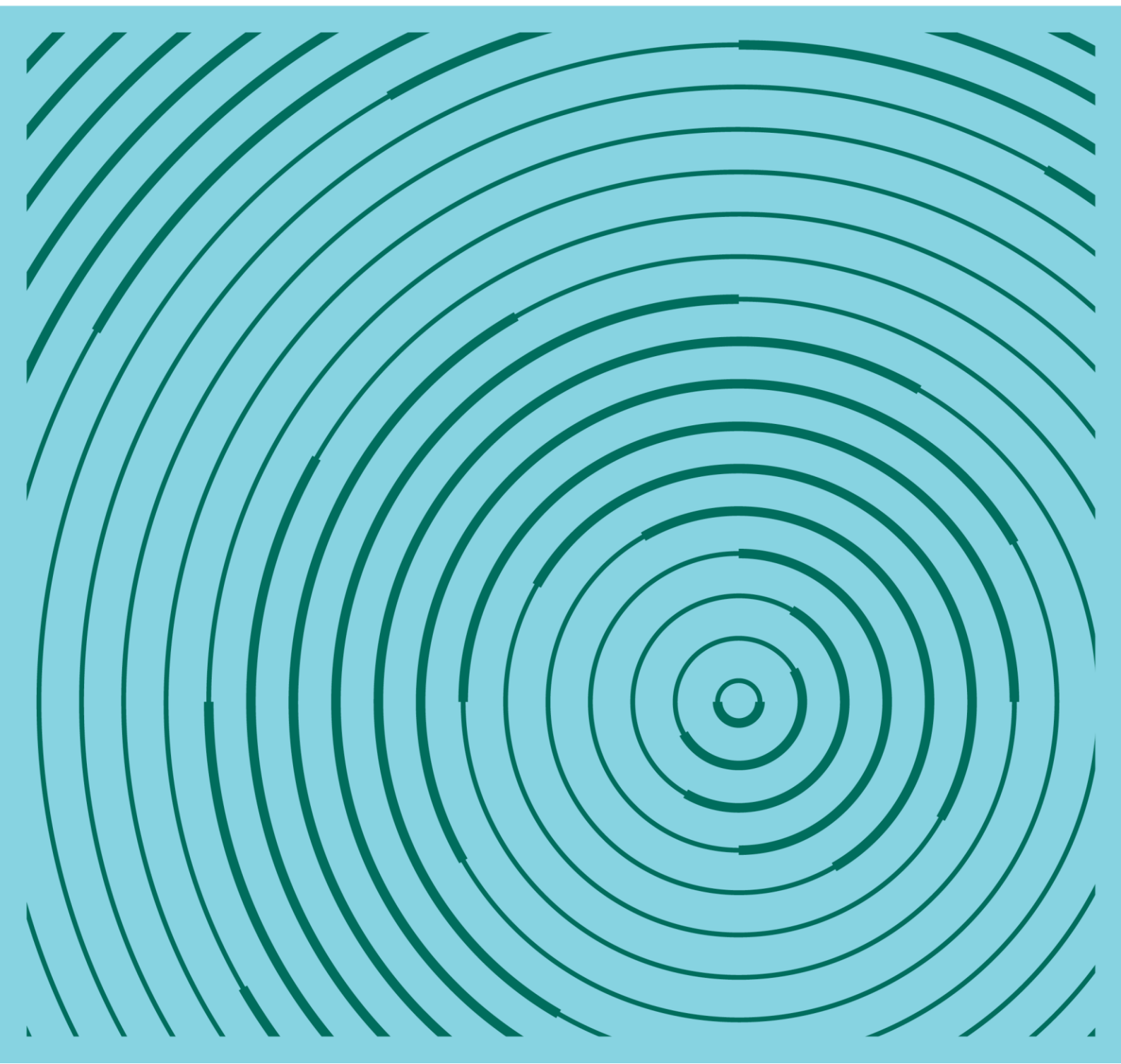
Taumata Arowai, 2022. Water Services (Drinking Water Standards for New Zealand) Regulations 2022. Available: <https://www.legislation.govt.nz/regulation/public/2022/0168/latest/versions.aspx>

ATTACHMENT A – LAB CERTIFICATES

Esc-MSR sludge leaching- factual report- V3

Mine Waste
Management

October 2024
25-000665



Author [REDACTED]

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2	30/9/2024	Dissolved metals reported to trace level
3	2/10/24	Paste pH of sludge included

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1. Scope

Mine Waste Management (MWM) requested an investigation into the potential effects of mussel shell reactor sludge (Esc-MSR) on contaminant loads in pit void water. Verum Group were provided with MSR sludge and water samples, and an experimental outline by MWM. This factual report details the methods and results of laboratory work undertaken by Verum Group following the experimental plan provided by MWM.

2. Methods

2.1 Samples

The following samples were received from MWM:

- 4 x 20 L bucket of "Pit 3 water 14/06/24".
- 1 x 20 L bucket of "Esc MSR sludge 14/06/24".

2.2 Sludge sub-sampling method

To ensure representative sub-samples were taken, the 20 L sludge sample was distributed onto a flat surface then manually mixed and large mussel pieces ground using a plastic tool. Once a consistent colour and particle size was visually observed, the sludge mixture was spread uniformly and divided into a three-by-three grid. Samples for ANC, SPLP and solids analysis were combined from the centre of each grid section. The remainder was returned to the bucket and sampled from there for the leaching experiments.

2.3 Test methods

The method of analysis for each sample type is listed in Table 1 below.

Table 1: Test method by sample type and analyte.

Sample	Analysis	Method
Sludge	% Solids	Tested as-received. Gravimetry, dried at 105°C.
Sludge	Acid neutralising capacity (ANC)	Air dried and milled before testing. AMIRA (2002)
Sludge	Paste pH	Tested as-received. 1:2 solid:water, AMIRA (2002)
Sludge	SPLP	Tested as-received. USEPA Method 1312 (modified-distilled water used as extractant)
Sludge SPLP leachate	Sulphide	Sample tested immediately on completion of SPLP. Hach methylene blue Method 8131 (modified). Sample clarified by centrifugation, total sulphide in supernatant analysed.
Sludge SPLP leachate	Dissolved metals (Al, Sb, B, Co, Fe, Mn, Se, Si, Th, Sn, As, Cd, Cr, Cu, Pb, Ni, Zn)	Sample filtered and acidified on completion of SPLP. Analysis sub-contracted to Hill Laboratories. APHA 3125 B ICP-MS, trace level.
Sludge SPLP leachate	Dissolved Hg	Sample filtered and acidified on completion of SPLP. Sub-contracted to Hill Laboratories. Bromine oxidation followed by atomic fluorescence. US EPA Method 245.7.
Sludge SPLP leachate	Nitrate-N	Sub-contracted to Hill Laboratories. Calculation: (Nitrite-N + Nitrate-N) – Nitrite-N. Nitrite-N: Azo dye colorimetry, FIA. Nitrite-N + Nitrate-N: Cd reduction, FIA. APHA 4500-NO ₃ ⁻ I (modified).
Sludge SPLP leachate	Ammoniacal-N	Sub-contracted to Hill Laboratories. Phenol/hypochlorite colorimetry, FIA. APHA 4500-NH ₃ H (modified).
Water	pH, specific conductance (EC), dissolved oxygen (DO), ORP, temperature	Calibrated YSI multi-probe
Water	Alkalinity	Sub-contracted to Hill Laboratories. Titration to pH 4.5. APHA 2320 B (modified).
Water	Acidity (7.0)	Sub-contracted to Hill Laboratories. Titration to pH 7.0. APHA 2310 B.
Water	Turbidity	Sub-contracted to Hill Laboratories, turbidity meter. APHA 2130 B (modified).
Water	Total suspended solids	Sub-contracted to Hill Laboratories. Filtration through nominal pore size 1.2 – 1.5 µm. Gravimetry. APHA 2540 D (modified).
Water	Total dissolved solids	Sub-contracted to Hill Laboratories. Filtration through 1.2 µm. Gravimetry. APHA 2540 C (modified).
Water	Dissolved metals (Al, Sb, B, Ca, Co, Fe, Mg, Mn, K, Se, Si, Na, Th, Sn, As, Cd, Cr, Cu, Pb, Ni, Zn)	Sample filtered and acidified. Analysis sub-contracted to Hill Laboratories. APHA 3125 B ICP-MS, trace level.
Water	Dissolved Hg	Sample filtered and acidified. Sub-contracted to Hill Laboratories. Bromine oxidation followed by atomic fluorescence. US EPA Method 245.7.
Water	Chloride, sulphate	Sub-contracted to Hill Laboratories. IC. APHA 4110 B (modified).

2.4 Experimental method

The experimental leaching method was carried out as per the experimental outline provided by MWM. Details are as follows:

1. All 4 buckets of “pit 3” water were mixed together until homogenous and aerated, as confirmed by consistent pH and EC, and a consistent and near saturated DO. Sub-samples of the water were taken for analysis as per Table 1..
2. Sludge was weighed into buckets and “pit 3” water was added in the amounts in below.

Table 2: Sludge weights and water volumes in each experimental bucket

Bucket	Sludge weight (g)	Water volume (L)
1	104	20
2	502	20
3	1002	20

3. The sludge and water were well mixed for 1 minute. The buckets were left undisturbed to settle for 24 hours.
4. After 24 hours settling time the supernatant from each bucket was sub-sampled for analyses as per Table 1.

3. Results and Observations

3.1 Esc-MSR Sludge

Observations:

- The sludge sample was highly heterogeneous and included large chunks of shell among orange/red sludge and some white precipitates (Figure 1).
- The sludge had no discernible odour of sulphide.



Figure 1: Esc-MSR sludge.

Results:
See Table 3.

Table 3: Esc-MSR sludge results for all analysed parameters.

Analysis	Unit	Replicate	Sludge: Esc-MSR	Sludge SPLP leachate: Blank	Sludge SPLP leachate: Esc-MSR
% solids	%	1	40.0	-	-
		2	38.5	-	-
Paste pH		1	5.95		
		2	6.17		
ANC	kg H ₂ SO ₄ /t	1	60.19	-	-
		2	62.86	-	-
Sulphide	µg/L S ²⁻	1	-	-	< 5
		2	-	-	< 5
Dissolved Aluminium	mg/L	1	-	0.005	0.007
Dissolved Antimony	mg/L	1	-	< 0.0002	< 0.0002
Dissolved Boron	mg/L	1	-	< 0.06	< 0.06
Dissolved Cobalt	mg/L	1	-	< 0.0002	0.0057
Dissolved Iron	mg/L	1	-	< 0.02	< 0.02
Dissolved Manganese	mg/L	1	-	0.001	0.33
Dissolved Mercury	mg/L	1	-	< 0.00008	< 0.00008
Dissolved Selenium	mg/L	1	-	< 0.0010	< 0.0010
Total Dissolved Silica	mg/L as SiO ₂	1	-	0.28	1.03
Dissolved Thallium	mg/L	1	-	< 0.00005	0.00063
Dissolved Tin	mg/L	1	-	< 0.0005	< 0.0005
Total Ammoniacal-N	mg/L	1	-	< 0.010	0.125
Silicon	mg/L	1	-	0.133	0.48
Nitrite-N	mg/L	1	-	< 0.002	< 0.002
Nitrate-N	mg/L	1	-	0.003	0.25
Nitrate-N + Nitrite-N	mg/L	1	-	0.003	0.25
Dissolved Arsenic	mg/L	1	-	< 0.0010	< 0.0010
Dissolved Cadmium	mg/L	1	-	< 0.00005	< 0.00005
Dissolved Chromium	mg/L	1	-	< 0.0005	< 0.0005
Dissolved Copper	mg/L	1	-	0.0012	0.001
Dissolved Lead	mg/L	1	-	< 0.00010	< 0.00010
Dissolved Nickel	mg/L	1	-	< 0.0005	0.0061
Dissolved Zinc	mg/L	1	-	0.0035	0.0016

3.2 Pit water Esc-MSR leachates

Observations:

All supernatants were turbid (Figure 2).

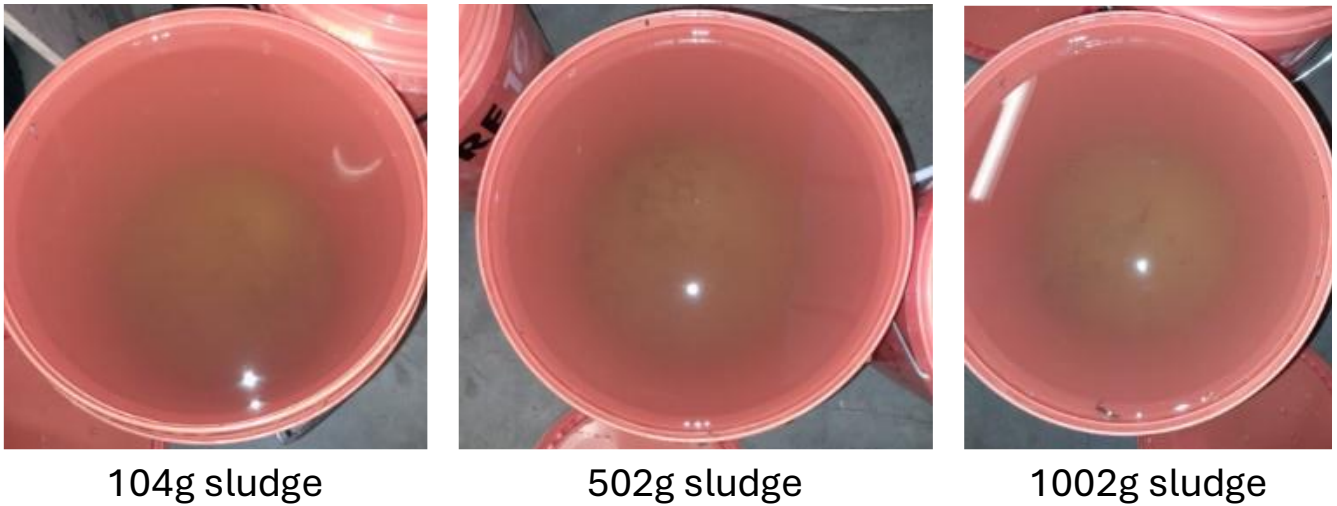


Figure 2: Pit 3 water mixed with different weights of sludge, after 24 hours settling time.

Results:

See Table 4.

Table 4: Results for the supernatant from Pit 3 water mixed with different amounts of Esc-MSR sludge.

Analysis	Unit	Pit 3 water	Pit water + 100g sludge	Pit water + 500g sludge	Pit water + 1000g sludge
Temperature	°C	8.3	8.7	8.6	8.9
pH		6.84	7.6	7.47	7.32
DO	%	100.6	103.5	103	103.2
DO	mg/L	11.83	12.04	11.98	11.95
Specific conductance (EC)	µS/cm	174.5	240.3	301.2	400.3
ORP	mV	219.2	181.7	183.9	191.4
Turbidity	NTU	1.76	3.8	4	3.7
Acidity (pH 7.0)	mg/L as CaCO ₃	< 1.0	< 1.0	< 1.0	< 1.0
Total Alkalinity	mg/L as CaCO ₃	31	30	31	34
Total Suspended Solids	mg/L	< 3	5	8	5
Total Dissolved Solids (TDS)	mg/L	96	136	196	240
Dissolved Aluminium	mg/L	0.02	0.011	0.008	0.006
Dissolved Antimony	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Dissolved Boron	mg/L	0.015	0.011	0.007	0.009
Dissolved Calcium	mg/L	30	36	53	75
Dissolved Cobalt	mg/L	0.0008	0.0016	0.0039	0.0056
Dissolved Iron	mg/L	< 0.02	< 0.02	< 0.02	< 0.02
Dissolved Magnesium	mg/L	1.14	1.1	1.09	1.03
Dissolved Manganese	mg/L	< 0.0005	0.039	0.168	0.27
Dissolved Mercury	mg/L	< 0.00008	< 0.00008	< 0.00008	< 0.00008
Dissolved Potassium	mg/L	0.61	0.67	0.78	0.81
Dissolved Selenium	mg/L	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Total Dissolved Silica	mg/L as SiO ₂	2.6	2.4	2.5	2.2
Dissolved Sodium	mg/L	3.6	3.1	2.8	4
Dissolved Thallium	mg/L	0.00016	0.00022	0.00067	0.00033
Dissolved Tin	mg/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Chloride	mg/L	2.8	2.8	2.9	3
Silicon	mg/L	1.2	1.14	1.15	1.03
Sulphate	mg/L	48	59	100	155
Dissolved Arsenic	mg/L	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Dissolved Cadmium	mg/L	< 0.00005	< 0.00005	< 0.00005	< 0.00005
Dissolved Chromium	mg/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Dissolved Copper	mg/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Dissolved Lead	mg/L	< 0.00010	< 0.00010	< 0.00010	< 0.00010
Dissolved Nickel	mg/L	0.0103	0.0084	0.0077	0.0078
Dissolved Zinc	mg/L	0.024	0.0031	0.0058	0.0042

APPENDIX H WHAREATEA MSR DESIGN

MEMORANDUM

INTERNAL MEMORANDUM

TO: [REDACTED]

DATE: 4/07/2025

SUBJECT: Whareatea Mussel Shell Bioreactor Design

Executive Summary

This document presents the methodology used to design the concept level north Whareatea Mussel Shell Bioreactor (MSR). This concept level design proves there is sufficient area, volume, and gradient within the designated MSR space for calculated seepage flows from the Whareatea ELF. Exact inflow and outflow heights into each MSR cell have not been provided, as these will be highly dependent on the uncovered coal floor topography.

Initial design criteria were provided by Mine Waste Management (MWM, 2025). These design criteria are based upon internal ELF basal catchment sizing and average sulfur values provided by Bathurst Resources derived from a spray mining schedule for the Escarpment Extended mine plan. In turn, design criteria provided to BRL were; Volume of MSR required, average depth, and surface area required.

All MSR's and/or polishing ponds will follow the same conceptual designs as shown in Figure 3 and Figure 4. Precise underdrain seepage bunds, flow splitting infrastructure, MSR inlet channel, riser, and spill way heights will be designed once coal floor in each prospective area is uncovered and surveyed. These conceptual designs demonstrate there is sufficient space allocated for MSR requirements upon mine closure. Volume of the conceptual MSR's have not been calculated at this time, as it is not a design constraint. Within all proposed conceptual designs, each cell has been excavated into coal floor and could be made deeper to increase MSR volume if required. Shown design depth is a minimum of 3.5 m for each cell and is beyond the 1.5 m of MSR depth required.

Conceptual designs show there is sufficient gradient to allow drainage via gravity from each cell and there is approximately 12,500 m² of excess area within the proposed design above MWM design criteria.

Design Criteria

The engineered landform (ELF) basal seepage catchment area was defined and provided to MWM with an estimated overburden schedule including acid-base accounting (ABA) data emplaced within the ELF as defined by each basal catchment polygon, as shown in Figure 1 for the Whareatea (WWH) ELF. The scheduled waste ABA data was from a source to destination waste schedule completed within Spry mining and scheduling software. The Material Schedule included each source block and collated Volume, Tonnes, Total Sulfur, Total Acid neutralising Capacity (ANC) and tracked these to its destination block within an ELF. Each destination block was then flagged as to the % volume of which lies within the proposed internal ELF catchment area. This methodology allows tracking of the source quality and quantity to the destination ELF.

This internal ELF catchment is defined by the original topography catchment underneath the central part of the ELF and the WH ELF Catchment underdrain, which separates the Conglomerate ELF and WWH ELF seepage basal catchments

(Figure 2). The Conglomerate ELF is the section of the input ELF which reports to the west and ultimately to the Conglomerate set of MSR's which will lie in the North West of the pit footprint. Design criteria shown in Table 1 were supplied to BRL by MWM, (MWM, 2025).

Figure 1: ELF Area reporting to Whareatea MSR

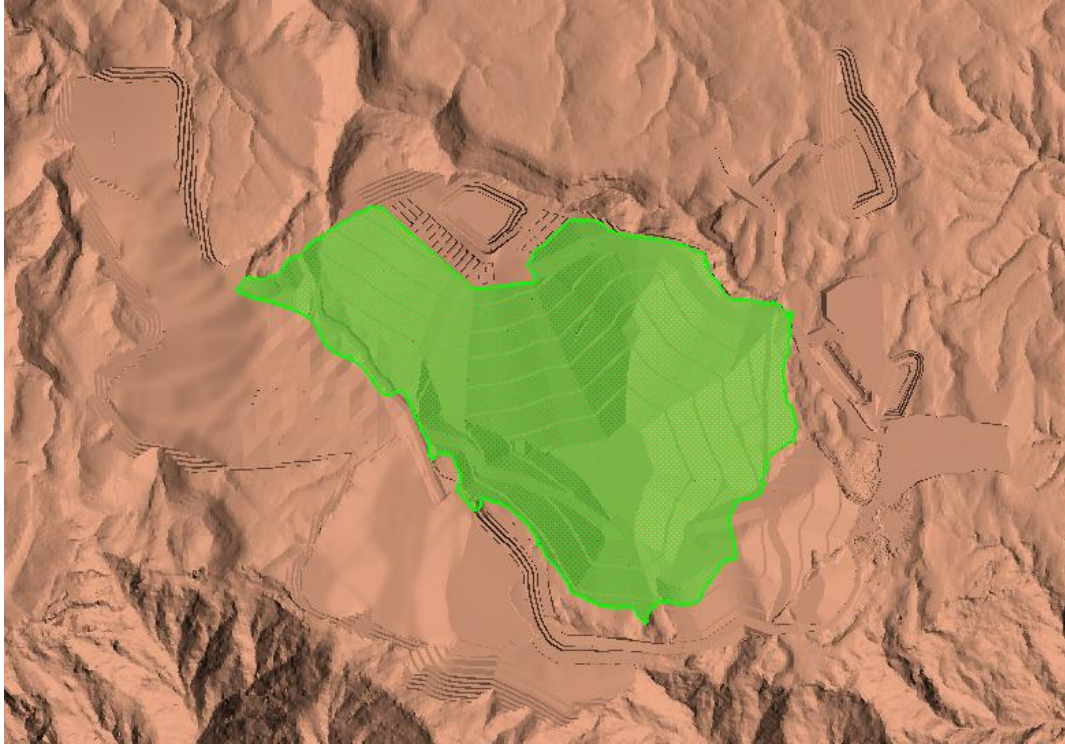
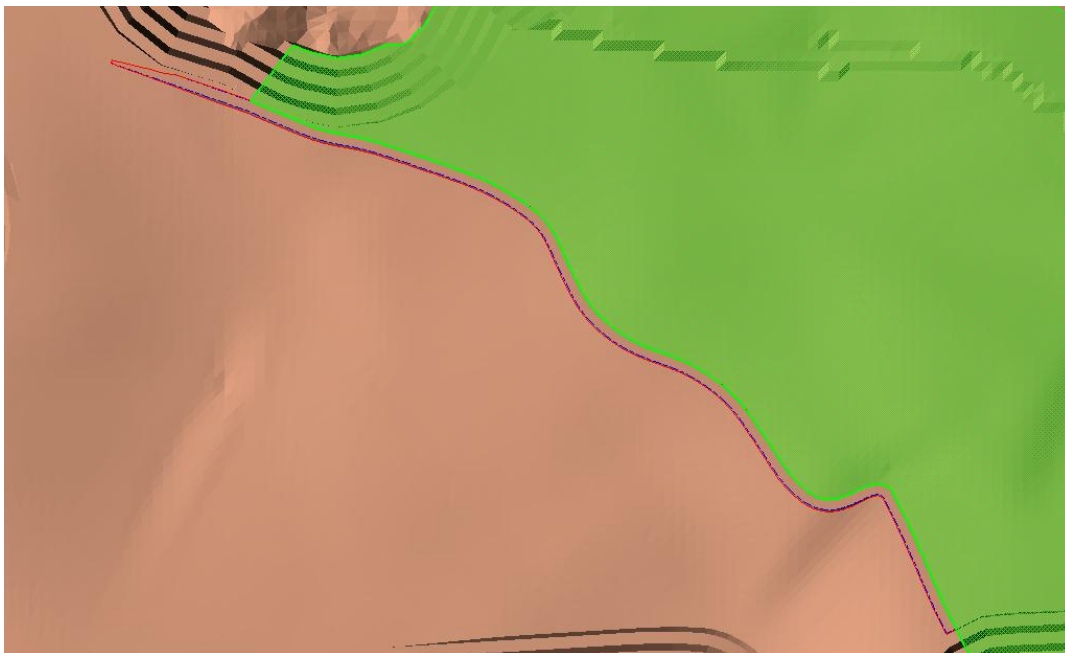


Figure 2: Underdrain separating the Whareatea and Conglomerate MSR Catchments



MEMORANDUM

Table 1: Whareatea MSR design parameters (Source MWM, 2025)

PARAMETER	VALUE
Area (ha)	169.2
Rainfall (mm/yr)	5,468
Infiltration coefficient	0.40
Flow Rate (L/s)	117
Acidity load (t CaCO ₃ /yr)	220 (440) ¹
MSR surface area + polishing pond (m ²)	25,982
MSR surface area (m ²)	12,991
Polishing pond area (m ²)	12,991
MSR depth (m)	1.5
MSR volume (m ³)	19,486
Shells pore volume calc (m ³)	10,133
Residence time (day)	1.00
1. where number in brackets represent the potential acidity load if the limestone was exhausted.	
Green: Low risk with regards to MSR treatment capacity.	
Orange: Moderate risk with regards to MSR treatment capacity	
Red: Higher risk with regards to MSR treatment capacity	

Design

Due to topographic limitations of the area designated for MSRs at the toe of the designed ELF, the initially defined ELF seepage catchment area was further divided into 3 smaller sub catchment areas using underdrain designs and the gradient of natural coal seam floor topography (Figure 5). All underdrains were designed with a minimum gradient of 1% and a basal drainage width of 10 m.

Each MSR or polishing pond cell was designed to a maximum width of 20 m, with an 8 m wide access bench in between each cell. This allows for access for equipment to provide cleaning and maintenance using a ~20t excavator and a light truck. A 20t excavator has sufficient boom length to reach into the centre of the MSR and can clean to the centre of each cell from each side of the MSR. The length of each cell was determined by the available area. Orientation of cells were perpendicular to general gradient of topography allowing passive flow from cell to polishing pond via gravity.

All MSR's and/or polishing ponds will follow the same conceptual designs as shown in Figure 3 and Figure 4. Precise inlet channel, riser, and emergency spillway heights will be designed once coal floor in each prospective area is uncovered, surveyed, and seepage flow rates are known.

Figure 3: Plan view Conceptual MSR design, with drainage lines.

MEMORANDUM

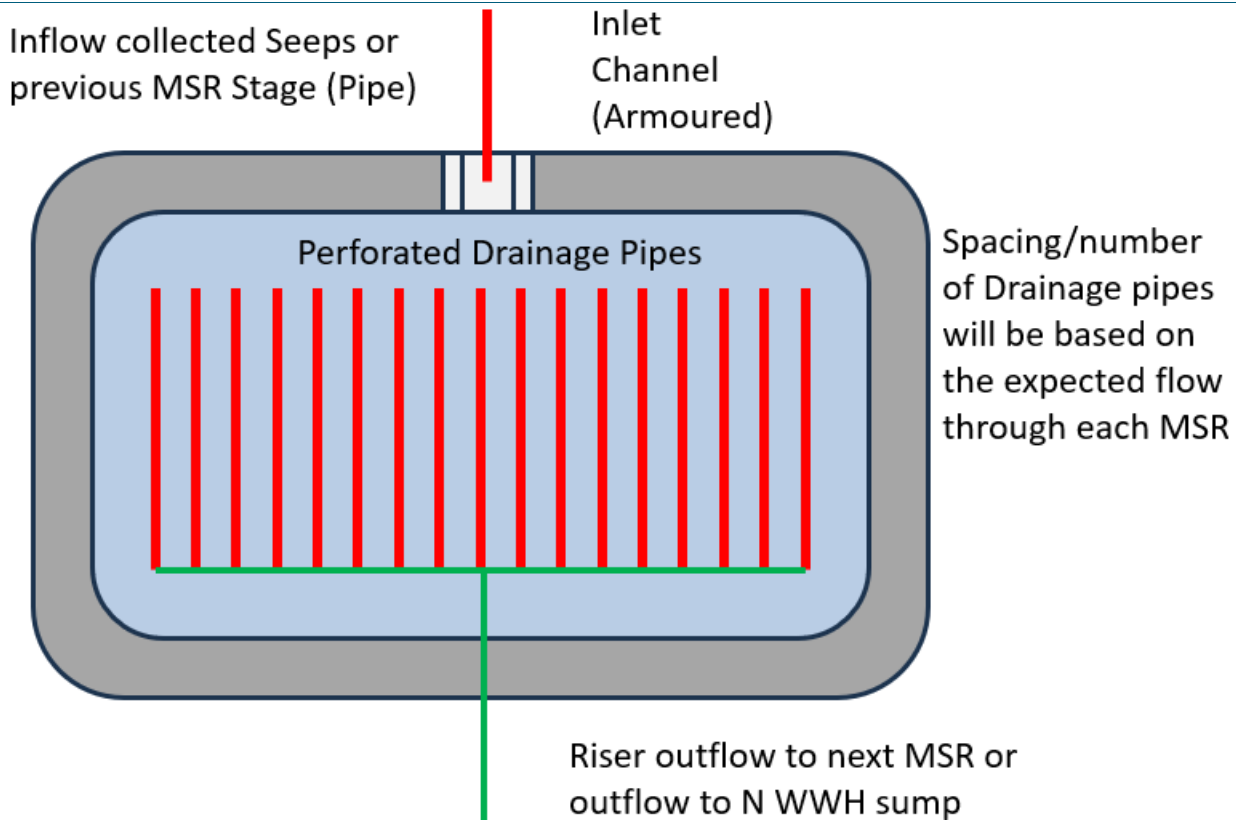


Figure 4: Conceptual MSR design Cross-sectional view.

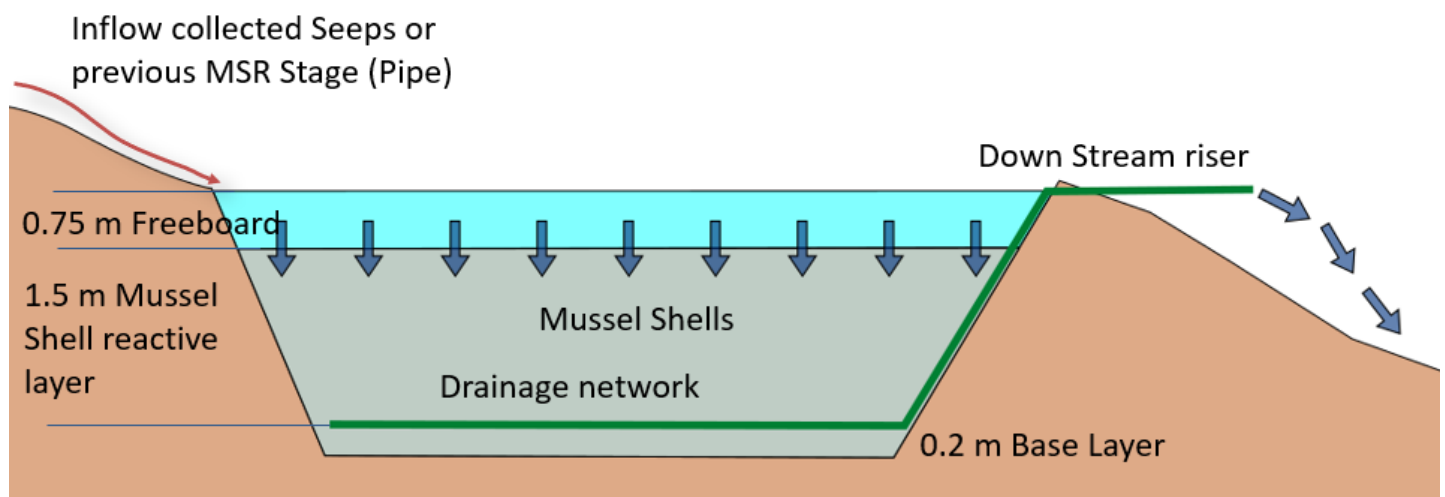


Table 2 shows the WWH ELF seepage catchment split up into three sub catchments with;

- Sub catchment area.
- Estimated required design area.
- The total designed capacities achieved.

MEMORANDUM

A concept area designed for MSR's and polishing ponds of 38,445 m² was achieved against a required area of 25,982 m². The total designed area is sufficient for the modelled WWH ELF seepage. The WH-East MSR designed area is shown to be ~ 2,117 m² smaller than estimated to be required, with the WH-Central area with the largest design capacity, 20,966 m², achieved versus estimated capacity, 10,237 m² WWH. WWH-West is an estimated 3,851 m² larger than required. Average flow data for the WWH ELF Seepage zone is still applicable as there is minimal variance of material residing within the top 10 m of the ELF Surface.

Figure 5: Whareatea catchment further divided into West, Central, and East Catchments.

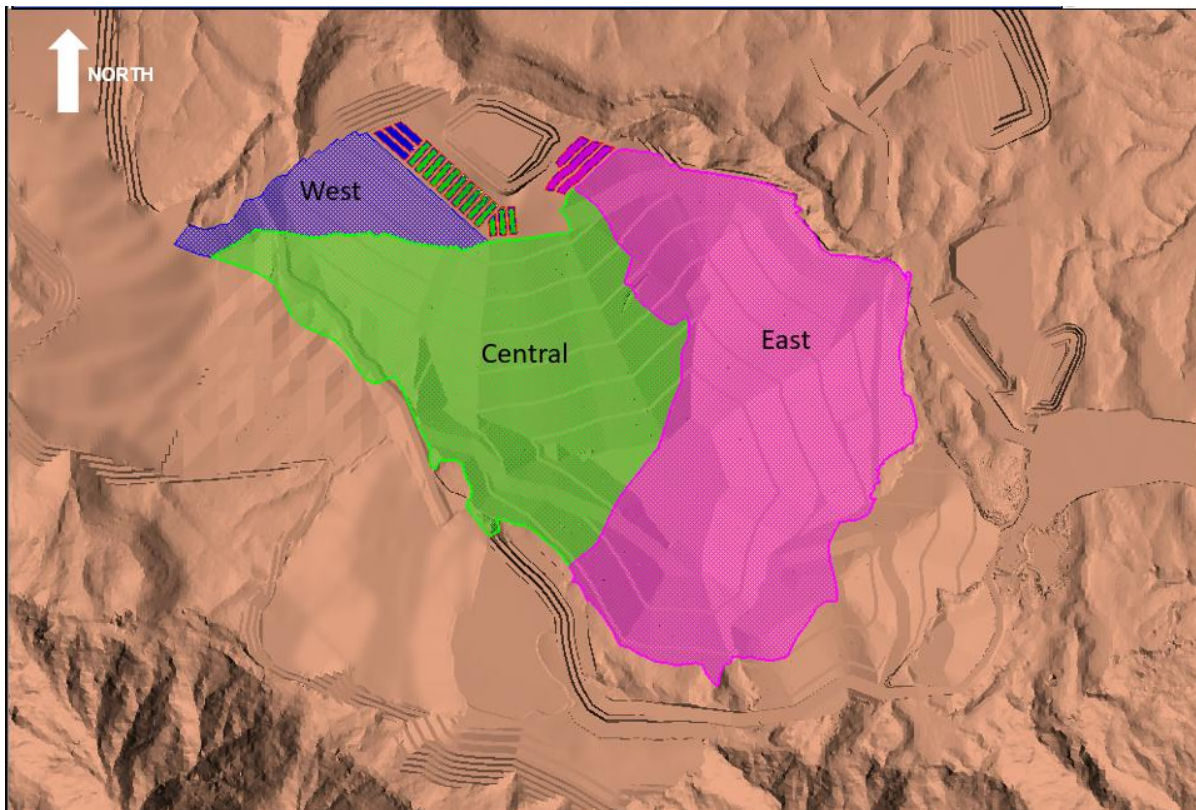
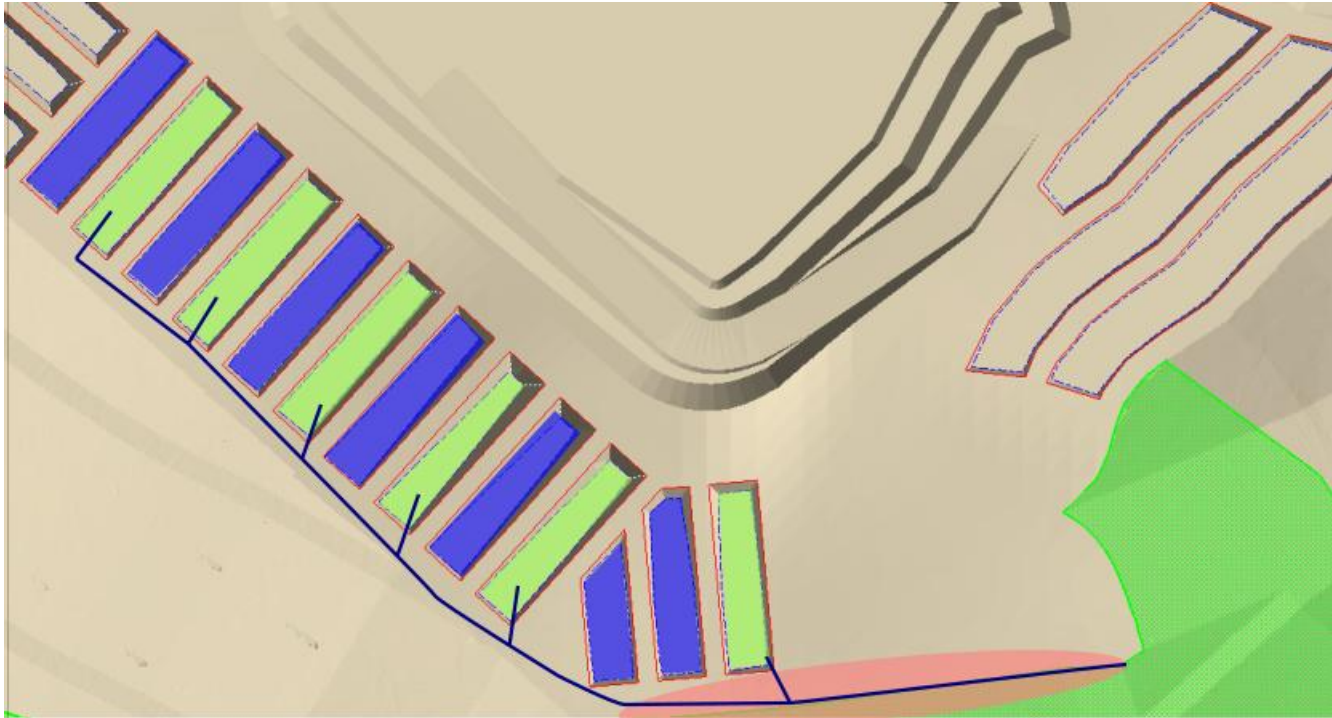


Table 2: MSR Sub catchments required design areas

MSR Catchment	m ²	ha	Percentage of total WWH Catchment	MSR required Area (m ²)	Polishing Pond Area (m ²)	Total Required Design area (m ²)	Total Concept MSR + Polishing Area (m ²)	Total Concept Design Area - Total Required (m ²)
WWH-West	135,350	13.5	8%	1,037	1,037	2,074	5,926	3,851
WWH-Central	667,922	66.8	39%	5,119	5,119	10,237	20,966	10,729
WWH-East	891,939	89.2	53%	6,835	6,835	13,670	11,553	-2,117
Total	1,695,211	170	1	12,991	12,991	25,982	38,445	12,463

While design area has been represented as a composite of smaller MSR's they will not operate in series. Underdrain seepage flow will be captured and distributed to functioning pairs of MSR and polishing ponds operating in parallel. See Figure 6 below where flows will be collected from a concentrated toe seepage bund and split and distributed to each MSR.

Figure 6: Seepage zone collection (red zone) and flow distribution to MSR (light green)/ Polishing Pond (dark blue) Pairs



Whareatea East

The WH-East MSR reporting area is driven by the original catchment below the WH-Central ELF and coal floor topography directing seepage flows to the WH-East MSR (Figure 7 and

Figure 8). The WH-East catchment area represents 891,939m² or 53% of the total Whareatea ELF Catchment. The total designed area for MSR and polishing ponds is 11,550m² (Table 2). Underdrains shown in

Figure 8, will capture seepage within the pink polygon directing it to WH-East MSR and polishing pond cells.

Figure 7: Ridge topography influencing Eastern MSR Catchment

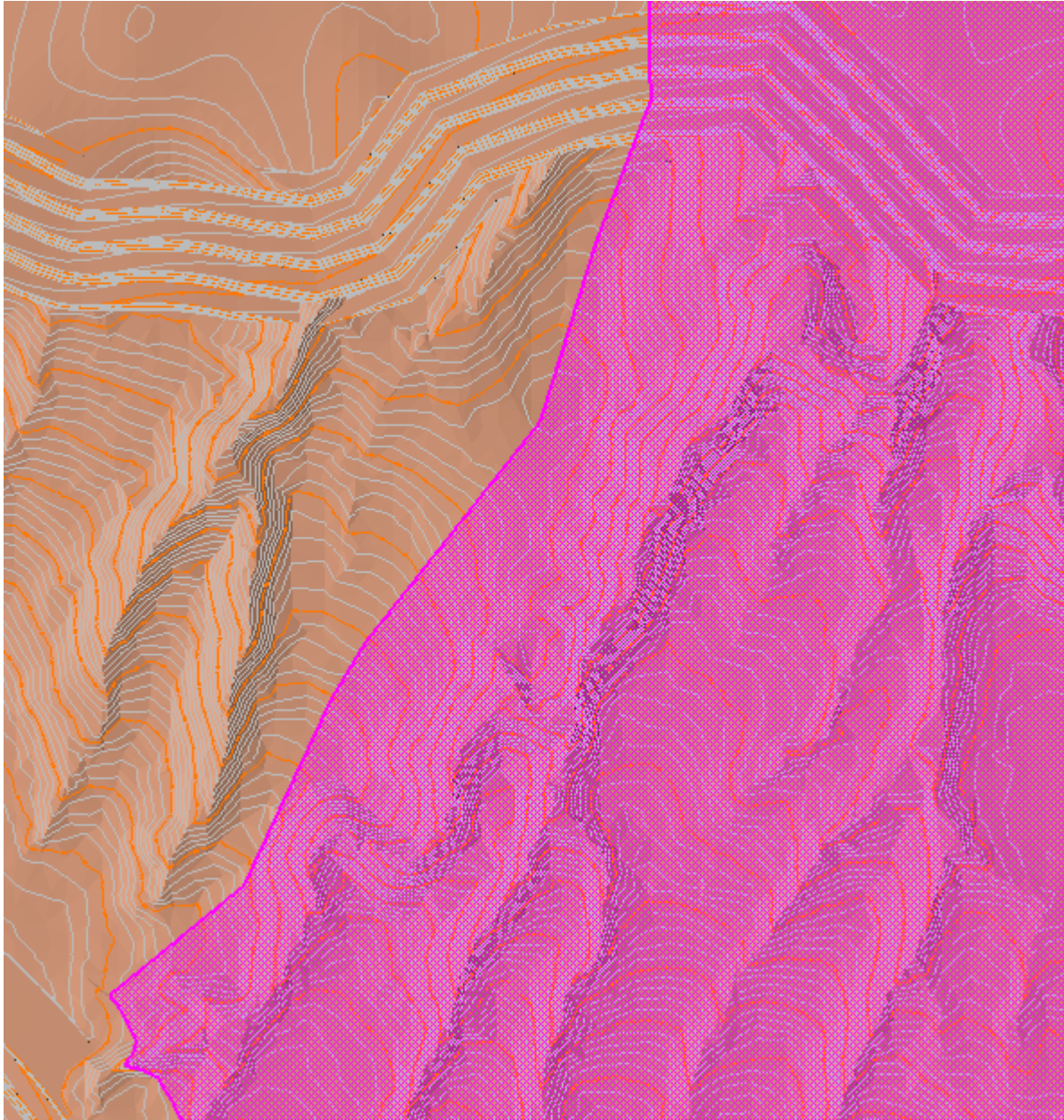
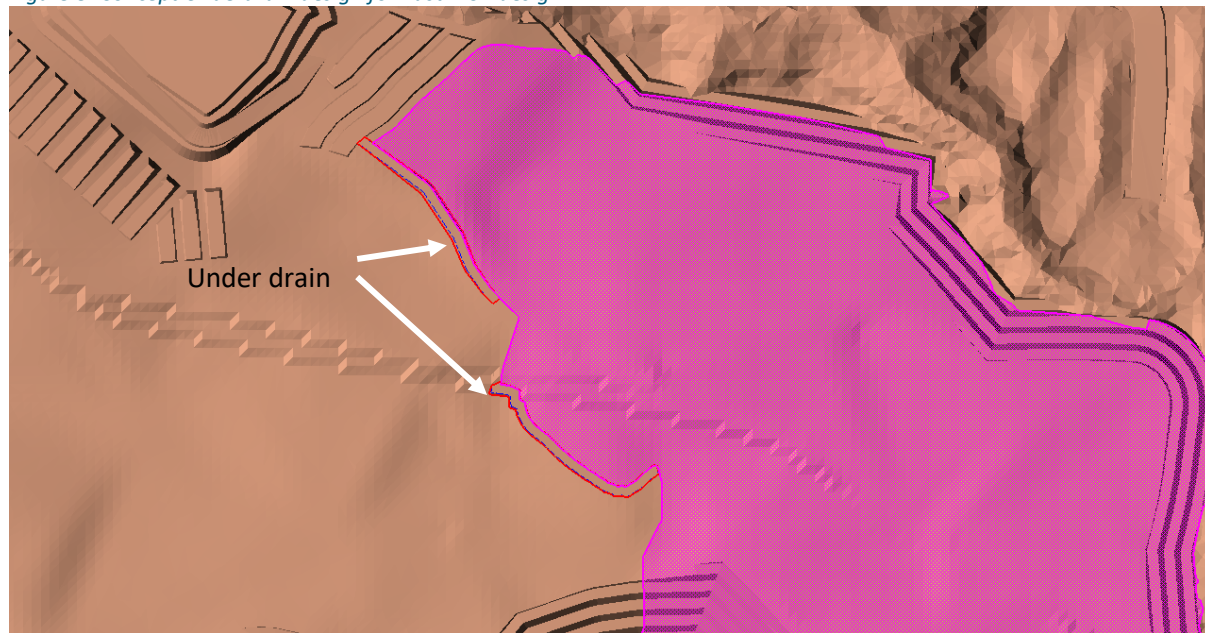


Figure 8: Concept Underdrain design for East MSR design



Gradient of floor topography over the WH-East MSR area will allow flow from South East to North West within the MSR and polishing ponds (Figure 9). The MSR design is cut into coal floor.

Figure 9: WH-East MSR and polishing ponds cross section

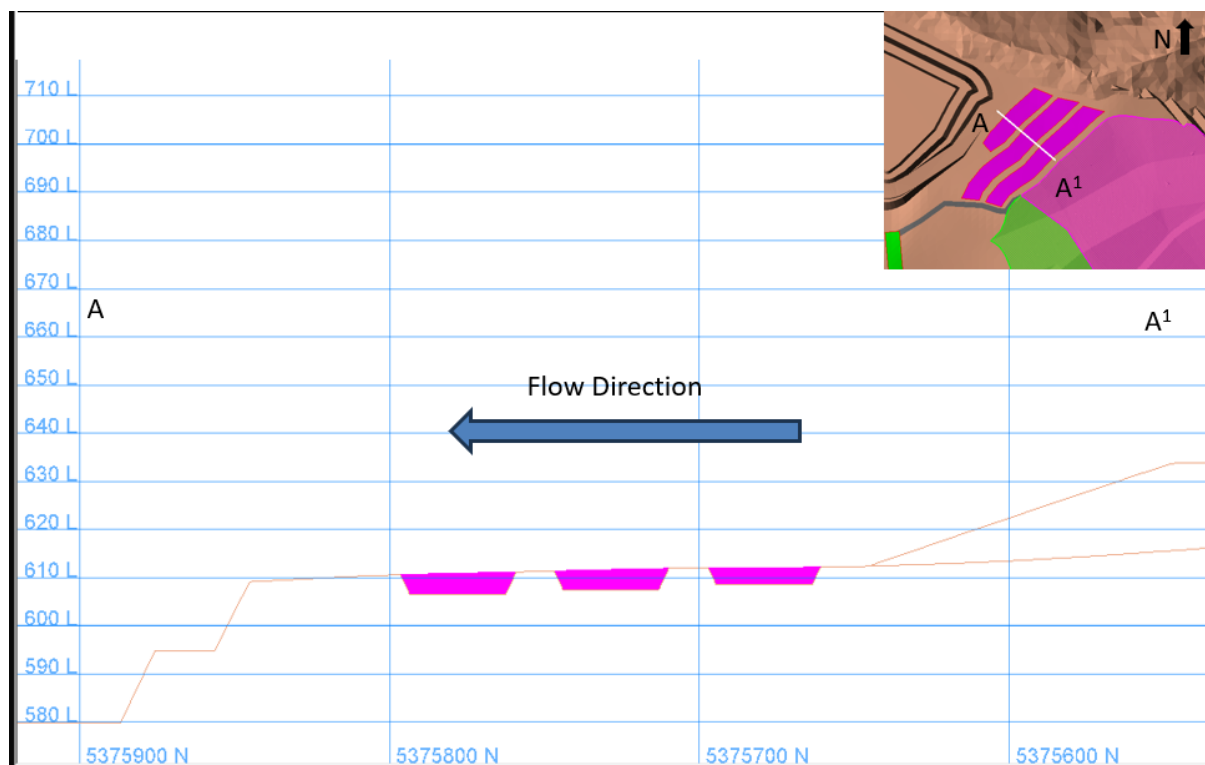
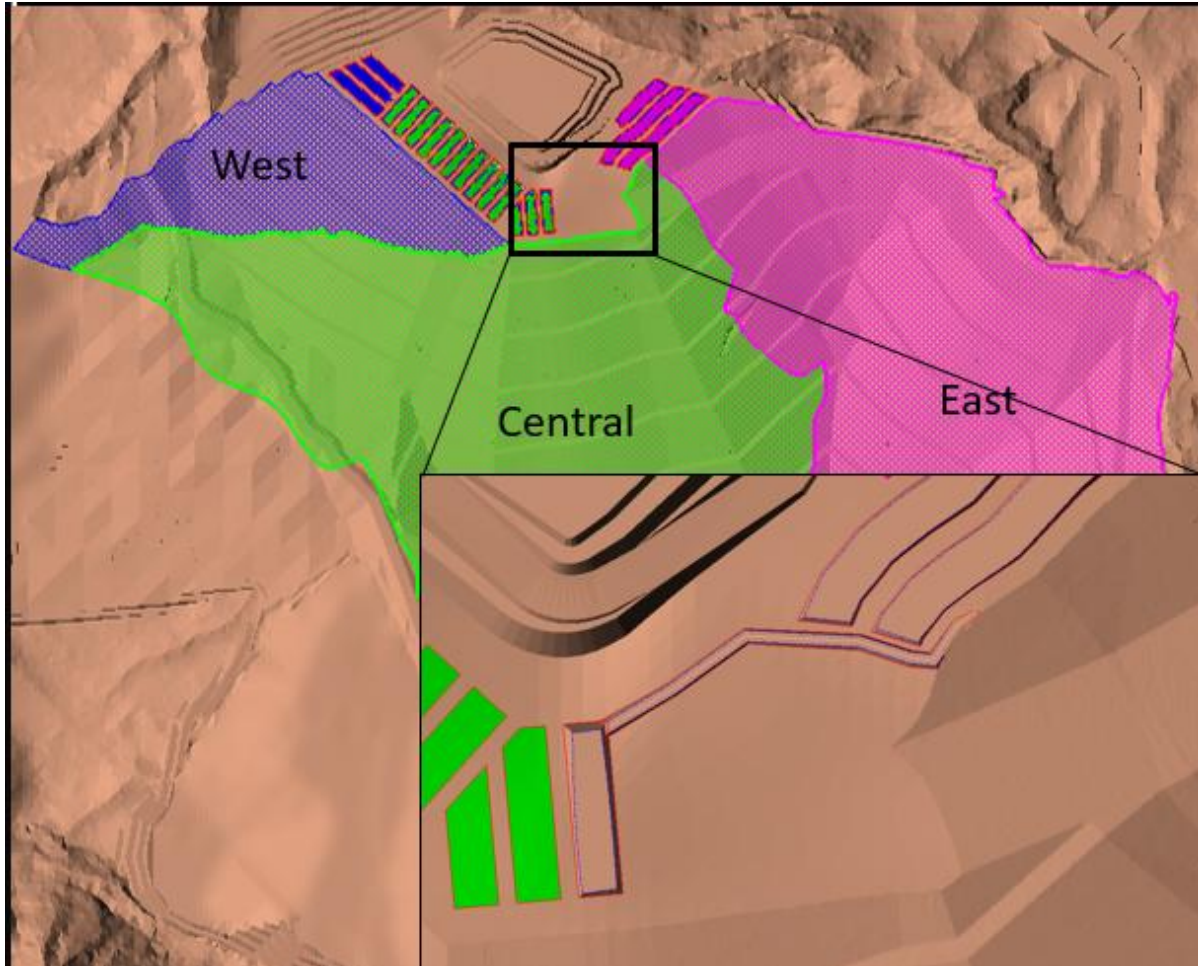


Table 2 shows the WH-East MSR and polishing ponds may be too small for the current modelled flows, by $\sim 2,100\text{m}^2$. If the measured seepage flows and loads are too high to treat effectively within the current WH-East MSR designs, a drain

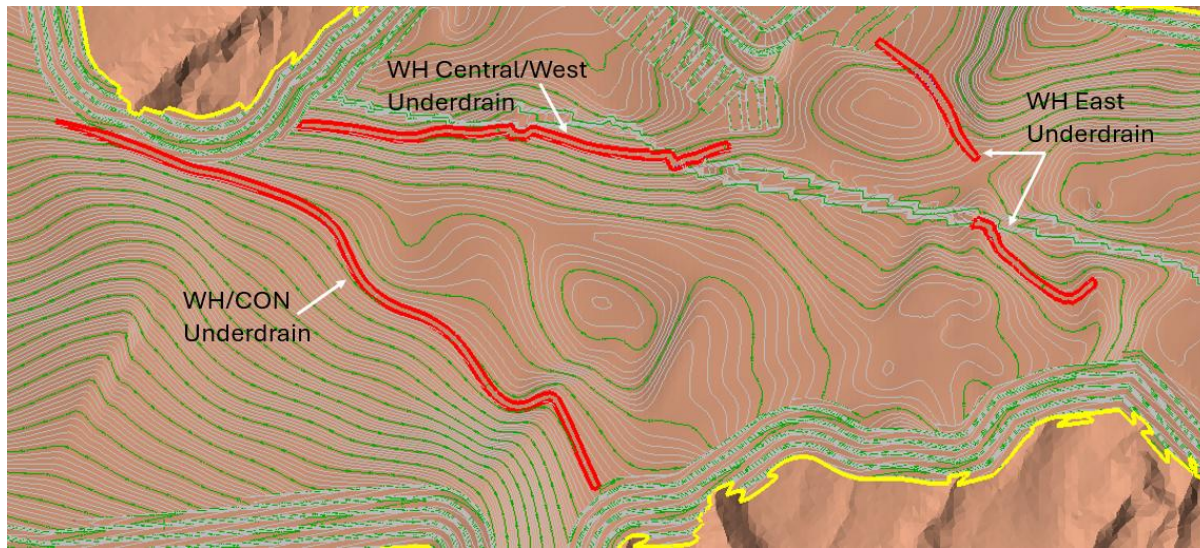
can be constructed to convey flows into the WH-Central MSR's and polishing ponds where current conceptual capacity exceeds design requirements by 10,700 m².



Whareatea Central

The WH-Central MSR and polishing pond design requirements are based on the underlying coal floor topography and a series of underdrains which divert seepage into the WH-Central MSR cells (Figure 10). The WH-Central catchment area represents 667,922 m² or 39% of the total Whareatea ELF Catchment. The total designed area for MSR and polishing ponds is 20,966 m² (Table 2).

Figure 10: West Underdrain in modelled Coal topography

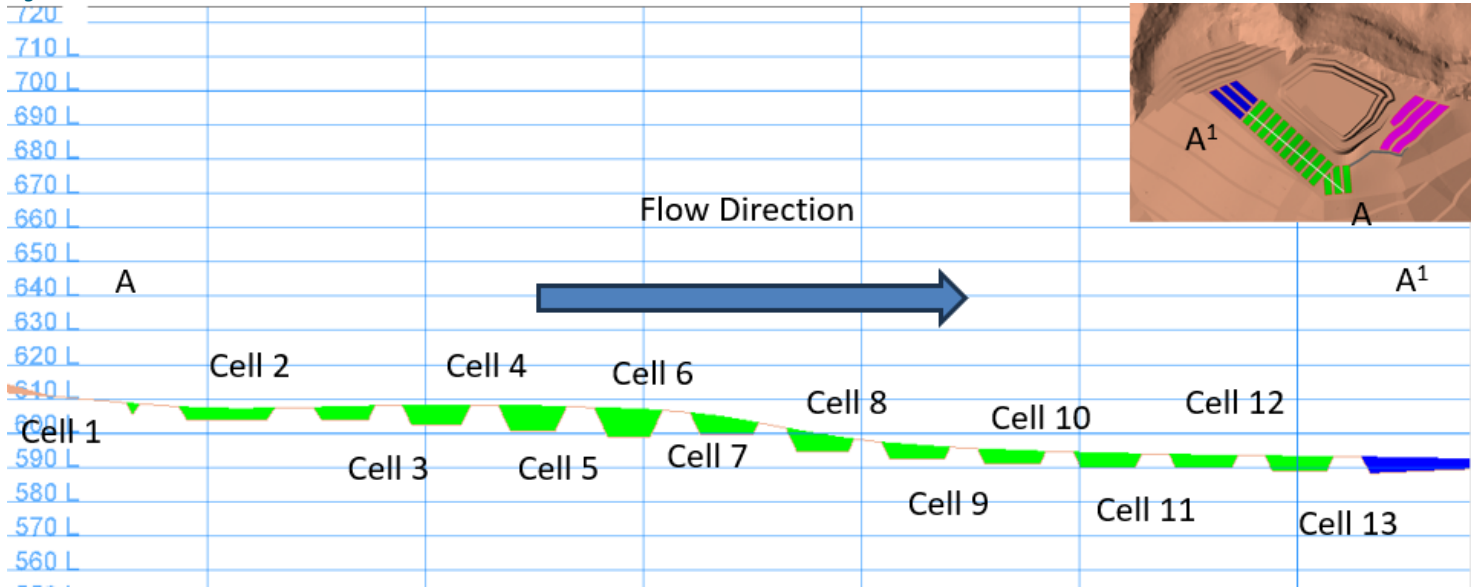


Flow direction in the central cells is generally Southeast to Northwest (Figure 11 and Figure 12). Current designs are excavated into coal floor.

Figure 11: Generalized Flow direction of Central MSR and Polishing Pond cells



Figure 12: Central Cross section



Whareatea-West

The WH-West catchment is defined by the same western underdrain which delineates the western boundary of the WH-Central catchment (Figure 10). The WH-West catchment area represents 135,350 m² or 8% of the total Whareatea ELF catchment. The total designed area for MSR and polishing ponds is 5,926 m² (Table 2). Flow direction is South West to North East as shown in Figure 14. Current designs are excavated into coal floor.

Figure 13: West MSR and Polishing Pond Catchment and cells (blue)

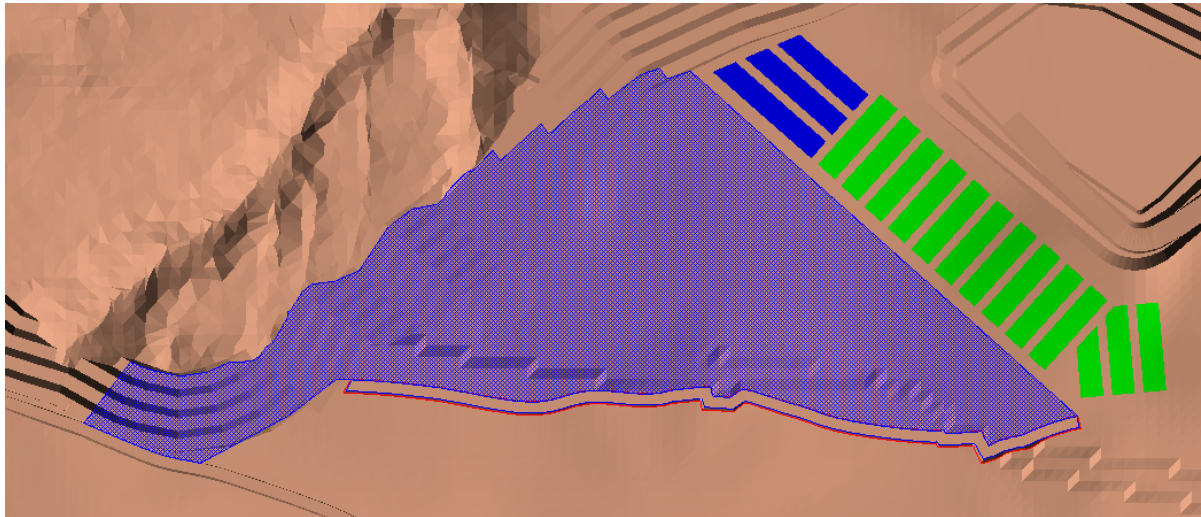
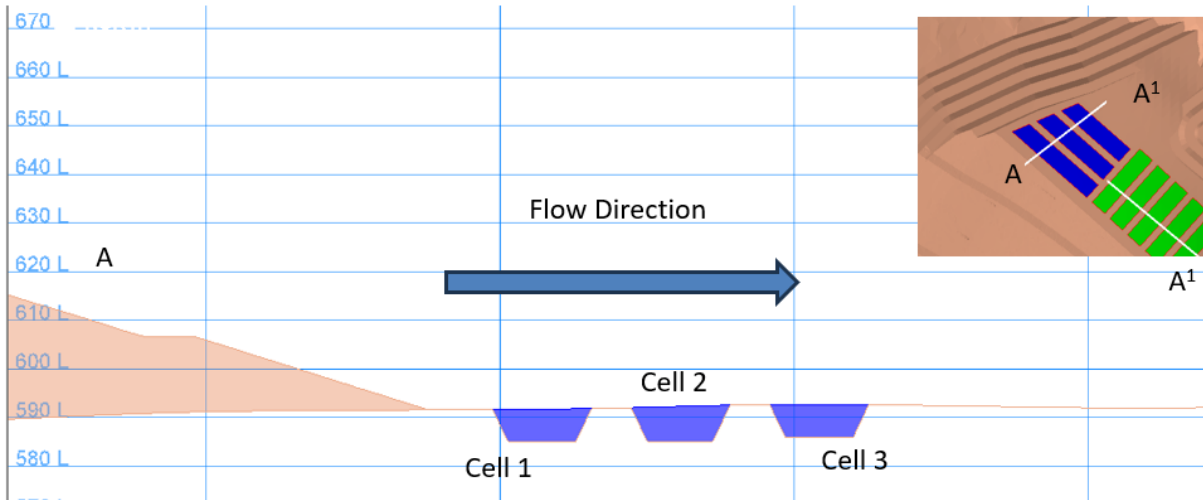


Figure 14: Cross section of WH-West MSR and polishing pond cells with generalised flow direction



Maintenance

Maintenance requirements for the MSR's are expected to be triggered as outlined in (MWM, 2025) by either:

- Sludge accumulation at or below the mussel shell layer surface, decreasing treatment capacity and resulting in untreated water spilling from the MSR; and/or
- Exhaustion of the Mussel shell acidity neutralising capacity (ANC).
- Reduced treatment efficiency for trace metals such as Zn.

The frequency for any maintenance activities (removal of sludge or exhausted MSR substrate) will be determined by the loads treated within in each MSR. To determine likely maintenance requirements performance monitoring of seepage reporting from each catchment area will be required prior to final design and construction of the MSR's to determine expected flow rates, iron (Fe) concentrations and concentrations of other potential constituents of concern and acidity loads. This will also determine if any diversion of seepage is required from WH-East to the WH-Central treatment cells.

To prepare for closure it is advised to construct toe collection bunds at the outlet of the underdrains and, after a period of performance monitoring. Construct the MSR's as early as practicable within the mine operation to collect data for inflow water quality which will in turn drive likely maintenance periodicity. It is anticipated that sludge removal will be driving maintenance timing as outlined in (MWM, 2025), and is likely in the 5-10 year range.

Bibliography

MWM. (2025). *ELF Water Quality and MSR Design Criteria*.

MWM. (2025). *Report J-NZ0453-005-R-Rev0*.

APPENDIX I TREATMENT OF SECONDARY MSR CONTAMINANTS

MEMORANDUM

Recipient: [REDACTED]

From: [REDACTED]

Date: 20 July 2026

Cc: [REDACTED]

Document Number: J-NZ0349-020-M-FINAL

Document Title: MSR Polishing Pond Secondary Contaminant Treatment

Bathurst Resource Limited (BRL) is seeking to obtain authorisation through the Fast-track Approvals Act (FTAA) to progress development and mining of the coal resources across the wider Buller Plateaux. This project is referred to as the Buller Plateaux Continuation Project (BPCP or Project). Mine Waste Management Limited (MWM) has developed this memorandum to support BRL with the assessment of environmental effects for its proposed mining activities associated with the BPCP.

This memorandum evaluates the performance of the Tara Mussel Shell Bioreactor (MSR) Scrubber, installed downstream of the Tara MSR at the Canterbury Coal Mine near Darfield to confirm the suitability of this technology for managing the potential secondary contaminants, specifically unionised hydrogen sulfide (H₂S), ammoniacal nitrogen (Amm-N), and low dissolved oxygen (DO), derived from the MSR proposed as part of the BPCP.

BACKGROUND

The post closure Tara Gully catchment water flow is designed to be sustained by two continuously discharging water sources: the CC02 underdrain, treated via the Tara MSR, and the N02 Pit Pond, discharging through the Tara Pond (Figure 1). These flows join below the Tara Pond spillway to form a single continuous discharge designed to restore natural baseflow conditions (i.e., mean annual low flow) through the wetland (Figure 2). The Tara MSR was established to treat acid and metalliferous drainage (AMD) impacted waters as part of the closure strategy for the mine, which is necessary to ensure the combined discharge meets the proposed water quality criteria and maintains ecological function in the receiving environment.

Water quality monitoring shows that the Tara MSR effectively reduces acidity and metal concentrations from the CC02 underdrain. However, the MSR effluent has elevated H₂S and Amm-N, as well as low DO, all of which present secondary contaminant concerns due to aquatic toxicity and oxygen demand. Arsenic was also initially identified as a secondary contaminant, but subsequent monitoring showed levels consistently below the limit of reporting (LOR) and continued to decline after 6-12 months.

To address these potential constituents of concern (PCOCs), a secondary treatment system, the MSR Scrubber, was installed downstream of the Tara MSR in 2023. This system has been operating in a commissioning mode with all treated waters being returned to the site water management system until the technology was proven as being reliable.

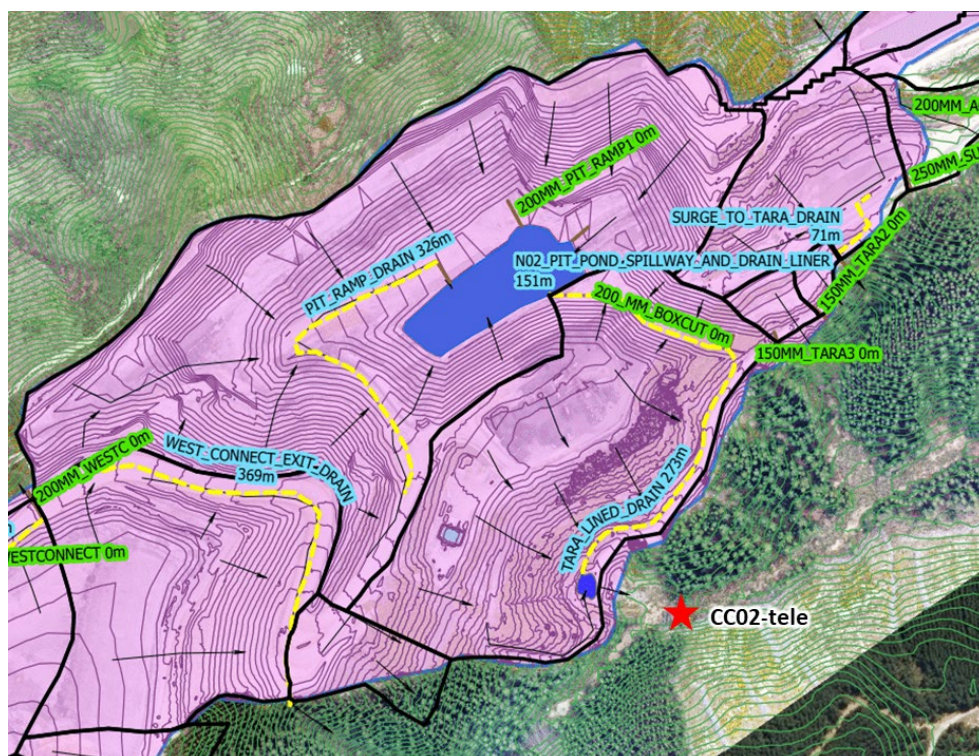


Figure 1: N02 Pit Pond drainage and drainage channels.

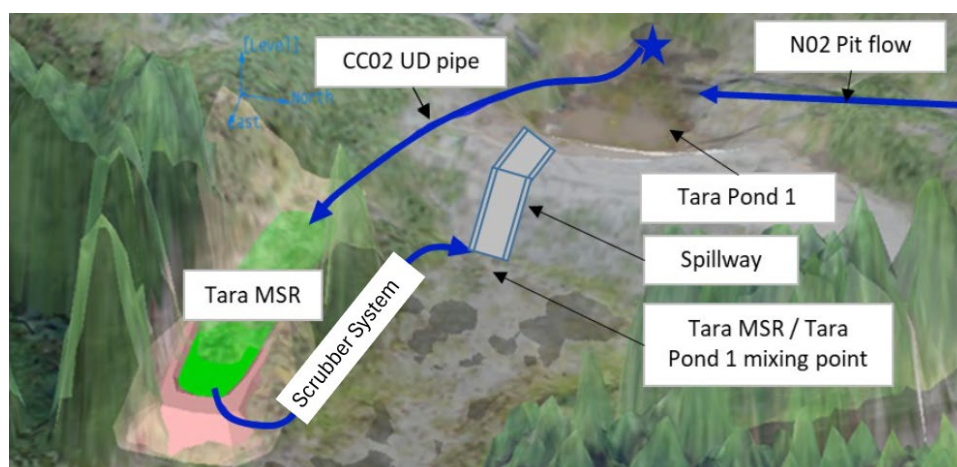


Figure 2: Tara MSR.

PERFORMANCE REVIEW

Throughout the commissioning phase, the scrubber effluent was not released to the receiving stream. This allowed for performance monitoring of both influent and effluent without discharging untreated water, while mitigating potential environmental impacts during system optimisation.

To evaluate the effectiveness of the scrubber system, data has been collected from the MSR outflow and MSR scrubber outflow to compare the PCOC concentrations before and after the secondary treatment (Table 1). The most recent data is considered most reliable as the system was being optimised over this period.

Table 1: Secondary contaminants in Tara MSR effluents and Scrubber outflow.

SECONDARY CONTAMINANT	CAUSE	PROPOSED COMPLIANCE LIMIT ⁴	SCRUBBER INFLOW (MSR OUTFLOW)	SCRUBBER OUTFLOW	POTENTIAL CONCERN
Unionised Hydrogen Sulfide (H ₂ S)	Byproduct of anaerobic treatment	0.002 mg/L ¹	Elevated above compliance limit	Mostly below LOR = 0.002 mg/L	Ecotoxicity, odour, oxygen depletion.
Dissolved oxygen (DO)	Anaerobic conditions	≥40% Saturation ²	Typically, below 40 % saturation	Increased to between 60 – 100 % saturation once the Scrubber was optimised	Low DO causes stress to ecosystems.
Ammoniacal N (Amm-N)	Byproduct of anaerobic treatment	0.4 mg/L ³	Elevated above compliance limit	Close to the compliance limit	Toxic, contributes to nutrient loads.
Nitrate-N (NO ₃ -N)	Nitrification	2.4 mg/L	Below 2.4 mg/L with occasional spikes	Below compliance limit with one higher spike	Eutrophication potential

1. Unionised H₂S limit from US EPA (2025). The concentration of unionised H₂S is dependent on pH. Compliance is to be assessed in accordance with ANZECC (2000) guidelines and associated tables using temperature and pH to derive a site-specific limit for H₂S concentrations. Note a consent limit of 0.002 mg/L is proposed, which is the LOR.

2. DO saturation limit of 40% is based on the 1-day minimum 'bottom line' value of 4.0 mg/L from the NPS-FM (MfE, 2020), calculated at 15°C. All DO results are now reported as percent saturation for consistency.

3. Amm-N limit is the maximum value for 95% species protection from NPS-FM (MfE, 2020). The amm-N concentration may be pH adjusted based on MfE (2015).

4. Based on draft resource consent conditions (CRC) for Canterbury Coal Mine.

The monitoring data collected for the MSR and scrubber outflows from January 2022 to May 2025, as provided by BRL from their water quality database, are plotted in Figure 3 to Figure 6. The following observations are provided:

- Unionised H₂S concentrations in both the MSR and the scrubber outflows were frequently below the LOR of 0.002 mg/L. Occasional spikes were due to hardware failure (i.e., failure of the aeration system).
- Amm-N concentrations in the MSR outflow appeared to gradually decline over time but remained above the proposed water quality limit of 0.4 mg/L. While the scrubber system effectively reduced the concentrations to around the proposed limit, they still frequently exceeded it. Similar trends were observed by BRL (2025), who reported all MSR effluent samples above 0.24 mg/L.
- Nitrate-N concentrations in the MSR outflow were generally below the LORs, with occasional spikes. It is noted that the LOR for nitrate-N has decreased from 0.1 to 0.005 mg/L over recent years. The scrubber outflow nitrate-N concentrations were higher than the MSR outflow concentrations, typically ranging from 0.1 to 2 mg/L due to the oxidation of Amm-N, but they remained below the water quality limit of 2.4 mg/L (except for one sample).
- DO was typically less than 40% in the MSR outflow. Following optimisation, the scrubber system increased DO to between 60% and 100% saturation, demonstrating a significant improvement in oxygenation, particularly toward the end of the commissioning phase once commissioning faults were resolved.

The scrubber system was progressively upgraded through to April 2025 (with additional aeration, an improved power supply, and new bacterial media), and a full commissioning report has been finalised in September 2025 (BRL, 2025).

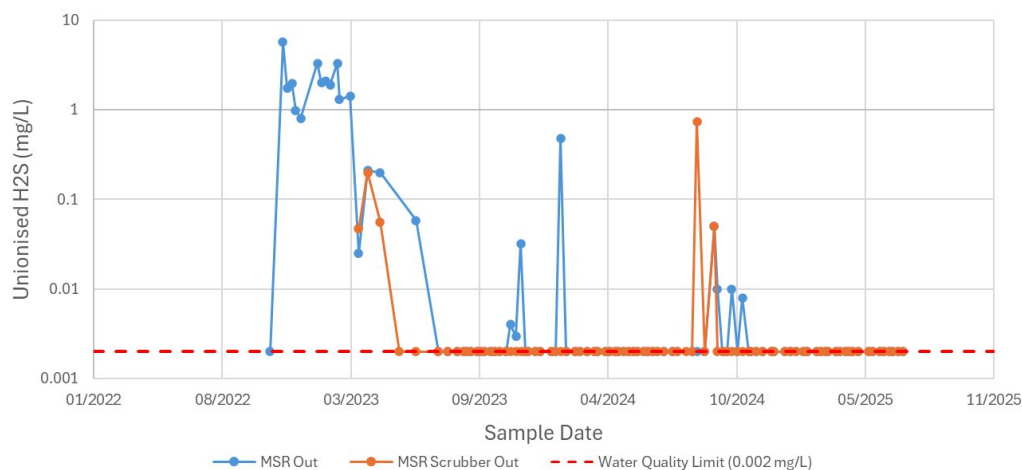


Figure 3: Unionised H_2S (mg/L) for the MSR outflow and MSR Scrubber outflow.

A water quality guideline of 0.001 mg/L was proposed, adjusted upwards to detection limit 0.002 mg/L for practical reasons.

BRL (2025) note that elevated unionised H_2S levels align with periods when the aerator was not in operation. Additionally, samples collected between August 2022 and March 2023 were likely entered incorrectly, resulting in inflow and outflow values being switched.

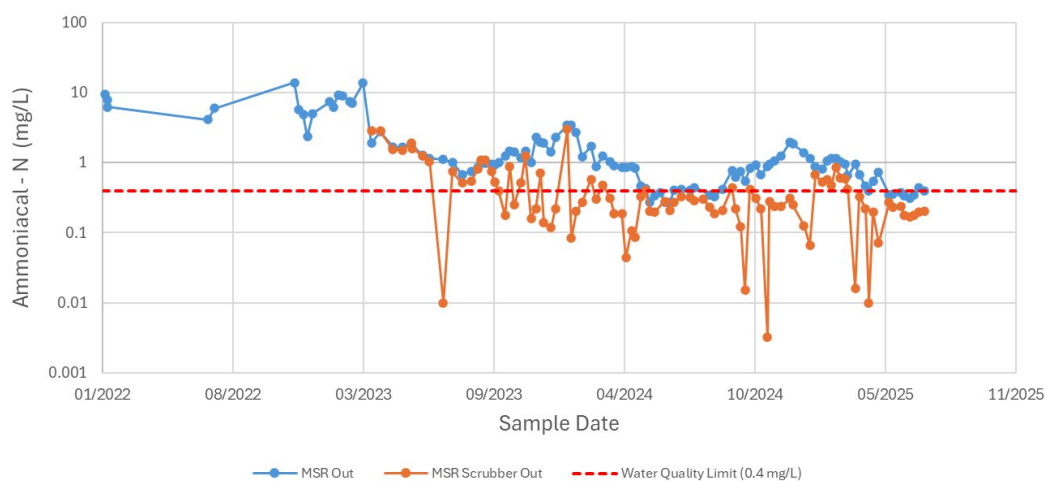


Figure 4: Ammoniacal-N (mg/L) for the MSR outflow and MSR Scrubber outflow.

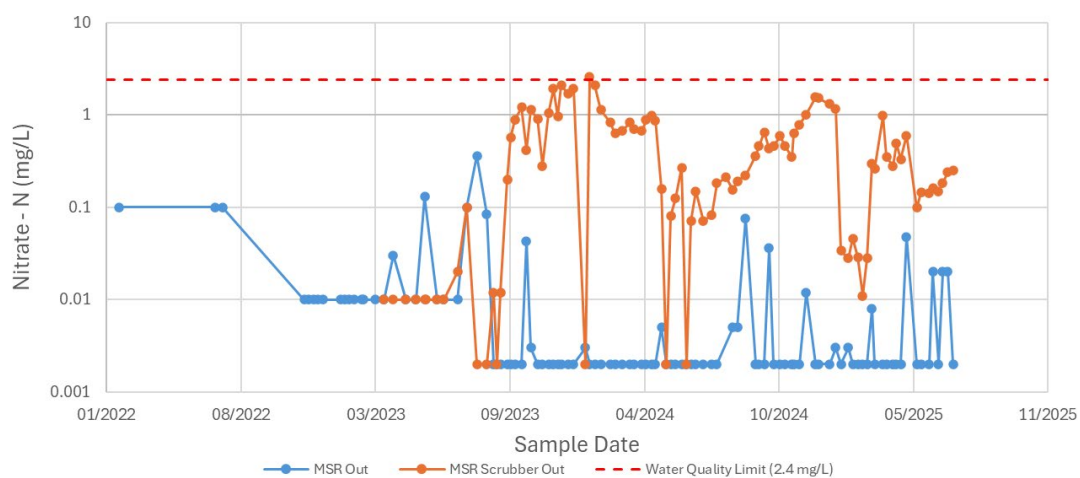


Figure 5: Nitrate-N (mg/L) for the MSR outflow and MSR Scrubber outflow.

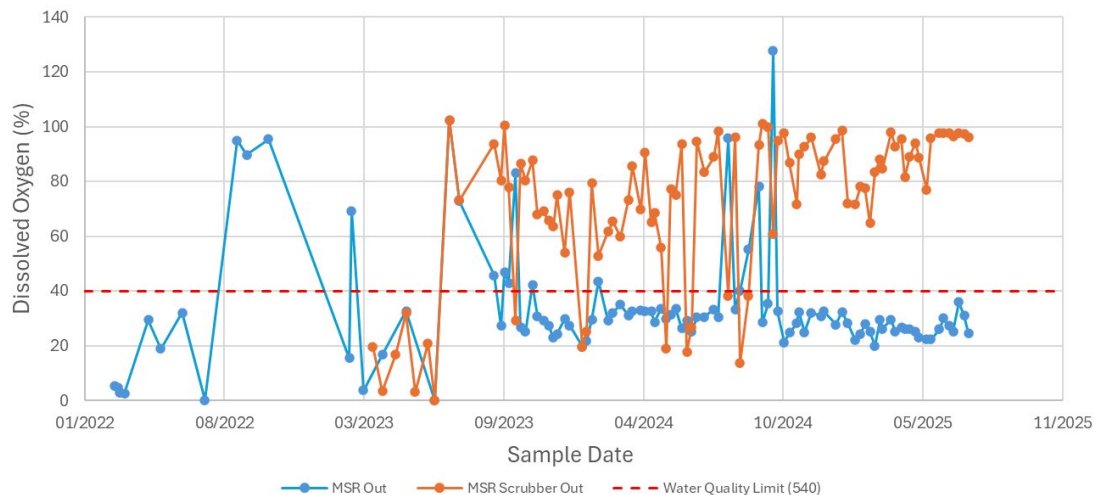


Figure 6: Dissolved Oxygen (%) for the MSR outflow and MSR Scrubber outflow.

TARA SCRUBBER PERFORMANCE

The scrubber system was initially in a commissioning stage, but strategic modifications have been implemented to enhance both system reliability and water quality performance.

Key improvements included the staged installation of additional aeration pumps (originally there was only one) to increase DO levels. To facilitate the growth of ammonia-oxidising bacteria, shade cloth was added inside the Intermediate Bulk Containers (IBCs) to serve as a bacterial growth medium, recognizing the requirement for time and favourable temperature to establish bacterial populations. The IBCs were also covered externally with shade cloth to limit light penetration.

The systems reliability has been further improved through the installation of additional solar panels and the integration of backup generator charging to support continuous aeration pump operation.

Monitoring results show that the MSR scrubber consistently improved effluent quality: reducing Amm-N concentrations from elevated MSR outflow levels to values close to the proposed 0.4 mg/L limit and raising DO from below 40 % saturation in the MSR outflow to typically between 60 and 100 % saturation once optimised.

SUMMARY

The post-closure water management strategy for the Tara Gully catchment is designed to maintain continuous baseflow through the Tara wetland while ensuring proposed water quality consent limits for Canterbury Coal Mine are met. The approach integrates treated discharge from the CC02 underdrain (via the Tara MSR and scrubber) and the flow from the N02 Pit Pond and Tara Pond to form a single continuous discharge.

The MSR scrubber is effective at improving the treated effluent water quality with respect to secondary contaminants of concern. While data indicates that water quality limits were occasionally exceeded in the scrubber discharge, particularly during early commissioning stage, the system demonstrated sustained improvement once optimised, with DO levels typically between 60 and 100 % saturation. Subsequent mixing with other site discharges is expected to result in a marked improvement in final water quality.

Overall, these results provide confidence that similar systems can be developed for the BPCP MSR effluent to treat potential secondary contaminants (Amm-N, H₂S, and low DO water).

CLOSING REMARKS

Please do not hesitate to contact Paul Weber at +64 3 242 0221 or [REDACTED] should you wish to discuss this matter in greater detail.

REFERENCES

ANZECC, 2000. Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand.

BRL (Bathurst Resources Limited), 2025. Canterbury Coal Mine Tara Mussel Shell Reactor Scrubber Commissioning Report, September 2025. Bathurst Resources Limited for Canterbury Regional Council.

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USEPA, 2021. National Recommended Water Quality Criteria - Aquatic Life Criteria Table <https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table>

APPENDIX J LIMITATIONS

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MINE WASTE MANAGEMENT

GREENROAD GROUP

APPENDIX P AMD SLUDGE MANAGEMENT

AMD Sludge Management

Buller Plateaux Continuation Project

20 July 2026

J-NZ0349-015-R-FINAL

AMD Sludge Management

Buller Plateaux Continuation Project

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EXECUTIVE SUMMARY

Bathurst Resources Limited (BRL) is seeking to obtain authorisation through the Fast-track Approvals Act (FTAA) to progress development and mining of the coal resources across the wider Buller Plateaux. This project is referred to as the Buller Plateaux Continuation Project (BPCP). There are five key project areas:

- Stockton mining area (Stockton)
- Mount Frederick South (MFS)
- Escarpment Extended (ESE)
- Upper Waimangaroa Haul Road (UWHR)
- Cypress mining area (Cypress)

This report evaluates the requirements and options associated with the management of acid and metalliferous drainage (AMD) sludge from water treatment processes proposed for MFS and ESE. AMD Sludge management at Stockton is discussed separately in the Stockton Operational Sludge Management Report (BRL, 2026a).

Report Objectives

The objectives of this report are to:

- Provide background information on AMD sludge generation processes.
- Summarise the quantities of the AMD sludge that will be generated by the BPCP at ESE and MFS.
- Explain how this AMD sludge will be managed over the project life.

General Background

AMD generated during mining requires treatment, which produces metal-rich sludge as a by-product. Both active treatment (e.g., calcium oxide dosing) and passive treatment (e.g., mussel shell bioreactors: MSR) precipitate metals like iron (Fe) and aluminium (Al), forming AMD sludge that requires management and disposal. During the construction and operational phases of the BPCP, AMD sludge will be heavily influenced by suspended sediments generated by ground disturbance (i.e., total suspended solids (TSS)), which will decrease as rehabilitation activities are completed, whilst the AMD component of the sludge will increase during the Operational Phase and then decrease during the Post Closure Phase. In the Post Closure Phase AMD will be dominated by Fe- and Al- hydroxide precipitates and TSS will be low.

The existing Stockton Mine AMD sludge management experience provides a practical analogue for managing these risks and future AMD sludge management at MFS and ESE, demonstrating the importance of:

- Understanding TSS and AMD components that contribute to AMD sludge and how to minimise TSS and AMD in mine-impacted waters.

- Reagent selection on AMD sludge volume and stability (e.g., limestone versus burnt and/or hydrated lime).
- Maintaining geochemical control (pH ≥ 5) to prevent metal leaching from AMD sludge.
- Management costs.
- AMD sludge disposal options.

AMD Sludge Quantities

For the BPCP, AMD sludge management must integrate site-specific chemistry, treatment system methods, availability of on-site disposal locations, and closure objectives, prioritising stable cost-effective disposal and long-term environmental safety. For the BPCP, AMD sludge will be generated over the four project phases as shown in Table E1.

The greatest quantities of AMD sludge will be generated in the Operational and Active Closure phases of the project when acidity loads are highest. Contributors to AMD sludge quantity include TSS and AMD (Fe, Al, calcium carbonate (CaCO_3)) as shown in Table E1.

Although quantities of AMD sludge are significant, they are low compared to the total quantity of overburden placed in the proposed Engineered Landforms (ELFs) at MFS and ESE. For instance, when peak AMD sludge is generated at ESE in FY36:

- MFS: In FY37 there is 2,113,100 bank cubic metres (bcm) of rock (MWM, 2026h) placed in the MFS ELFs (i.e., 5.07 Mt, based on a density of 2.4 t/m³) and 847 t of AMD sludge (dry basis) as shown in Table E2, which is a small proportion of the rock placed.
- ESE: In FY36 there is 9,802,600 bcm of rock (MWM, 2026h) placed in the ESE ELFs (i.e., 23.5 Mt, based on a density of 2.4 t/m³) and 4,353 t of AMD sludge (dry basis) as shown in Table E2, which is a small proportion of the rock placed.
- Across MFS and ESE this equates to 0.02% AMD sludge (dry basis) placed in the ELFs in FY36.

Pond Fines

- It is anticipated that high quantities of pond fines will be generated as part of sediment and erosion control procedures (e.g., check dams, silt ponds, active working pits, etc) during the Operational Phase (and to a much lesser extent during the Construction Phase). These materials may contain potentially acid forming (PAF) materials but will not contain water treatment plant (WTP) or passive treatment (PTS) AMD sludge.
- Pond Fines will be disposed into pond fine disposal areas, which are simple bunded cells built in the advancing tiphead of the ELFs at ESE and MFS, which is the generally accepted approach for the management of these materials. There is no specific designation for where the materials will be placed, other than within an ELF (where sediment loss from the facility is controlled).

Table E1: Mine Phases and AMD treatment sludge quantities for MFS and ESE

PHASE	TREATMENT METHOD	TSS CONTRIBUTION	AMD CONTRIBUTION	AMD SLUDGE QUANTITIES (WET)
Construction Phase	Portable active treatment systems	Moderate	Low	Moderate (10,000 to 20,000 m ³ /yr) ¹
Operational Phase	Active water treatment	High	High	High (~40,000 m ³ /yr) ²
Active Closure Phase	Active and passive water treatment	Moderate to low	High decreasing to moderate	High decreasing to moderate (~16,000 m ³ /yr decreasing) ³
Post Closure Phase	Passive water treatment	Low	Moderate	Moderate (~1,000 m ³ /yr) ⁴

Note: Estimates of sludge quantities are provided from the water and load balance models (WLBMs) for BPCP sub-areas ESE and MFS (MWM, 2026a,b) for the Operational, Active Closure, and Post Closure phases. AMD sludge estimates for the Construction Phase are based on material movements and sludge estimates from the first year of the WLBMs (pro rata based on material quantities).

1. Based on 3 wt% solids for the 2-year Construction Phase (Table 6 of this report).

2. Based on 12 wt% solids for the Operational Phase (Table 5 on this report).

3. Based on 12% solids for FY2045 (Table 5 on this report).

4. Passive treatment estimated to be >20% solids.

Active Treatment: AMD Sludge Quantities

AMD sludge volumes have been calculated based on estimated WTP influent water quality derived from the 'Base Case Water Model' derived in the Water and Load Balance Models (WLBMs) for ESE and MFS (MWM, 2026a,b). These data are presented in Table E2 and show expected sludge volumes from the bottom of the lamella clarifier (e.g., 3 wt%) and after additional mechanical dewatering (e.g., >12 wt%).

AMD sludge quantities (Base Case Water Model)) were determined by the following process with the main contributors to AMD sludge being TSS, Fe, and Al and unreacted CaO used to neutralise acidity:

- Data for influent water to the WTP at ESE and MFS were obtained from the WLBMs with data being summed into annual loads as tonnes per year (t/yr).
- TSS (t/yr) was provided by the WLBMs (dry weight equivalence).
- Al and Fe (t/yr) were converted to Al(OH)₃ and Fe(OH)₃ with a subsequent increase in weight by 2.89 and 1.91 times respectively.
- Acidity (t CaCO₃/yr) was used to determine the amount of unreacted limestone present in the CaO (estimated to be 5% based on typical safety data sheet results for CaO). Hence unreacted limestone (CaCO₃) in the sludge was calculated as 5% of the annual acidity load to the WTP.
- The contribution to sludge volume by trace metals is not significant with regards to the total sludge volume.

- The formation of gypsum was considered minor, mostly because the concentration of sulfate was <1,800 - 2,000 mg/L and hence gypsum is assumed to be under saturation (i.e., will not precipitate).
- $\text{TSS} + \text{Al}(\text{OH})_3 + \text{Fe}(\text{OH})_3 + \text{CaCO}_3$ was then used to calculate the AMD sludge content (dry weight basis).
- AMD sludge was then converted to a wet volume (m^3) based on 3 wt% solids (lamella clarifier) and 12 wt% solids (by mechanical dewatering (Process Flow, 2026a) where $1 \text{ t} = 1 \text{ m}^3$ to simplify the calculation.
- An assessment of the acidity load versus the volume of AMD sludge generated (3 wt% solids) was undertaken (i.e., AMD sludge (m^3) per tonne of acidity treated). Data indicates that:
 - Over the active water treatment period the ESE and MFS water treatment plants generate an average of 38 m^3 of AMD sludge per tonne of acidity. This is comparable to estimates at Stockton of $\sim 20 - 40 \text{ m}^3$ (MWM, 2025f) derived from earlier assessments and site-based experience.
 - Maximum estimated MFS and ESE AMD sludge volume to acidity load ratios ($67 - 117 \text{ m}^3/\text{t}$) occur in the early years of the BPCP (MFS and ESE) when acidity loads are low in comparison to TSS loads (i.e., TSS loads are higher and acidity loads are lower during this phase of the project). These higher numbers are likely overly conservative as a heavy sediment load will have a higher sludge density, which would decrease the volume of sludge generated per tonne of acidity neutralised.
 - Lower AMD sludge volumes to acidity loads occurs in the later years of the project when acidity loads are high in comparison to TSS loads ($17 - 21 \text{ m}^3/\text{t}$).

Table E2: AMD Sludge volumes (m^3) for ESE and MFS WTP - WLBM

INDICATIVE YEAR	TOTAL SLUDGE WET 3% SOLIDS		TOTAL SLUDGE WET 12% SOLIDS		TOTAL SLUDGE DRY	
	ESE	MFS	ESE	MFS	ESE	MFS
Year 2027	*	*	*	*	*	*
Year 2028	47,114	*	11,779	*	1,413	*
Year 2029	60,619	10,388	15,155	2,597	1,819	312
Year 2030	65,838	12,313	16,459	3,078	1,975	369
Year 2031	88,960	12,844	22,240	3,211	2,669	385
Year 2032	88,898	15,097	22,225	3,774	2,667	453
Year 2033	103,857	17,441	25,964	4,360	3,116	523
Year 2034	117,838	19,707	29,459	4,927	3,535	591
Year 2035	132,928	27,177	33,232	6,794	3,988	815
Year 2036	145,091	28,247	36,273	7,062	4,353	847
Year 2037	123,436	31,906	30,859	7,977	3,703	957
Year 2038	123,090	32,985	30,773	8,246	3,693	990
Year 2039	107,442	30,099	26,861	7,525	3,223	903
Year 2040	121,239	29,149	30,310	7,287	3,637	874

INDICATIVE YEAR	TOTAL SLUDGE WET 3% SOLIDS		TOTAL SLUDGE WET 12% SOLIDS		TOTAL SLUDGE DRY	
	ESE	MFS	ESE	MFS	ESE	MFS
Year 2041	128,821	33,207	32,205	8,302	3,865	996
Year 2042	113,369	30,930	28,342	7,732	3,401	928
Year 2043	104,894	15,766	26,224	3,942	3,147	473
Year 2044	72,627	3,038	18,157	759	2,179	91
Year 2045	62,137	1,185	15,534	296	1,864	36
Year 2046	20,335	1,173	5,084	293	610	35
Year 2047	17,528	-	4,382	-	526	-
Year 2048	16,026	-	4,006	-	481	-
Year 2049	14,768	-	3,692	-	443	-
Year 2050	13,688	-	3,422	-	411	-
Year 2051	12,918	-	3,230	-	388	-
Year 2052	12,431	-	3,108	-	373	-
Year 2053	11,970	-	2,993	-	359	-
Year 2054	11,566	-	2,892	-	347	-
Year 2055	11,196	-	2,799	-	336	-
Year 2056	10,866	-	2,717	-	326	-
Year 2057	10,669	-	2,667	-	320	-
Total	1,972,160	352,653	493,040	88,163	59,165	10,580

‘-’ Active water treatment is not proposed

Construction Phase (green) – Minor AMD treatment with AMD sludge being disposed to Pit 3 Pit Lake at ESE (200,000 m³) and within a purpose-built construction facility at MFS near the MFS Coal Storage Pad (10,000 m³).

* Further details are provided in Table 6.

Red text relates to the Active Closure Phase and expected AMD sludge quantities.

The data presented in Table E2 indicates that total AMD sludge quantities that will be generated over the BPCP life of mine at MFS and ESE will be in the vicinity of 600,000 m³ (based on 12% solids), which will be disposed predominantly into ELF's as backfill to purpose constructed cells. Based on 171 Mm³ (lcm¹) that will be placed in the ELF's, this quantity of AMD sludge represents ~0.4% (wet basis) and ~0.04 wt% on a dry basis of the total material placed at ESE and MFS.

Passive Treatment: AMD Sludge Quantities

MSRs are proposed for the passive treatment of basal seepage from ELF's at the ESE and MFS sub-areas. MSR will be installed progressively as mining operations in specific catchments are completed and land rehabilitated (some MSR starting within a few years). The start of the Post Closure Phase commences once all ELF basal seepage is being treated passively.

Projected sludge quantities generated by MSRs at ESE and MFS are shown in Table E3. MSRs require desludging every 5-years with desludging volumes varying depending on acidity and contaminant loads and the size of MSR.

¹ Loose cubic metres

Table E3: AMD Sludge Generation Rates for ESE and MFS MSR

BPCP SUB-AREA	ELF	MSR ACTIVATION DATE	MSR DESIGN ACIDITY (t/yr) ¹	MSR SURFACE AREA (m ²) ¹	SLUDGE QUANTITY AFTER 5 YEARS (m ³)	SLUDGE THICKNESS AFTER 5 YEARS (mm)
-	BV-ELF	-	10	350	74.9	214
ESE	BVE	2058	38.2	1,537	286	186
ESE	CON	2058	174.4	8,339	1,308	157
ESE	NSUL	2046	5.1	1,994	39	19
ESE	PPG	2058	0.1	306	1	3
ESE	WWH	2030	299.1	12,991	2,243	173
ESE	ESC	2030	11.9	245	89	363
MFS	MSR1	2045	11.2	512	84	165
MFS	MSR2	2045	2.7	128	20	159
MFS	MSR3	2045	3.8	345	28	82
MFS	MSR4	2045	16.1	345	121	351
MFS	MSR5	2045	24.2	1,582	182	115
MFS	MSR6	2045	5.3	375	39	105
MFS	MSR7	2045	28.5	1,683	214	127
MFS	MDC1	2029	0.1	49	0.7	15
MFS	MDC2	2029	0.1	42	0.4	10
MFS	MSR8	2047	43.3	2,644	325	123
MFS	MSR9	2047	5.1	331	38	115
MFS	MSR10	2047	2.7	204	20	98
MFS	MSR11	2029	8.6	244	65	265
MFS	MSR12	2029	8.9	244	67	274
Total					5,170	

1. Data from MWM (2025c). Acidity loads are based on the activation date of the MSR as per the water and load balance models.

Data indicates that the quantity of sludge generated after 5 years is variable and is a function of the influent acidity load, normalised against the existing BV ELF MSR acidity loads (MWM, 2026d). A total of ~5,170 m³ of sludge will be generated every 5 years once all MSRs are operating at MFS and ESE, although there is a steady decay in loads with time. A time period of 5 years is used as this relates to the expected desludging requirements (e.g., MWM, 2026c).

AMD Sludge Disposal

Proposed AMD sludge disposal options are summarised in Table E4.

Table E4: AMD sludge disposal summary

MINE PHASE	SELECTED OPTION	EXPLANATORY NOTES
Construction Phase	- ESE – within Pit 3 - MFS – within a temporary sump built for construction phase water management.	- Minor AMD treatment is expected in the Construction Phase (~60 t H₂SO₄/yr and 90 t H₂SO₄/yr at ESE and MFS respectively) - ESE: The existing Pit 3 Pit Lake will be used to settle sludge. Backfill of mine rock will eventually bury this AMD sludge (noting the pit lake will be drained first by pumping to Lake Brazil to drain into Cascade Creek Trib (V8)). - MFS: A temporary sump of 10,000 m³ will be built near the MFS Coal Storage Pad. This will be operational until the MFS WTP is constructed and will manage treatment (e.g., Ca(OH)₂, MgO, or NaOH) of any AMD and TSS during the Construction Phase. Once the WTP is operating this AMD sludge sump will be backfilled. The MFS facility will require periodic cleaning and removal of AMD sludge to ESE or Stockton to ensure sufficient capacity for AMD sludge settlement in this sump. - In the second year of Construction at MFS and ESE, AMD sludge will be placed in unlined cells within ELF's (BRL, 2026b). - Management processes will be developed to dewater AMD sludge prior to removal and disposal.
Operational Phase	Placement within cells within the ELF's as they are being constructed. AMD Sludge will not be placed in cover layers, NAF² layers, or lower sulfur zones (10 m ELF shells, i.e., within 10 m of the ELF final surface).	- Unlined cells within ELF's (BRL, 2026b) where high acid forming (HAF) materials are avoided. - Seepage from ELF's will be fully managed and treated by the two WTP. - AMD sludge may be disposed of with Pond Fines. - Other options for AMD sludge disposal will be investigated during the Operational Phase. These options are discussed in Table 1 and Section 5.2.

² Non-acid forming

MINE PHASE	SELECTED OPTION	EXPLANATORY NOTES
Active Closure Phase	Disposal of AMD sludge onsite.	- AMD sludge from MFS and ESE will be disposed into engineered cells (or other similar management processes) on the ESE Coal Infrastructure area. - AMD sludge may also be transported to Stockton for disposal, which will have operating AMD sludge disposal facilities. - Other AMD sludge disposal options assessed during the Operational Phase will also be considered.
Post Closure Phase	Disposal of AMD sludge onsite.	- AMD sludge will be disposed at Stockton (which will have ongoing AMD treatment), or by other approved methods that may be developed over the Operational Phase of the BPCP for minor quantities of AMD sludge generated in the Post Closure Phase by the MSR. - Other options include disposal to an approved offsite landfill.

Disposal Risks

The contribution to sludge volume by trace metals is not significant with regards to volume effects as explained below:

- Al and Fe hydroxides contribute to ~ 95% of the sludge volume (dry weight basis).
- Major trace metals (Manganese (Mn), Nickel (Ni), Zinc (Zn) hydroxides) contribute ~5% of the sludge volume (1.6%, 0.5%, 2.9% respectively).
- All other trace metals contribute to < 0.5% of the sludge volume (dry weight basis).
- During the first year, the ratio of TSS to Al + Fe load is low with Al + Fe contributing to ~5% of the total sludge volume (dry weight basis) for ESE Year 2028; at the end of the Active Treatment Phase Fe + Al load contributes to ~42% of the total sludge volume (dry weight basis) for ESE Year 2057.

However, studies indicate that trace metals that are preferentially mobilised from sludge (Mn > Cobalt (Co) = Zn > Ni) are also more difficult to remove by passive treatment using MSR (Mn – 58.6%; Co – 82.8%, Zn, 63.7%, Ni – 40.2%). A higher trace metal load may require a longer active treatment period.

Supporting Studies

The following supporting studies and related reports are relied on for this AMD Sludge Management Report:

- WLBM for MFS and ESE (MWM, 2026a,b)
- Process Flow WTP design reports (Process Flow 2026a,b).
- Passive Treatment Design Toolkit (MWM, 2026c).

- Water Treatment Report (MWM, 2026e).

These reports are discussed in this document. The technical content summarised in this report is used to support the development of the BPCP AMD Water Management Plan for ESE, MFS, and UWHR (BRL, 2026b).

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1 **INTRODUCTION**

Mine Waste Management Limited (MWM) has developed this report on acid and metalliferous drainage (AMD) sludge management for Bathurst Resources Limited (BRL) who is seeking to obtain authorisation through the Fasttrack Approvals Act 2024 (FTAA) to progress development and mining of the coal resources across the wider Buller Plateaux. This project is referred to as the Buller Plateaux Continuation Project (BPCP). There are five key project areas:

- Stockton mining area (Stockton)
- Mount Frederick South (MFS)
- Escarpment Extended (ESE)
- Upper Waimangaroa Haul Road (UWHR)
- Cypress mining area (Cypress)

This report evaluates the requirements and options associated with the management of AMD sludge from MFS and ESE. AMD sludge management at Stockton is discussed in BRL (2026a).

1.1 **Report Objectives**

The objectives of this report are to:

- Provide background information on AMD sludge generation processes.
- Summarise the quantities of the AMD sludge that will be generated by the BPCP at ESE and MFS.
- Explain how this AMD sludge will be managed over the project life.

2 BACKGROUND AND LITERATURE REVIEW

This section summarises relevant background information on AMD sludge.

2.1 Principles of AMD Treatment and AMD Sludge Formation

AMD is a general term used to describe waters impacted chemically by mining activities and can contain quantities of metals, salts, and acidity. AMD is typically generated by the excavation of rocks that contain sulfide minerals, such as pyrite. When these minerals are exposed to oxygen and water, they undergo weathering processes and oxidise, generating acidity and releasing metals. AMD will be generated at the BPCP. The treatment of AMD by active treatment or passive treatment processes results in two effluent streams:

- A clean treated water that can typically be released into the receiving environment (assuming treatment performance criteria are met) or back into the mine water circuit.
- AMD sludge that contains metal hydroxide precipitates (e.g., iron hydroxide ($\text{Fe}(\text{OH})_3$) and aluminium hydroxide ($\text{Al}(\text{OH})_3$)) and other products including TSS³ from mine impacted water (MIW), and unreacted neutralant (e.g., limestone (CaCO_3), mussel shells, etc.).

2.2 Background Experience: Stockton and Escarpment Mines

BRL, BT Mining Limited, and its predecessor, Solid Energy (NZ) Limited, have been treating MIW and managing AMD sludge at the Stockton Mine for almost 20 years. Significant technical expertise, experience, and skill in terms of managing AMD and MIW have developed over this timeframe. Further details on treatment at Stockton are available (e.g., Elder et al., 2011; GHD, 2026). This section reviews AMD sludge management at the Stockton BPCP sub-area.

2.2.1 AMD Treatment

AMD treatment of the Mangatini Stream (Stockton Mine) has been ongoing since ~April 2007 with continuous treatment by either ultrafine limestone ($\text{CaCO}_3 < 100 \mu\text{m}$) (Elder et al., 2010) or in later years (i.e., 2015 onwards) by CaO. Significant improvements in water quality were measured in the Ngakawau River (site NR), downstream of the Stockton Mine, after treatment commenced as shown by a pH increase (Figure 1) and an Aluminium (Al) decrease (Figure 2).

³ Total suspended solids

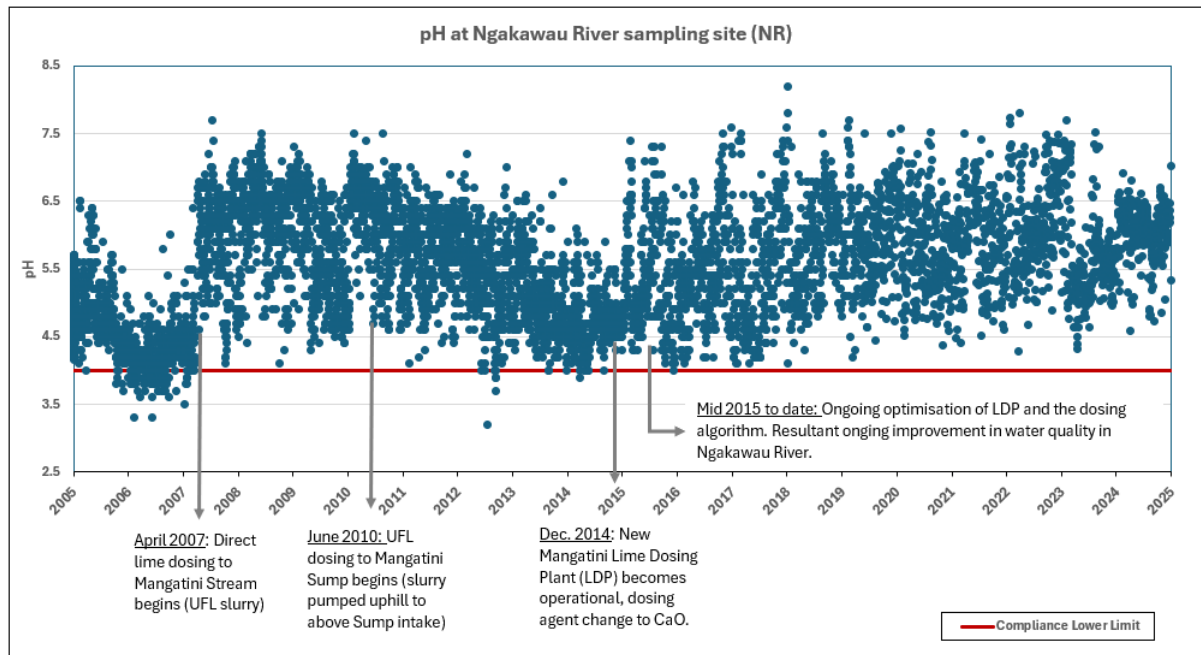


Figure 1: pH results (daily) for the Ngakawau River (Site NR)

Source: BRL

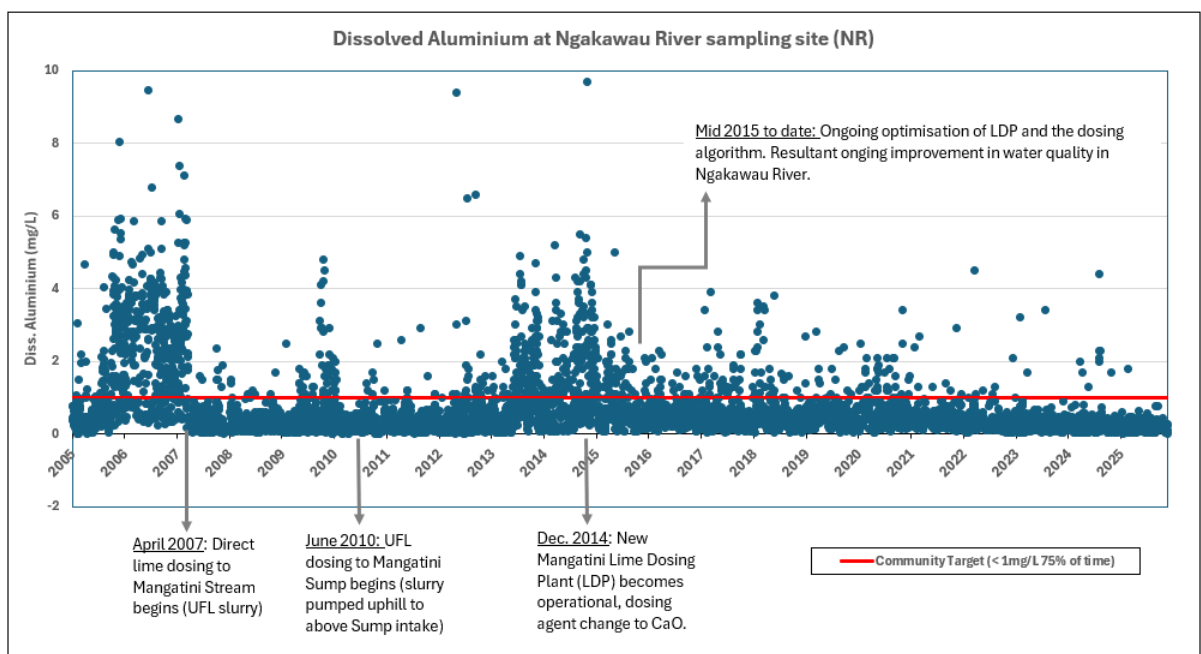


Figure 2: Dissolved aluminium results (daily) for the Ngakawau River (site NR).

Source: BRL

2.2.2 Mangatini Sump

AMD sludge (TSS + AMD) at Stockton is collected in the Mangatini Sump (Figure 3), which was designed and commissioned in June 2010 to capture and settle AMD sludge generated from the treatment of mine impacted waters prior to its discharge to the receiving environment (Elder et al., 2010). The sump is a significant component of the Stockton Water Management Project assisting to achieve community water quality targets in the Ngakawau River (Elder, et al., 2011). The total

excavation volume of the Mangatini Sump is approximately 1.8 million m³, which makes it one of the largest sediment and AMD control structures in New Zealand. The total water storage capacity for the normal operating level (RL 593.5 m) is about 900,000 m³ of which approximately 443,000 m³ is live storage. Flows below ~15 m³/sec are diverted from the Mangatini Stream into the sump via a low diversion structure located on the Mangatini Stream (Elder et al., 2011). A floating decant structure decants treated water from the surface of the Mangatini Sump and conveys it through a tunnel back to the Mangatini Stream.



Figure 3: Mangatini Sump

Source: Elder et al. (2011)

Treatment of AMD acidity by a lime-based product neutralises this acidity. At Stockton, AMD sludge is classified into three main types (Figure 4):

- Deltaic Sediment: Coarser TSS material near the sump inlet with high acid neutralising capacity (ANC) of ~251 to 255 kg H₂SO₄/t and a whiter appearance due to the limestone.
- Ultrafine Limestone (UFL) AMD Sludge: This sludge was generated by neutralisation of AMD by ultrafine calcium carbonate (CaCO₃) treatment prior to the site converting to CaO for AMD treatment. The sludge generally had a high density (~6 wt% solids) and contains finer TSS.
- Calcium Oxide (CaO/Quicklime) AMD Sludge: This sludge is generated by neutralisation of AMD by CaO treatment. The sludge has a low density (~3 wt% solids) compared to AMD sludge treated using UFL and is often called low density sludge (LDS) and contains finer TSS.

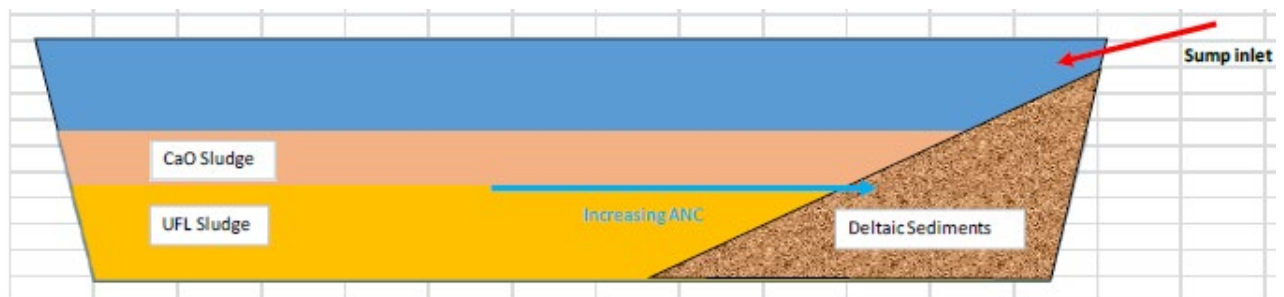


Figure 4: Conceptual model of sludge zones and types.

Source: Pope and Christenson (2016).

AMD sludge properties within the Mangatini Sump can be heavily influenced by suspended sediment. Figure 5 shows sludge types at varying distances from the sump inlet, with coarser sediments near the delta (sump inlet (i.e., 2 m)) and finer sediments in distal parts of the sump away from the inlet (i.e., 20 m). Figure 6 presents the general sampling locations associated with the sludge types presented in Figure 5. This is in contrast to AMD sludge at Stockton, generated when suspended sediment is low (i.e., TSS is low and acidity is high), which is visibly dominated by Iron (Fe)- and Al- hydroxide flocs (Figure 7).

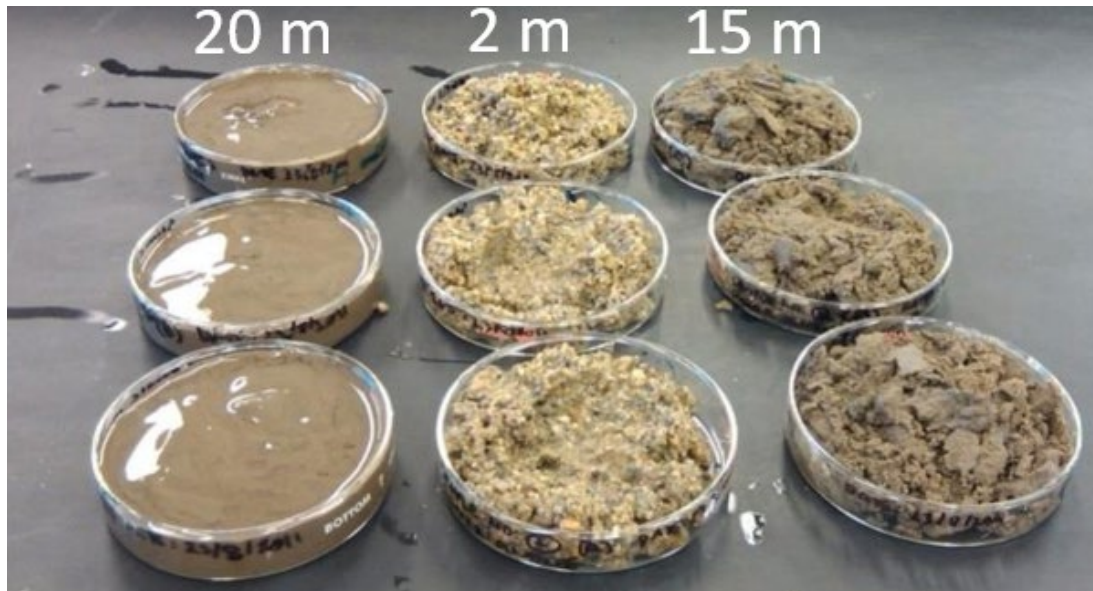


Figure 5: AMD Sludge Types in the Mangatini Sump, which is influenced by TSS load,

Source: Wallace (2011) .



Figure 6: AMD sludge sampling locations: Mangatini Sump

Source: Wallace (2011). Sampling locations (2m, 15m, 20m) represent samples shown in Figure 5. Noting the sump is ~340 m long.

2.2.3 AMD Sludge Density

Sediment dominated AMD sludge is expected at ESE and MFS during the Construction and Operational phases of the project. As mining advances towards closure and areas are rehabilitated, the AMD will transition to a Fe/Al dominated AMD sludge, as sediment loads decrease.

There is a significantly higher volume of AMD sludge generated when CaO or Ca(OH)₂ is used for AMD treatment compared to the use of ultrafine CaCO₃ (UFL) treatment (Figure 7). Previous work (e.g., Wildy, 2015) suggests this is close to 3 wt% solids for Ca(OH)₂ compared to UFL that is closer to 6 wt% solids. The difference is due to CaO forming 'cotton wool' type flocs due to rapid neutralisation and nucleation of the Fe/Al flocs that forms poorly ordered mineral structures; whereas CaCO₃ neutralisation is slower and Fe/Al floc form more structured/ordered minerals due to slower nucleation process that have a higher density.

CaO is proposed for the ESE and MFS project sub-areas (Process Flow, 2026a) - noting further studies are being undertaken at Stockton into the use of MgO (BRL, 2026a) and this may be used at MFS and ESE if better outcomes can be achieved. Studies for MFS and ESE indicate that AMD sludge will be 3 wt% solids (Process Flow, 2026a) prior to any further densification processes.

Operational experience at Stockton Mine and test work completed by Verum (2023) suggests the AMD sludge is around 2 wt% solids and this number is used for design purposes and estimating pumping requirements at Stockton Mine. A value of 3 wt% solids for AMD Sludge is used for MFS and ESE, which has additional lamellar clarifiers.

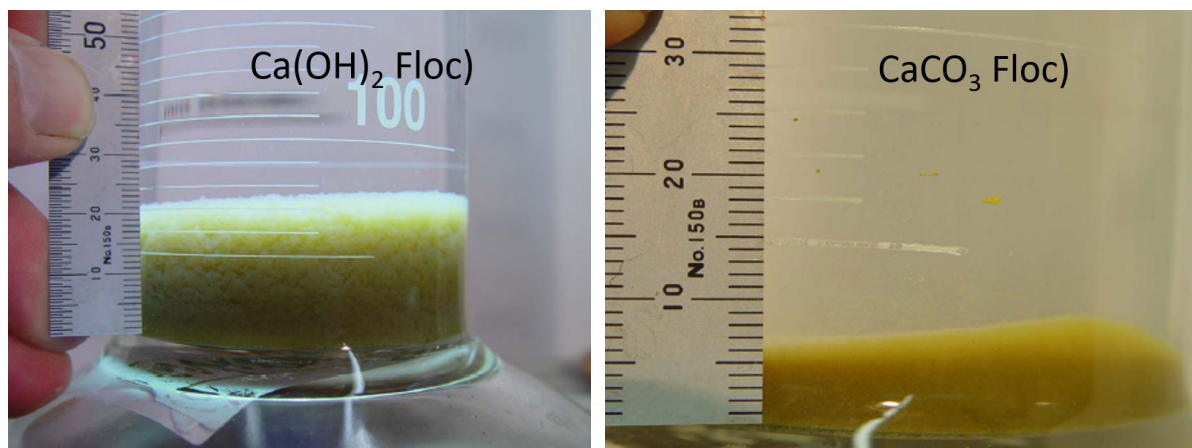


Figure 7: Stockton AMD sludge (low suspended solids content) following neutralisation by Ca(OH)₂ and CaCO₃.

Source: Wildy (2015).

2.2.4 Geochemical Stability of AMD Sludge

Site-specific studies (Pope and Christenson, 2016) on the geochemical stability of AMD sludge from the Mangatini Sump have identified that the sludge produced is pH sensitive. Toxicity Characteristic Leaching Procedure (TCLP) testing indicates that below pH 5 (Figure 8):

- Aluminium and iron hydroxides dissolve and the Fe and Al are remobilised into solution, and
- Trace metals (Zinc (Zn) and Nickel (Ni)) are released via desorption from Al and Fe hydroxides.

These effects are most pronounced below pH 4 for aluminium and pH 3 for Fe, which aligns with pH-hydroxide formation relationships.

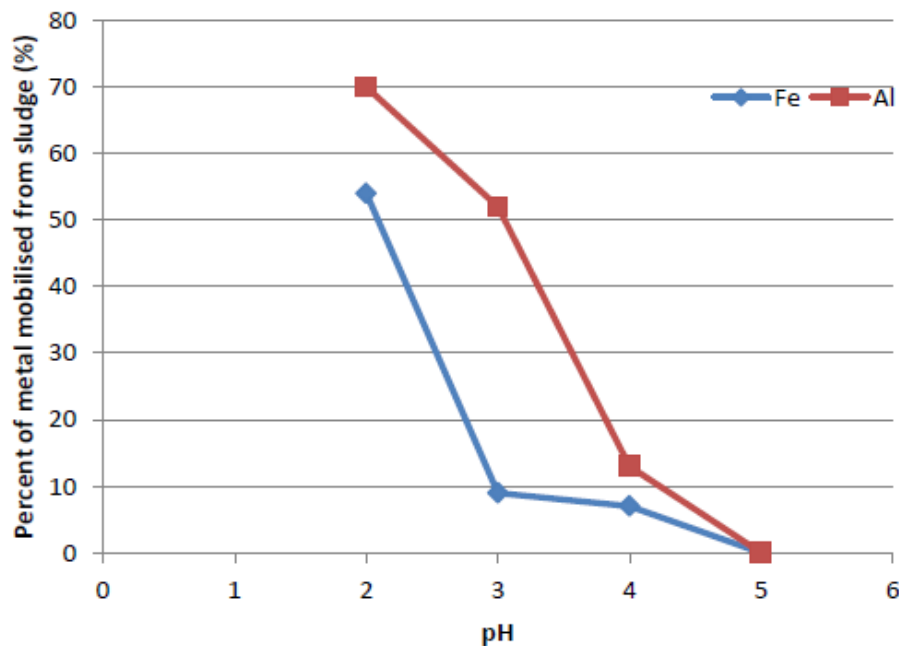


Figure 8: Percentage of metal mobilised from AMD sludge at varying environmental pH values.

Source: Pope and Christenson (2016).

Other studies at Stockton Mine further confirm that AMD sludge is only stable when maintained above pH 5.0, and that residual ANC may offer only temporary buffering against acid exposure (Wildy, 2015). Other site-specific studies also corroborate this finding, noting that sludge dissolution and metal remobilisation occurs in acidic settings (e.g., Wallace, 2011).

2.2.4.1 AMD Sludge Column Leach Test Trials - 2018

Laboratory column leach trials (Figure 9) were undertaken to assess the risks (e.g., release of metals) of AMD sludge (referred to as low density sludge (LDS)) using LDS derived from Stockton Mine mixed with non-acid forming (NAF) granite and potential acid forming (PAF) Brunner Coal measures (BCM) to provide guidance on sludge management options for Stockton Mine. Results (O'Kane, 2018) indicate that:

Acid soluble metal loads (assessed by acid digestion, i.e., 4 M HCl extraction) of PAF and LDS material was significantly higher than the water-soluble fraction suggesting metal loads from both materials would be significantly higher in an acidic environment.

- All columns that contained PAF became acidic; all granite columns remained circum-neutral (Figure 10).
- If AMD sludge and PAF rock are combined at a volumetric ratio of ~1:4, the low density of the LDS (1.1 t/m³) and high moisture content (~90 wt%) mean that on a dry basis, LDS is a relatively small proportion of the total mass (LDS:PAF ratio of ~1:50 by weight). This limits the potential for LDS to contribute significantly to contaminant loads from a PAF/LDS co-disposal ELF.
- Leach data showed that contaminant loads from the 'PAF Only' column were typically higher than the PAF/LDS columns (Figure 11). This suggests the risk (e.g., acidity/metal release) for

AMD sludge disposal in a PAF ELF is lesser than the risks associated with PAF materials. This is likely to be associated with the unreacted limestone that will be contained in the AMD sludge.

- Data indicates that there is a slight buffering of acidity by addition of LDS to the PAF columns (Figure 12). However, once PAF/LDS columns became acidic there was no significant pulse of metals from the LDS of the timeframe of the test that was greater than the contaminant load already derived from the PAF rock.

For completeness, a number of metals were assessed (Figure 11) as part of the study but not all metals are of concern. For instance, arsenic is shown in this figure, however studies have shown it is low in AMD impacted waters across the Buller Plateaux (MWM, 2026d).

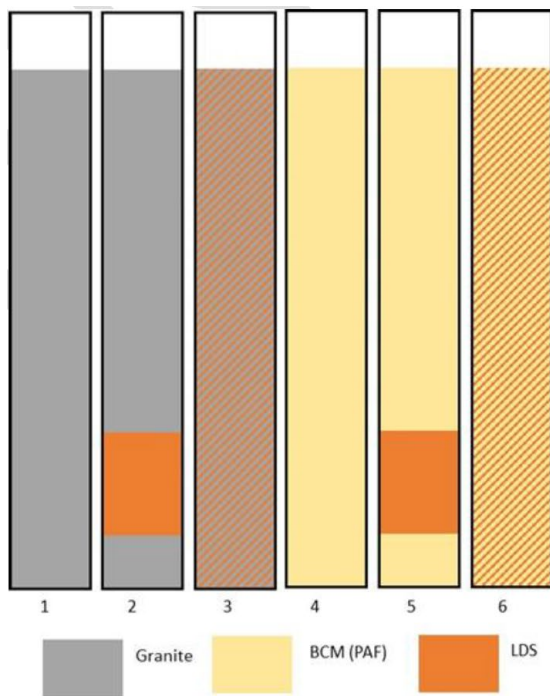


Figure 9: AMD Sludge column configuration.

Source: O'Kane (2018); hatched indicates blending of LDS

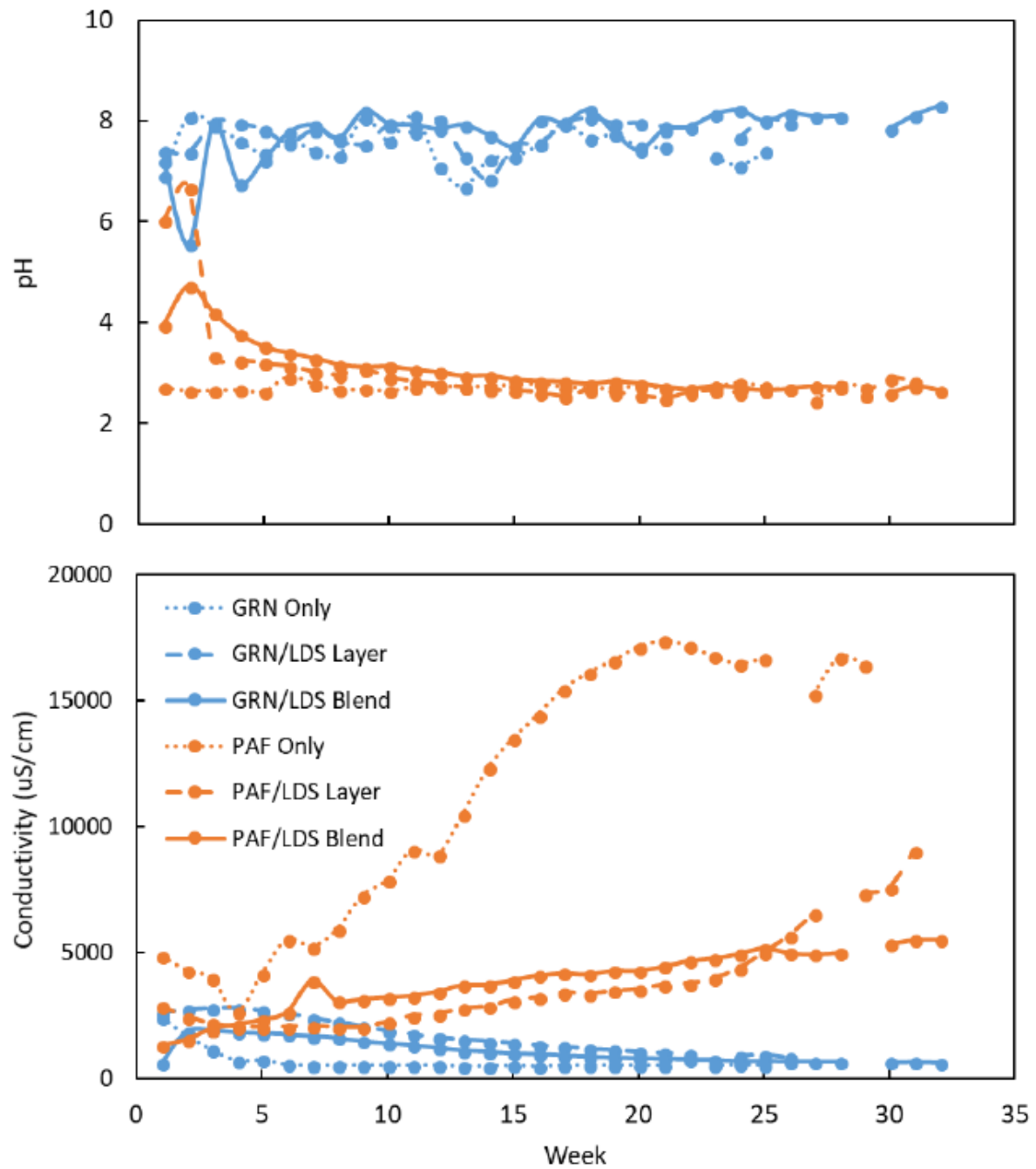


Figure 10: Column Leach test pH and conductivity.

Source: O'Kane (2018). Note GRN = granite

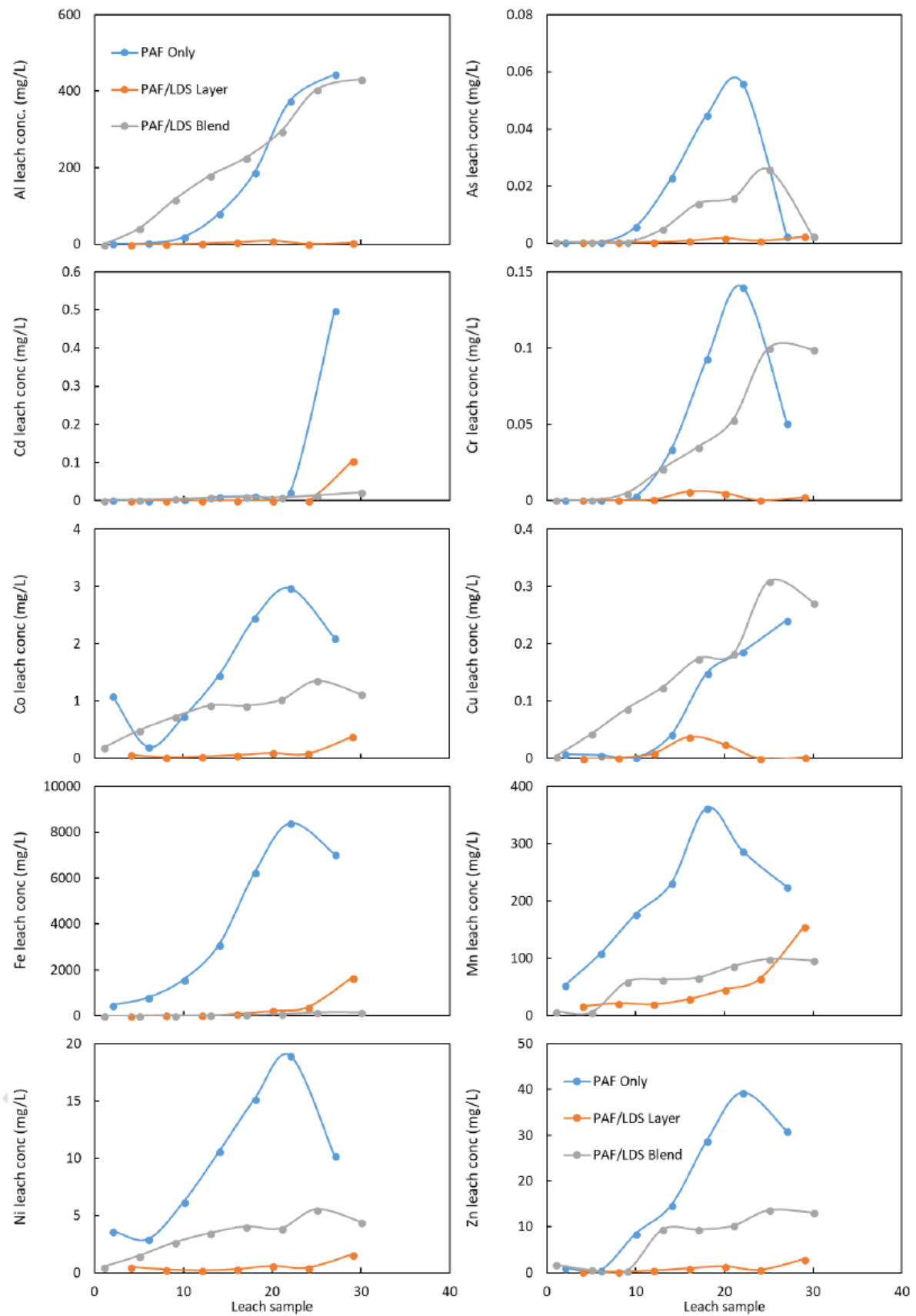


Figure 11: PAF and PAF/LDS leach contaminant concentrations – metals

Source: O'Kane (2018)

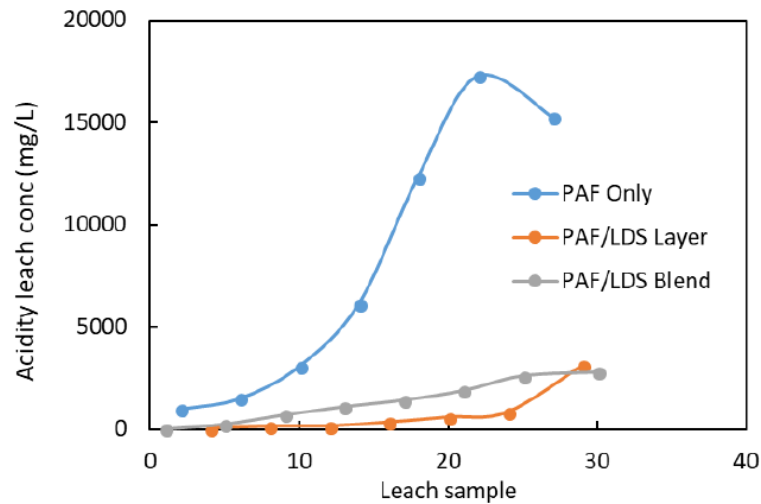


Figure 12: PAF and PAF/LDS leachate concentration – acidity.

Source: O'Kane (2018)

2.2.4.2 AMD Sludge Field Trials - 2021

MWM (2021) reported on large field trials that were completed at Stockton Mine where AMD sludge was layered with high sulfur (0.657 wt% S) PAF material (Figure 13). This involved an upward sequence of 0.3 m PAF, 1.0 m LDS, and 0.4 m PAF as shown in Figure 13. This resulted in an overall layer thickness ratio of 0.7 PAF:1 LDS. This ratio is significantly higher than the anticipated operational layer thickness ratio of 4 PAF:1 LDS (e.g., Stockton Mine has the operational assumption that a low volumetric LDS:PAF ratio of 1:4 would be required for stability reasons (i.e., 1 m LDS layer in a 5 m PAF lift). Hence, the trial is likely to exaggerate the effect of LDS on leachate chemistry of the trial (noting pH is comparable – hence mobilisation of metals from AMD sludge would be elevated compared to the anticipated management process).

The trial compared leachate water quality for two large in-dump polythene lined cells. One cell contained only potentially acid forming (PAF) material (referred to as PAF cell) as a control while the second cell contained both LDS and PAF (referred to as LDS cell) as the test pond. Leachate samples were collected and analysed periodically. The purpose of the liner was to capture water for analysis rather than installing an engineered liner to control AMD sludge leachate.

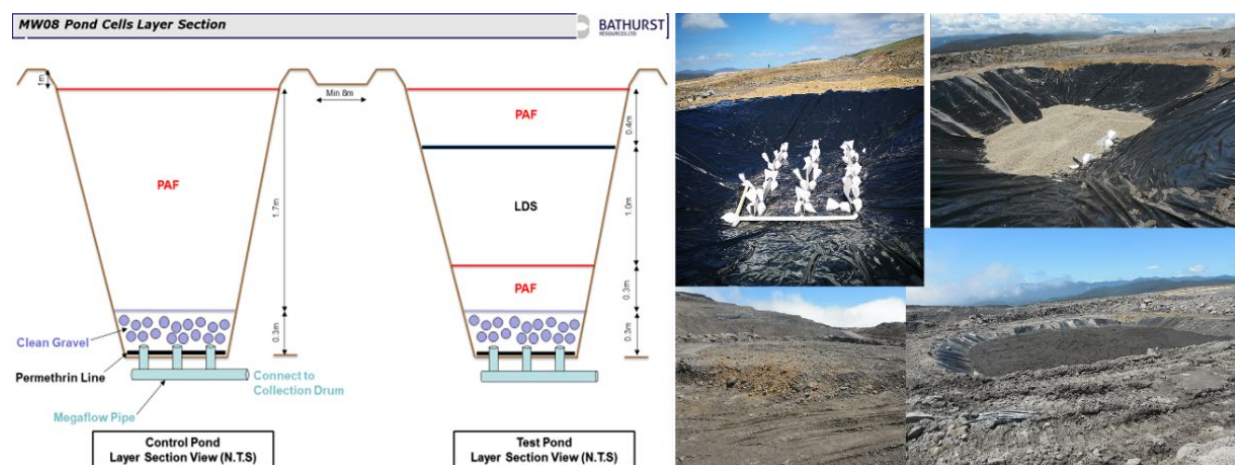


Figure 13: LDS disposal field trial cell configuration and construction photos.

Source: MWM (2021)

Comparisons between leachate chemistry over the trial period were used to evaluate the feasibility of LDS co-disposal in PAF ELF's from an AMD management perspective.

Results of the LDS disposal field trials largely corroborated those of previous laboratory studies (e.g., O'Kane, 2018), showing:

- Initially the LDS cell leachate had a higher pH and lower acidity than the PAF cell leachate, indicating LDS suppression of acidity in the PAF material (due to the inherent acid neutralisation capacity of the AMD sludge). This extended to initially lower leachate concentrations for some contaminants of interest, particularly acid soluble metals (e.g. Manganese (Mn), Ni, and Zn).
- The LDS suppression of acidity lasted until approximately day 100 when leachate acidity and several contaminant concentrations from the LDS Cell generally started to increase. Concentrations spiked between day 100 and 400. By day 400, the LDS Cell leachate acidity and contaminant concentrations had stabilised, showing a steady decay over the remaining trial period.
- A key group of contaminants in the LDS disposal field trial context were identified, with a hierarchy of additional mobilisation through LDS/PAF co-disposal of Mn > Cobalt (Co) = Zn > Ni. The leachate concentration of these contaminants spiked between day 100 and 400 with sustained concentrations (and concentrations exceeding the corresponding PAF Cell sample concentration for the same date). This suggests preferential mobilisation of these contaminants from LDS under acidic conditions (i.e., Mn > Co = Zn > Ni).
- Arsenic (As), Cadmium (Cd), and Chromium (Cr) leachate concentrations from the LDS Cell were either similar to, or lower than PAF Cell leachate concentrations over the trial period (Group 3). This suggests that LDS addition to PAF backfill has either no effect or potentially suppresses mobilisation of these contaminants.

Data for the field trials are presented in Figure 14 to Figure 17.

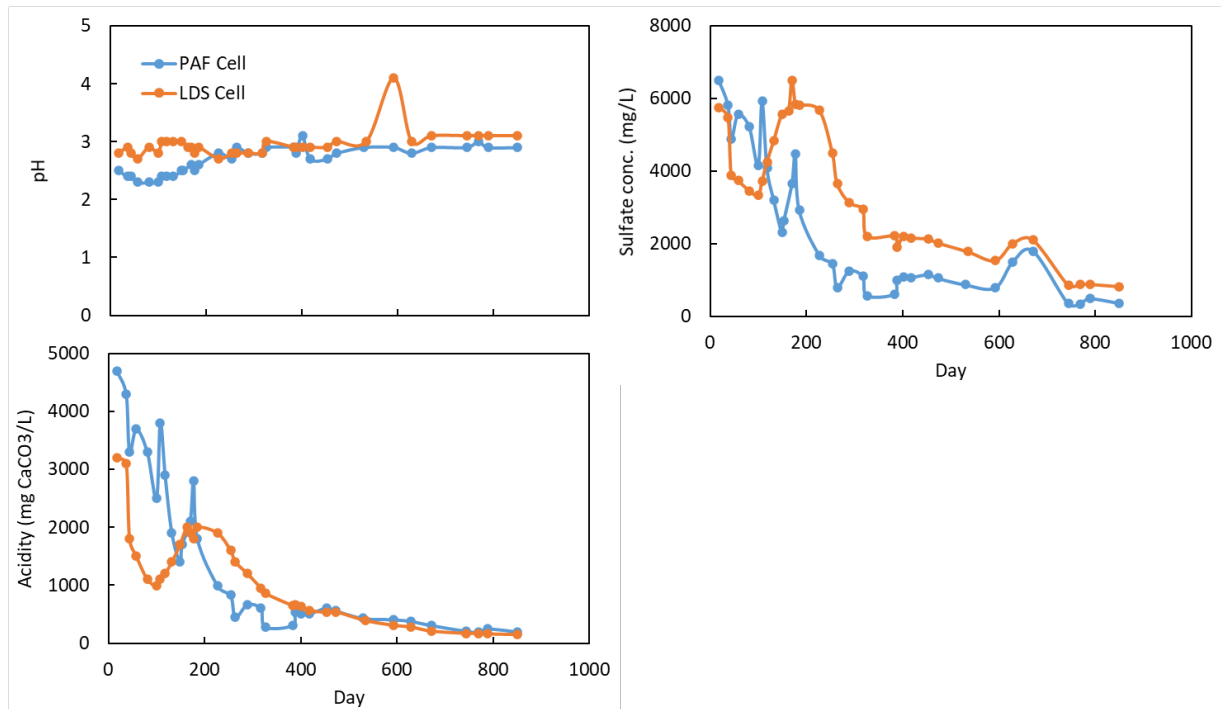


Figure 14: Indicators of acidity generation and stored sulfate mobilisation

Source: MWM (2021)

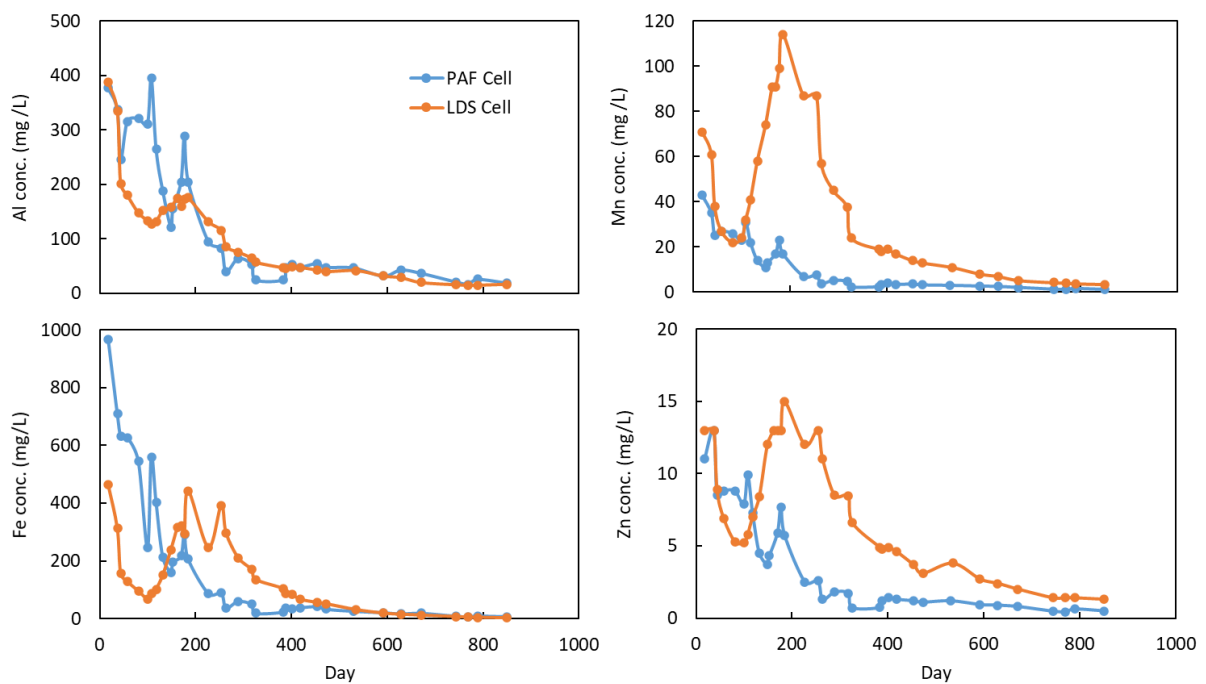


Figure 15: LDS disposal field trial leachate contaminant concentrations

Source: MWM (2021)

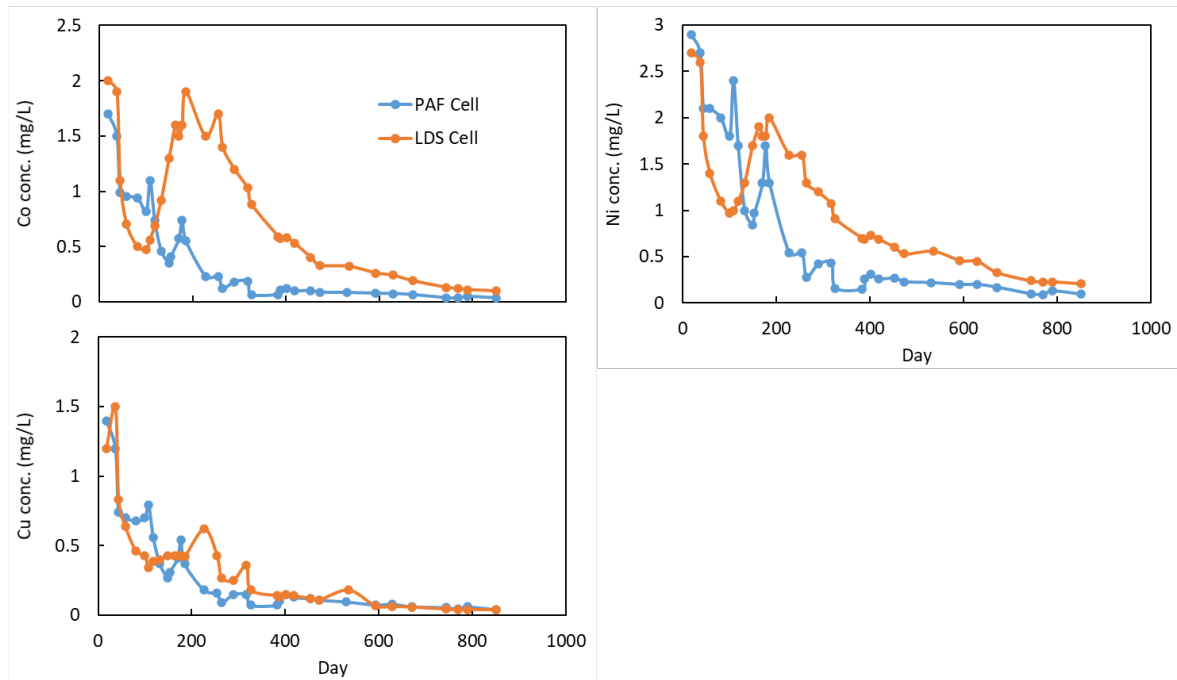


Figure 16: LDS disposal field trial leachate contaminant concentrations

Source: MWM (2021).

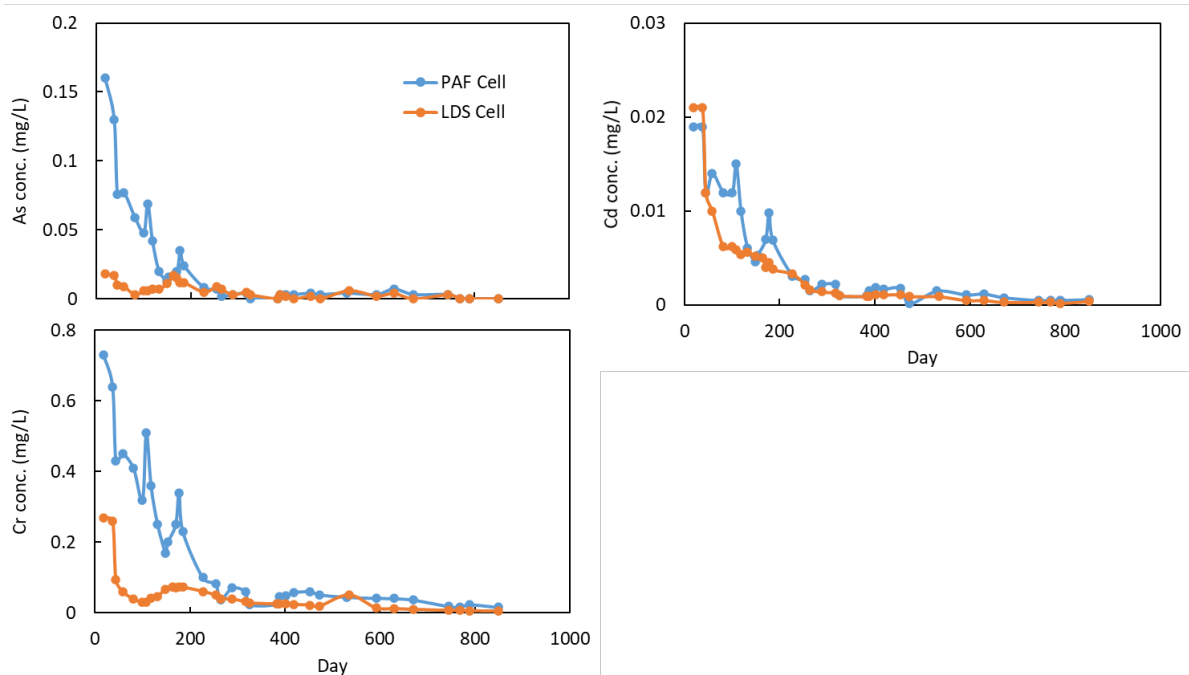


Figure 17: LDS disposal field trial leachate contaminant concentrations.

Source: MWM (2021).

Overall, the LDS disposal field trial data suggests the following hierarchy in regards to contaminants of potential concern (PCOC):

- Potential additional mobilisation through LDS/PAF co-disposal: Mn > Co = Zn > Ni; and
- Negligible additional mobilisation through LDS/PAF co-disposal: As, Cd, Cr, and Cu.

2.2.5 *Summary: Co-disposal Trials*

The data presented in this section indicates that:

- The PAF component of the ELF is most likely to be the dominant long term factor influencing leachate contaminant loads and concentrations from LDS co-disposal with PAF in a landform. This is because the volume of PAF disposed in any landform will continue to be substantially greater than the volume of LDS / PAF co-disposed material.
- The co-disposal trials undertaken for LDS and PAF are likely to be an extreme disposal environment (0.657 wt% S) compared to ESE and MFS where the average sulfur content of ELF is lower (0.28 – 0.43 wt% S for ESE ELFs and 0.12 – 0.28 wt% S for MFS ELFs).

Disposal of AMD sludge with PAF materials or within acidic areas of any ELF is unlikely to generate significant risks for the receiving environment (noting that some metals such as Mn > Co = Zn > Ni could be elevated). If this was to occur, then placement should be in areas where seepage can be captured for further treatment.

2.2.6 *Passive Treatment AMD Sludge*

Mussel shell bioreactors (MSR) are the preferred technology for the long-term treatment of AMD impacted waters during the Post Closure Phase. Studies were completed at the Escarpment Mine to assess the rates of AMD sludge generation within the Barren Valley ELF MSR (BV-MSR). Full details are provided in MWM (2026c).

The BV-MSR was designed to treat acidic drainage from the BV-ELF and was constructed by BRL in September 2016 as a field trial to evaluate MSR performance under local site conditions (Robertson et al., 2017). The BV-MSR was designed to:

- Treat acidic flows captured by the BV-ELF underdrain.
- Supply alkalinity to Pit 3 Pit Lake to improve water quality.
- Operate with minimal ongoing maintenance, primarily by limiting sediment inputs that could reduce system permeability (i.e., sediment runoff from rehabilitated surfaces).

To characterise sludge formation rates, three test pits were excavated within the BV-MSR (approximately 200 mm × 400 mm). Samples were collected from the layers that form within the mussel shell bioreactors (Figure 18), representing different geochemical zones within the MSR:

- Fe-rich zone (orange zone): dominated by iron hydroxide precipitate.
- Al-rich zone (white zone): containing primarily aluminium hydroxide, however this zone can overlap with the iron hydroxide horizon.
- H₂S-rich zone (black zone): Reducing conditions with sulfide formation.



Figure 18: Sludge and Fe + Al precipitation zones within the BV-MSR.

Note: Draining the MSR resulted in the filamentous algae drying out as a thin black layer on the sludge surface (pictured)

Over seven years of operation, the BV-MSR accumulated approximately 75 m³ of sludge. The Al (white) and Fe (orange) zones averaged 104 mm and 110 mm in depth, respectively, producing a total sludge thickness of 214 mm and a corresponding in-situ volume of approximately 75 m³ within the reactor.

The volume of sludge generated per tonne of acidity treated is significantly lower than the sludge volume generated by active treatment (i.e., 1-2 m³/tonne of acidity (MSR) versus 20-40 m³/tonne acidity (CaO treatment). This is likely a function of: slower neutralisation processes generating coarser floc (that generates a denser sludge – e.g., Figure 7), lower TSS in MSR sludge (TSS contributes to sludge bulk in active treatment); and other factors such as sludge formation at depth in the MSR reactor. Overall, this suggests the change from active treatment to passive treatment will decrease AMD sludge quantities by at least an order of magnitude.

2.3 Literature review - AMD Sludge Management and Disposal Options

2.3.1 Introduction

The most common methods of AMD sludge disposal are presented in Figure 19. Zinck and Griffith (2013) conducted an international survey of MIW treatment facilities, although this was dominated by Canadian mine sites. Data from this survey indicates that disposal to Sludge Ponds is the most favoured option (Zinck and Griffith, 2013). Less common are active management strategies that involve reprocessing, smelting, or offsite transport as a hazardous waste.

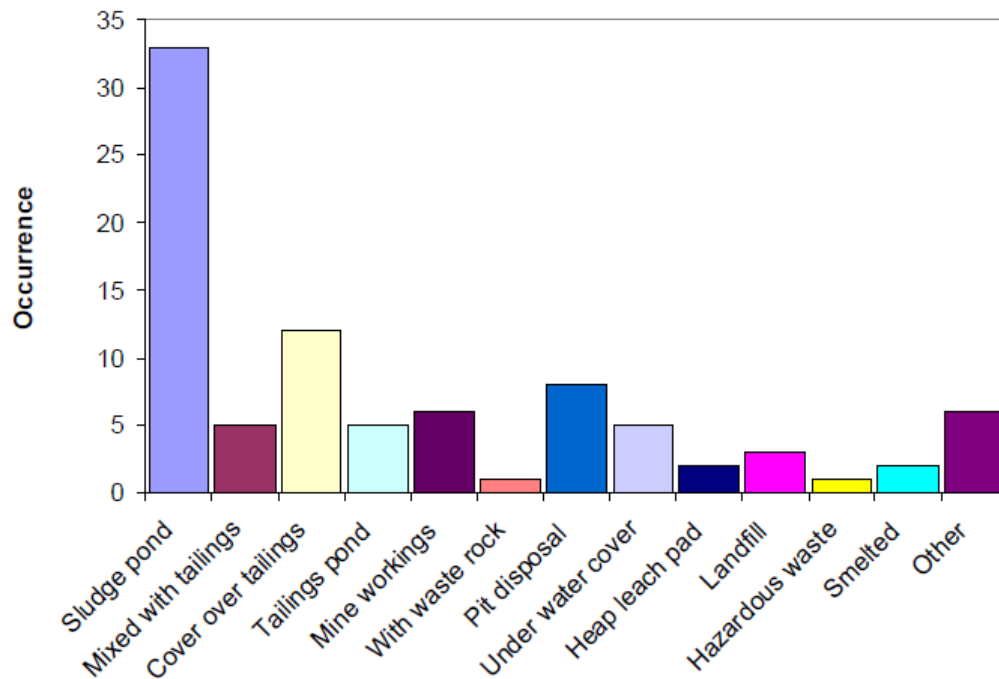


Figure 19: Sludge management practice reported.

Source: Zinck & Griffith (2013)

Solid/liquid separation is an important step in the management of sludge produced from AMD treatment. This process reduces sludge volume, improves handling characteristics, and enhances the suitability of the material for subsequent disposal or reuse. Various methods as reported by Zinck and Griffith (2013) can be employed as shown in Figure 20. Subsequent sections discuss sludge management options that are appropriate for the BPCP at ESE and MFS.

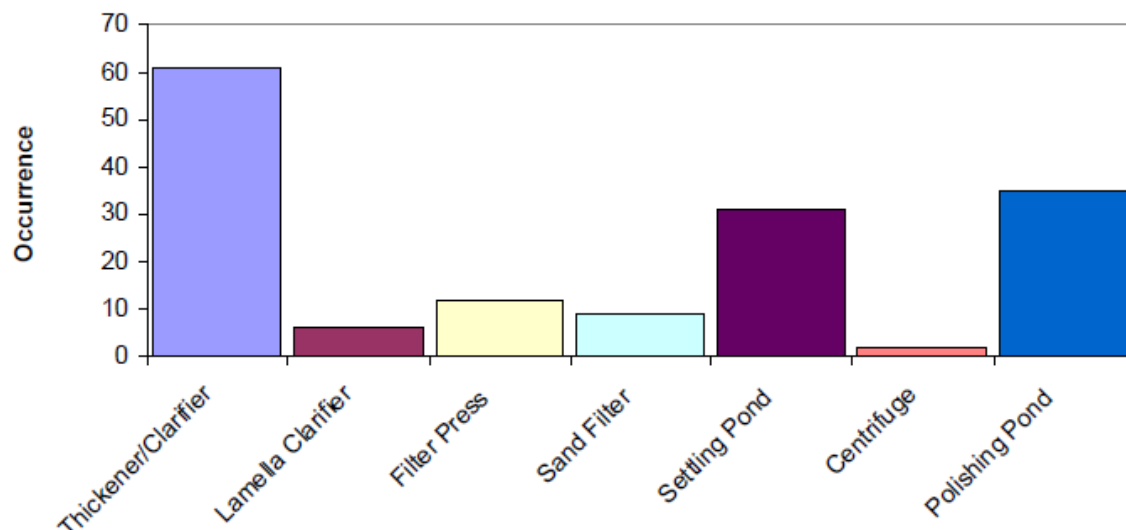


Figure 20: Solid/liquid separation methods used to reduce sludge volumes.

Source: Zinck & Griffith (2013)

2.3.2 Sludge / Sediment Pond Disposal

Sludge pond disposal involves the placement of AMD sludge in settling basins or impoundments for passive dewatering and long-term containment. This is one of the most common and cost-effective

methods globally and increases AMD sludge stability (Zinck & Griffith, 2013). Wildy (2015) recommended pond or impoundment-based sludge disposal as the most internationally accepted method. Mangatini Sump at Stockton mine is an example of pond storage.

2.3.3 *Underground Mine Workings*

AMD sludge placement in underground mine voids can utilise existing infrastructure, providing permanent containment while improving mine water quality. Studies have shown that AMD sludge with residual neutralising capacity can buffer acidic mine pools, increase pH and reduce dissolved metals concentrations (Zinck & Griffith, 2013).

The effectiveness of this method depends heavily on site specific factors such as mine hydrology, void connectivity, and sludge chemistry. Although this approach reduces surface disposal requirements, there is limited control over sludge distribution and long-term monitoring once emplacement occurs.

At the ESE and MFS sub-areas there are numerous underground workings. These workings drain to many local streams and may not be favourable for AMD sludge disposal.

2.3.4 *Co-Disposal with Waste Rock*

Blending AMD sludge with tailings or waste rock can reduce storage infrastructure requirements and, in some cases, provide localised alkalinity. Some studies have reported increased zinc and iron leaching when sludge is in contact with acid-forming materials (Zinck, 2005; McDonald et al., 2006).

Studies completed by MWM (2021), as discussed in Section 2.2 suggest that co-disposal is a viable option. Co-disposal will require dewatering of the AMD sludge to enable transport of the material to the disposal location.

2.3.5 *Landfill Disposal*

Engineered landfills provide a controlled containment system with liners, leachate collection, and monitoring systems. While effective in isolating contaminants, landfilling AMD sludge in approved offsite facilities is generally considered a last-resort option due to high costs, limited capacity, and the requirement for extensive dewatering prior to placement (Earle, 2021).

2.3.6 *Disposal to Pit Lakes*

Disposal of AMD sludge into flooded open pits or pit lakes presents a passive, space-efficient disposal option, particularly where large volumes of submerged storage are available. This method has been successfully implemented at other mine sites where sludge addition to pit lakes was shown to improve water quality (due to remnant ANC within the AMD sludge; an artifact of AMD treatment with lime-based products) without increasing suspended solids or dissolved metals (Zinck and Griffith, 2013).

Potential for metal mobilisation due to stratification is a risk with open pit disposal. The long-term success of AMD sludge disposal in pit lakes is dependent on a range of site-specific factors, including lake chemistry, seasonal or episodic pit lake turnover patterns, and groundwater connectivity.

MWM (2026c) assessed the feasibility of underwater sludge disposal into Escarpment Pit 3 Pit Lake, specifically evaluating sludge generated from the Barren Valley Mussel Shell Bioreactor (BV-MSR). The study aimed to understand potential impacts and benefits of this disposal strategy. Notably, Pit 3 receives residual alkalinity from the BV-MSR effluent, likely enhancing its buffering capacity and potentially improving its suitability for sludge placement.

Laboratory trials conducted to evaluate sludge interactions with Pit 3 water involved three different sludge addition rates, 100 g, 500 g, and 1,000 g of sludge into 20 L of Pit 3 water, which respectively corresponded to dilution ratios of ~1:200, 1:40, and 1:20 by mass. These conservative test conditions were designed to simulate low water-to-sludge ratios, assessing potential short-term impacts.

Key observations from the trials included:

- Sulfate (SO₄) concentrations increased with higher sludge additions, suggesting the presence of soluble SO₄ salts in the sludge.
- pH remained stable and circumneutral across all scenarios with a slight increase in total alkalinity. Acidity levels remained below the limit of reporting.
- Nickel (Ni) and Zn concentrations decreased with increasing sludge additions, likely due to adsorption or co-precipitation at near-neutral pH. This aligns with findings from MWM (2026c), which documented Zn adsorption to Fe-hydroxides and Al hydroxides (Pope, 2006).
- Conversely, cobalt (Co) and manganese (Mn) concentrations increased, indicating possible desorption from the AMD sludge matrix.

While initial results are promising for Pit 3, further studies are required to validate the long-term viability of this disposal method for AMD sludge across other BPCP pit voids. For short term management of AMD sludge during the Construction Phase, the option of using Pit 3 is reasonable given the time frame involved (1-2 years) and the low quantity of AMD sludge.

2.3.7 Geotubes

Geotubes have been used at Stockton to facilitate dewatering of AMD sludge (Murray and Walker, 2022). Process Flow Ltd (2026a) evaluated three dewatering options for the proposed WTP for MFS and ESE:

- Mechanical dewatering (e.g. plate and frame pressure filtration)
- Geotubes dewatering.
- Passive dewatering cells.

All systems appear capable of producing a dewatered 'spadable' AMD sludge post treatment that can be transported to site for disposal in an ELF (i.e., truckable). However, both Geotubes and dewatering cells have large operational footprints, and there is insufficient space available at MFS and ESE for these systems to operate as the main method for dewatering AMD sludge during the Operational Phase of the project. However, generating 'spadable/ truckable' AMD sludge at the ESE and MFS WTP's by mechanical dewatering will overcome the spatial constraints, and avoid the need for re-handling sludge from the Geotubes or dewatering cells for disposal.

Preliminary studies suggest that Geotubes (31 m x 27.4 m) can hold approximately 150 dry tonnes of sludge and may be a practical option for long term AMD sludge disposal. Further work is required to validate this option if the technology were to proceed.

2.3.8 Filter Beds – 2022

BRL have been investigating alternative AMD sludge management processes (Murray and Walker, 2022) including filter beds (Figure 21).

During fine weather the sludge is pumped to filter beds. Filter beds were created using stripped overburden material from a mining pit, lined with a pH neutral sealing layer, strategically placed Megaflo drainage pipe that was covered in drainage metal, then a 0.5 m layer of coal fines. These coal fines are a reject material from the coal handling and processing plant and provide an ideal filter medium that retain the solids from the LDS while allowing free draining of the water. Reject coal fines typically have a particle size range from fine silt to pebble. The dewatered sludge is of a density that can be removed from the filter beds using diggers and trucks. The dewatered sludge generally has a moisture content of between 88 and 93%. Further details are available (BRL, 2026a).



Figure 21: Stockton AMD sludge filter beds.

Source: Murray and Walker (2022).

2.4 Comparison of AMD Sludge Disposal Options for ESE AND MFS

The following section discusses the available options for AMD sludge disposal for the ESE and MFS sub-areas of the BPCP.

2.4.1 Overview

A comparative assessment of the main AMD sludge storage and disposal methods is presented in Table 1, which summarises the relative advantages, limitations, indicative costs, and long-term stability of each method, as well as their potential suitability to site conditions at the BPCP. The comparison draws on findings from Zinck & Griffith (2013), McDonald et al. (2006), Wildy (2015), Pope & Christenson (2016), and MWM (2026c).

Table 1: Comparison of AMD sludge storage and disposal options.

DISPOSAL OPTION	BENEFITS	RISKS	RELATIVE COST	LONG-TERM STABILITY	BPCP SUITABILITY
Sludge Ponds / Sediment Ponds	Simple, low-cost, proven globally. Mangatini Sump at Stockton Mine is an example. Allows passive dewatering.	Spatial constraints. Maintenance required.	Low	Moderate (improved under water cover)	Suitable. Spatial constraints may prevent this option being suitable. MSR polishing ponds could be used for AMD sludge storage (this would require increasing the depth of the polishing ponds).
Underground Mine Workings	Utilises existing voids. Improves mine water pH. Long-term isolation.	Site-specific hydrology. Limited ability to control sludge emplacement Limited retrievability. Requires site specific monitoring plan.	Low	High (if circumneutral pH maintained)	Not suitable. Most underground workings that will remain drain to receiving streams. Underground mine water pH too acidic.
Co-disposal with overburden	Reduces separate infrastructure – e.g., no additional stand-alone infrastructure required. Potential alkalinity benefit.	Risk of metal leaching with PAF contact – lab and field tests indicate this risk is low except for some trace metals (Mn > Co = Zn > Ni).	Low	Good, provided control of long-term oxygen flux to sulfide bearing materials is managed	Suitable. Lab and field trials demonstrate suitability. Recommendation to avoid placement with high acid forming (HAF) materials to minimise metal remobilisation risk. Placement within an unlined disposal cell is proposed. All ELF seepage is captured and directed for treatment (Active and MSR at closure) – e.g., any effects will be managed.
Offsite Landfill disposal	Controlled containment; suitable for hazardous waste.	Cost. Limited capacity. Requires dewatering. Long-term liability.	High	High (engineered)	Suitable. Impractical for large sludge volumes – suitable in the Post Closure Phase when volumes are low.
Pit Lake Disposal	Passive. Spatially efficient. Potential water quality benefits.	Requires neutral pH. Pit lake stratification risks. Site-specific.	Low	High (underwater storage)	Suitable. Requires further studies to confirm AMD sludge stability in the long term once suitable trial locations become available. Pit voids could also be filled with AMD sludge prior to flooding.
Geotubes	Good dewatering	Spatial constraints	Moderate	High	Suitable. Geotubes are considered an option for the ESE

DISPOSAL OPTION	BENEFITS	RISKS	RELATIVE COST	LONG-TERM STABILITY	BPCP SUITABILITY
					during the Active Closure Phase of the BPCP.
Filter Beds	Passive dewatering after pumping to filter beds enabling a spadable product.	Spatial constraints	Moderate	Low	Not suitable. Spatial constraints limit the applicability of this technology at ESE and MFS.
Pond Fines Disposal Cell (within active tipheads)	Pond fine disposal cells will already be available as a location for AMD sludge disposal.	Risk of metal leaching with PAF contact – field tests indicate this risk is low.	Low	Good, provided control of long-term oxygen flux to sulfide bearing materials is managed	Suitable. Cells will already be constructed for silt pond disposal. Recommendation to avoid placement with high acid forming materials to minimise metal remobilisation risk.

BRL (2026) identified that long-term sludge management at the BPCP must prioritise geochemical stability, containment integrity, and cost-effective handling to align with closure objectives. Under the current conceptual design, sludge generated from both active and passive treatment systems will require transfer to permanent containment/disposal areas during the operational and closure phases.

2.4.2 Pond Fines

It is anticipated that significant quantities of fine sediment will accumulate as pond fines as part of sediment and erosion control procedures (e.g., check dams, silt ponds, active working pits, etc). These materials may contain potentially acid forming (PAF) materials but will not contain WTP or PTS AMD sludge.

Pond fines will typically be disposed of into a simple bunded cell built in the advancing tiphead of the proposed ELF at ESE and MFS, which is the general accepted approach for the management of these materials. There is no specific designation for where the materials will be placed, other than within an ELF (where sediment loss from the facility is controlled).

3 ACTIVE WATER TREATMENT AMD SLUDGE MANAGEMENT

This section discusses active treatment of Mine Impacted Waters (TSS and AMD) in the MFS and ESE water treatment plants (WTPs), outlines the quantities and nature of the AMD/TSS sludge that is generated, and describes the proposed management of the AMD sludge.

The MFS and ESE plants will use identical processes to treat the AMD and TSS present in MIWs prior to discharge. The plants will be customised to the sites, and plant capacities will reflect the scale of the mining operations in each area.

3.1 Prevention and Minimisation of AMD Sludge

The overall approach undertaken for the management of AMD and TSS is to understand the source hazards and then implement source control to prevent the generation of waters impacted by mining operations. This is embodied in the six steps of AMD management, which is in alignment with international guidance documents (e.g., INAP, 2014; DFAT, 2016):

1. Determine the closure objectives for the mine.
2. Understand the source hazards.
3. Prevent oxidation of sulfide minerals – Engineering Control.
4. Minimise the mobilisation of stored oxidation products – Engineering Control.
5. Control and treatment of AMD-impacted waters – Engineering Control.
6. Complete an assessment of the potential effects.
7. Monitor performance to facilitate adaptive management.

Source control and passive management of TSS is discussed in BLR (2026c). Control, prevention, and minimisation of AMD from ELFs, the greatest contributor to AMD load, are discussed in MWM (2026i), which will reduce AMD loads but treatment of mine-impacted waters will still be required.

3.2 Overview of Active Treatment

The MFS WTP plant schematic is shown in Figure 22. The ESE WTP is similar (not shown) but has a higher capacity (Process Flow, 2026a).

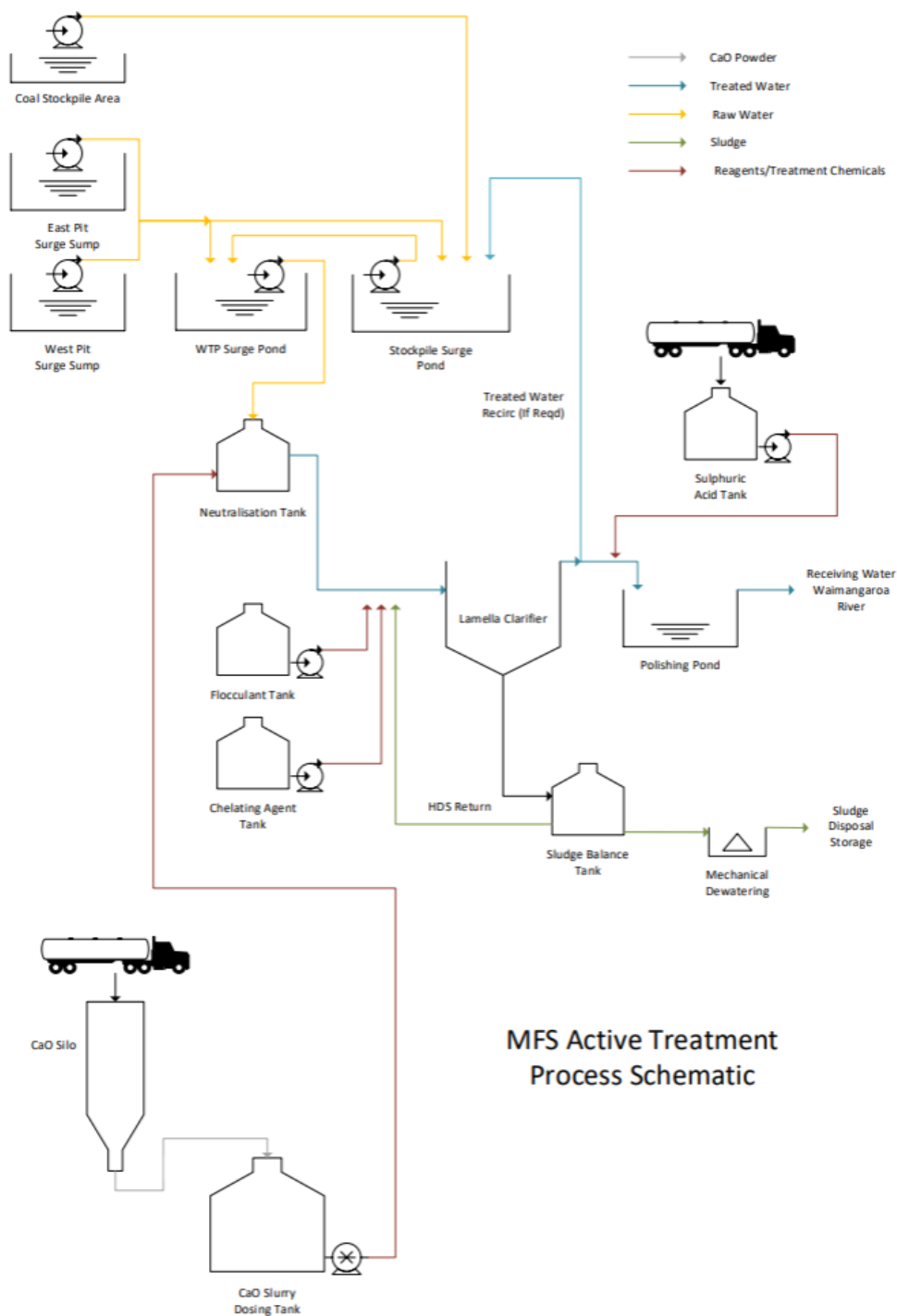


Figure 5.3 MFS WTP Process Schematic

Figure 22: MFS Active Treatment Process Schematic

Source: Process Flow (2026a).

Both the ESE and MFS WTPs include the following treatment processes:

- WTP Surge Ponds (the “Stockpile Surge Pond” at MFS and the Ex-Pit Seal Pit at ESE) – receiving water from the run-off, seepage areas, and from pumping from the pit sumps.

- Powdered CaO silos and mixing tanks to generate a neutralising slurry for MIW water from the surge ponds.
- Pontoon mounted pumps to transfer water from the surge ponds to the acidity neutralisation tank.
- pH controlled CaO slurry dosing of AMD in the acidity neutralisation tank.
- Flocculant and metal-chelating agent dosing to CaO neutralised water prior to transfer to the Lamella Clarifiers.
- Separation of suspended and precipitated solids in the Lamella Clarifier with partial sludge return to the Lamella Clarifier in-flow (i.e., High Density Sludge (HDS) loop).
- Lamellar clarifier sludge is thickened with flocculant and pumped to a pressure filter for dewatering to create a "filter cake". Dewatered filter cake is discharged to a bunker for loadout and trucking to disposal areas. At closure other options may be investigated such as pumping slurry to Geotubes or in-pit disposal, in which case the pressure filtration may not be required.
- Sulfuric acid (i.e., pH) trimming of the Lamella Clarifier thickener overflow (treated supernatant) where required to remove additional metals and meet pH compliance limits.
- Treated supernatant will report to a polishing pond after the pH correction before discharge to the receiving environment.
- Under high rainfall conditions the following may occur:
 - Bypass and direct discharge from pit sumps when river flows are >95th %ile and >90th %ile respectively.
 - Mine pit surge sumps and WTP surge ponds spill no more than 5% of the time on average.

This is discussed in more detail in the WLBM reports (MWM, 2026a,b).

Water treatability trials conducted by Process Flow (2026b) determined that neutralisation with calcium oxide (CaO), coagulation with Metalzorb FZ, and flocculation with Rheomax 1030 effectively reduces TSS and dissolved metals in the supernatant, producing water quality consistent with ESE and MFS guideline objectives (Hickey, 2026a,b).

WTP treated water discharge design standards are shown in Table 2 and are applied to WTP discharge at both ESE and MFS within the WLBM to understand effects on the receiving environment.

Table 2: WTP treated water discharge design standards.

PARAMETER	INFLUENT (mg/L) ³	EFFLUENT CONCENTRATION (mg/L)	TREATMENT EFFICIENCY (%)
Acidity	360	2.5	99.3
Alkalinity	0.5	5.5	-
Ca	62	Calculated ¹	-
Mg	19.2	Mg input water quality ²	-
Na	3.1	Na input water quality ²	-
K	7.1	K input water quality ²	-

PARAMETER	INFLUENT (mg/L) ³	EFFLUENT CONCENTRATION (mg/L)	TREATMENT EFFICIENCY (%)
SO ₄	570	SO ₄ input water quality ²	-
Al	44	0.074	99.8
Fe	9.5	0.01	99.9
Ni	0.197	0.0027	98.6
Mn	1.78	0.18	89.9
Cr	0.0045	0.0011	75.6
Cd	0.00088	0.000025	97.2
Co	0.081	0.001	98.8
Cu	0.0133	0.00025	98.1
Pb	0.00116	0.00005	95.7
Tl	0.0026	0.00117	55.0
Zn	1.04	0.0058	99.4
DOC	1	0.25	75.0
TSS	16	1.5	90.6
pH	3.2	6.4	-

¹ Calcium is calculated (as is done in the water and load balance models). The amount of Ca in the WTP treated water is a function of influent Ca concentration and the amount of CaO required to neutralise the influent acidity.

² These parameters are not affected by active treatment. Hence the inflowing concentration is the same as the effluent concentration.

³ Influent data collected from Manchester Street at Stockton.

⁴ Arsenic (As) is not assessed as previously studies on the Barren Valley ELF (MWM, 2026d) indicate that it is below the limit of reporting (< 0.001 mg/L); other studies in MWM (2026d) confirm this work.

Sludge management will comprise thickening and dewatering of sludge for final disposal. AMD sludge disposal is discussed in Section 5.

3.3 AMD Sludge Volumes – Active Treatment

Forecasting AMD sludge generation rates is essential for planning disposal strategies. The WLBM for ESE and MFS were used (MWM, 2026a,b) to determine the quantity of sludge (dry basis) that would report to the water treatment plants.

3.3.1 Methodology

Sludge quantities were determined by the following process with the main contributors to AMD sludge being TSS, Fe, and Al (see Figure 23 and Figure 24) and unreacted CaO used to neutralise acidity (metal acidity and H⁺ acid):

- Data for influent to the WTP at ESE and MFS were obtained from the WLBM with data being summed into annual loads (t/yr).
- TSS (t/yr) was provided by the WLBM (dry weight equivalence).
- Al and Fe (t/yr) were converted to Al(OH)₃ and Fe(OH)₃ with a subsequent increase in weight by 2.89 and 1.91 respectively.
- Acidity (t CaCO₃/yr) was used to determine the amount of unreacted limestone present in the CaO (estimated to be 5% based on typical safety data sheet results for CaO). Hence unreacted limestone (CaCO₃) in the sludge was calculated as 5 wt% of the annual acidity load to the WTP.

- The contribution to sludge volume by trace metals is not significant with regards to volume effects. For instance (using Barren Valley ELF water quality data⁴):
 - Al and Fe hydroxides contribute to ~ 95% of the sludge volume (dry weight basis) from metals.
 - Major trace metals (Mn, Ni, Zn hydroxides) contribute ~5% of the metal sludge volume (1.6%, 0.5%, 2.9% respectively).
 - All other trace metals contribute to < 0.5% of the metal sludge volume (dry weight basis).
 - During the first year, the ratio of TSS to Al + Fe load is low with Al + Fe contributing to ~5% of the total sludge volume (dry weight basis) for ESE Year 2028; at the end of the Active Treatment Phase Fe + Al load contributes to ~42% of the total sludge volume (dry weight basis) for ESE Year 2057.
- The formation of gypsum was considered minor, mostly because the concentration of sulfate was <1,800 - 2,000 mg/L and hence gypsum is assumed to be under saturated (i.e., will not precipitate).
- TSS + Al(OH)₃ + Fe(OH)₃ + CaCO₃ was then used to calculate the sludge content (dry weight basis).
- Sludge was then converted to a wet volume (m³) based on 3 wt% solids (lamellar clarifier) and 12 wt% solids (by mechanical dewatering: Process Flow, 2026a) where 1 t = 1 m³ to simplify the calculation. These data are shown in Table 5.

The raw WTP influent data (acidity, TSS, Al, and Fe loads) for ESE and MFS are provided in Table 3 and Table 4 respectively. Data are provided as outputs from the ESE and MFS water and load balance models (WLBMs) (MWM, 2026a,b) for the Operational and Active Closure Phases (i.e., when the WTPs are operating). Further details on MIW treatment are provided in MWM (2026e).

Table 3: ESE WTP Influent

INDICATIVE YEAR	PROJECT STAGE	ACIDITY LOAD (TONNES)	TSS (TONNES)	Al LOAD (TONNES)	Fe LOAD (TONNES)
2028	0	404	1,226	44	20
2029	1	724	1,499	76	33
2030	2	702	1,662	75	32
2031	3	1,426	2,041	149	65
2032	4	1,866	1,825	200	89
2033	5	2,373	2,042	255	114
2034	6	3,017	2,197	317	142

⁴ Which is the empirical dataset used for water quality models (MWM, 2026d).

INDICATIVE YEAR	PROJECT STAGE	ACIDITY LOAD (TONNES)	TSS (TONNES)	Al LOAD (TONNES)	Fe LOAD (TONNES)
2035	7	3,774	2,351	386	173
2036	8	4,515	2,419	455	205
2037	9	4,502	1,778	452	206
2038	10	4,081	1,949	410	185
2039	11	3,200	1,845	325	146
2040	12	4,133	1,878	414	187
2041	13	4,457	1,975	444	201
2042	14	4,028	1,688	402	183
2043	15	3,384	1,703	339	154
2044	16	2,325	1,176	235	109
2045	17	1,637	1,152	167	77
2046	18	1,211	99	119	56
2047	19	1,008	99	99	47
2048	20	898	99	89	42
2049	21	807	99	80	38
2050	22	729	99	73	34
2051	23	673	99	67	31
2052	24	637	100	64	30
2053	25	604	100	61	28
2054	26	574	100	58	27
2055	27	547	100	55	26
2056	28	522	100	53	25
2057	29	508	100	51	24

Table 4: MFS WTP Influent

INDICATIVE YEAR	PROJECT STAGE	ACIDITY LOAD (Tonnes)	TSS (Tonnes)	Al LOAD (Tonnes)	Fe LOAD (Tonne)
2029	1	89	276	9	3
2030	2	92	333	9	3
2031	3	100	345	10	4
2032	4	121	405	12	4
2033	5	144	466	14	5
2034	6	168	524	16	6
2035	7	239	719	23	9
2036	8	297	727	29	12

INDICATIVE YEAR	PROJECT STAGE	ACIDITY LOAD (Tonnes)	TSS (Tonnes)	Al LOAD (Tonnes)	Fe LOAD (Tonne)
2037	9	309	833	30	12
2038	10	307	866	30	12
2039	11	321	773	31	13
2040	12	324	743	31	13
2041	13	315	869	30	12
2042	14	265	821	26	10
2043	15	193	391	20	8
2044	16	141	29	14	7
2045	17	46	14	5	3
2046	18	47	14	5	2

The benefits of quantifying AMD sludge generation rates include:

- Assisting with WTP design requirements.
- Enabling estimation of AMD sludge disposal requirements.
- Supporting optimisation of chemical dosing to minimise excess solids.
- Providing a flexible framework for planning treatment adjustments in response to changing water loads or AMD characteristics.

3.3.2 AMD Sludge Quantities – Active Treatment

AMD sludge volumes have been estimated based on estimated WTP influent water quality derived from the WLBM for ESE and MFS (MWM, 2026a,b). These data are presented in Table 5 and show expected sludge volumes from the bottom of the lamella clarifier (e.g., 3 wt%) and after additional mechanical dewatering (e.g., 12 wt%).

An assessment of the acidity load versus the volume of AMD sludge generated (3 wt% solids) was undertaken (i.e., volume (m³) AMD sludge per tonne of acidity treated). Data indicates that:

- Over the active water treatment period the ESE and MFS water treatment plants generate an average of 38 m³ of AMD sludge per tonne of acidity. This is comparable to estimates at Stockton of 20 – 40 m³ (MWM, 2026f).
- Maximum estimated BPCP (MFS and ESE) AMD sludge volume to acidity load ratios (67 – 117 m³/t) occur in the early years of the BPCP (MFS and ESE) when acidity loads are low in comparison to TSS loads (i.e., TSS loads are higher and acidity loads are lower during this phase of the project). These higher numbers are likely overly conservative as a heavy sediment load will have a higher sludge density, which would decrease the volume of sludge generated per tonne of acidity neutralised.

- Lower AMD sludge volumes to acidity loads occur in the later years of the project when acidity loads are high in comparison to TSS loads (17 - 21 m³/t) as shown in Table 5.

Table 5: AMD sludge volumes (m³) for ESE and MFS WTP (WLBM base case models)

STAGE	TOTAL SLUDGE WET 3% SOLIDS (m ³)		TOTAL SLUDGE WET 12% SOLIDS (m ³)		TOTAL SLUDGE DRY (m ³)		SLUDGE VOL. PER TONNE ACIDITY (m ³) ¹
	ESE	MFS	ESE	MFS	ESE	MFS	Total
Year 2027	*	*	*	*	*	*	*
Year 2028	47,114	*	11,779	*	1,413	*	117
Year 2029	60,619	10,388	15,155	2,597	1,819	312	87
Year 2030	65,838	12,313	16,459	3,078	1,975	369	98
Year 2031	88,960	12,844	22,240	3,211	2,669	385	67
Year 2032	88,898	15,097	22,225	3,774	2,667	453	52
Year 2033	103,857	17,441	25,964	4,360	3,116	523	48
Year 2034	117,838	19,707	29,459	4,927	3,535	591	43
Year 2035	132,928	27,177	33,232	6,794	3,988	815	40
Year 2036	145,091	28,247	36,273	7,062	4,353	847	36
Year 2037	123,436	31,906	30,859	7,977	3,703	957	32
Year 2038	123,090	32,985	30,773	8,246	3,693	990	36
Year 2039	107,442	30,099	26,861	7,525	3,223	903	39
Year 2040	121,239	29,149	30,310	7,287	3,637	874	34
Year 2041	128,821	33,207	32,205	8,302	3,865	996	34
Year 2042	113,369	30,930	28,342	7,732	3,401	928	34
Year 2043	104,894	15,766	26,224	3,942	3,147	473	34
Year 2044	72,627	3,038	18,157	759	2,179	91	31
Year 2045	62,137	1,185	15,534	296	1,864	36	38
Year 2046	20,335	1,173	5,084	293	610	35	17
Year 2047	17,528	-	4,382	-	526	-	17
Year 2048	16,026	-	4,006	-	481	-	18
Year 2049	14,768	-	3,692	-	443	-	18
Year 2050	13,688	-	3,422	-	411	-	19
Year 2051	12,918	-	3,230	-	388	-	19
Year 2052	12,431	-	3,108	-	373	-	20
Year 2053	11,970	-	2,993	-	359	-	20
Year 2054	11,566	-	2,892	-	347	-	20
Year 2055	11,196	-	2,799	-	336	-	21
Year 2056	10,866	-	2,717	-	326	-	21
Year 2057	10,669	-	2,667	-	320	-	21
Total	1,972,160	352,653	493,040	88,163	59,165	10,580	38 (average)

‘-’ Active water treatment is not proposed

Construction Phase (green) – see Section 3.3.3

* Further details are provided in Table 6.

1. Sludge:acidity ratio derived from total AMD sludge from MFS and ESE divided by total acidity from MFS and ESE.

Red text relates to the Active Closure Phase and expected AMD sludge quantities

A graphical analysis of the key parameters contributing to AMD sludge are presented in Figure 23 and Figure 24. Results demonstrate:

- MFS: Generally constant acidity (and Fe and Al) with TSS concentrations increasing.
- MFS: A steady decline in sludge generation rates derived from Al, Fe, and acidity from 2040 as AMD loads from the project decline.
- MFS: A significant drop in TSS after 2042 once rehabilitated surfaces stabilise and sediment loss decreases.
- MFS: After Year 2042 the AMD sludge will transition from the sediment dominated sludge (as shown by the photographs in Figure 5) to a chemically dominated sludge (as shown by the photographs in Figure 7).
- ESE: Increasing acidity over the first 6-7 years of the project.
- ESE: A steady decline in sludge generation rates derived from Al, Fe, and acidity from 2040 as AMD loads from the project decline.
- ESE: A significant drop in TSS after 2045 once rehabilitated surfaces stabilise and sediment loss decreases.
- ESE: After Year 2044 the AMD sludge will transition from the sediment dominated sludge (as shown by the photographs in Figure 5) to a chemically dominated sludge (as shown by the photographs in Figure 7).

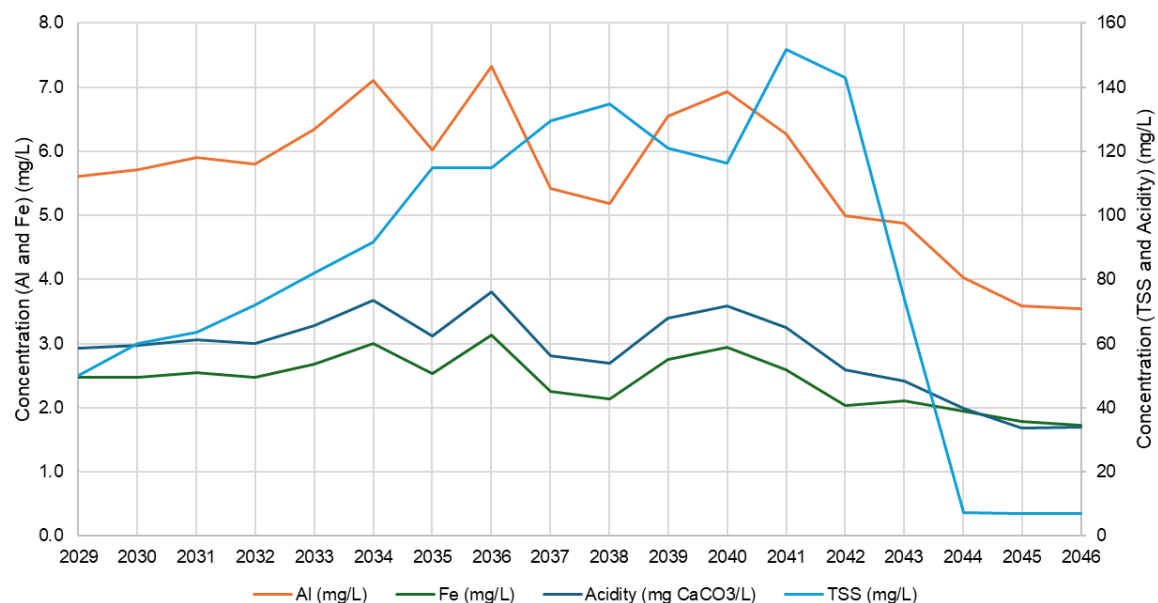


Figure 23: MFS key parameters that generate AMD sludge (WLBM base case model).

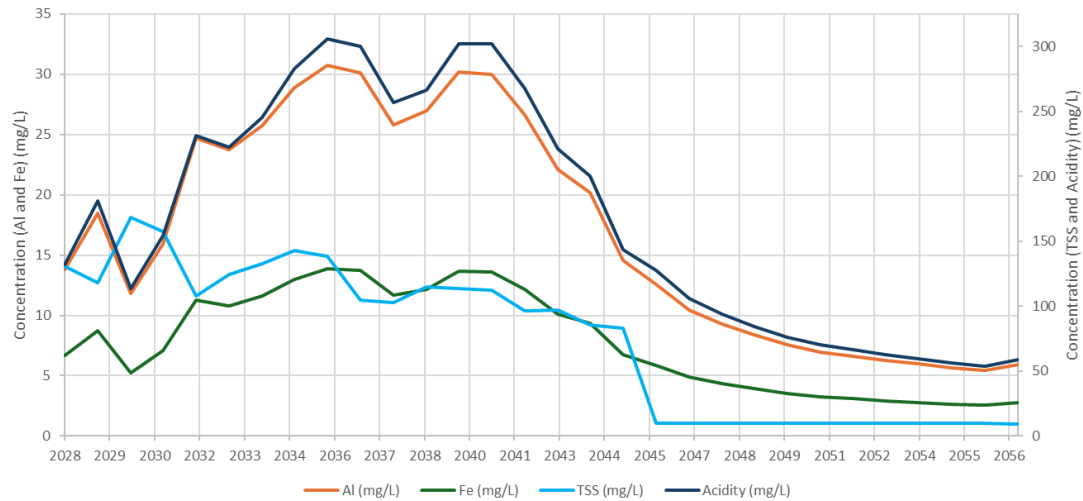


Figure 24: ESE key parameters that generate AMD sludge (WLBm base case model).

3.3.3 Construction Phase AMD Sludge Generation

The WLBm does not cover the full time Construction Phase of the MFS sub-area and only Stage 0 of the ESE sub-area, when significant earthworks commence. To estimate AMD sludge management requirements, the quantity of rock disturbed is used as an indicator of potential AMD treatment requirements and hence AMD sludge generation.

Material quantities are derived from the BRL project schedule, which have been provided in MWM (2026h). Material quantities, acidity loads, and AMD sludge volumes from the first year of the WLBm for MFS and ESE (grey) have been used to determine acidity loads and AMD sludge volumes for the Construction Phase as a function of rock quantity. Data are presented in Table 6 and the following is noted for the Construction Phase:

- It is estimated ~ 190 tonnes of acid will be treated generating 20,000 m³ of AMD sludge at MFS over the two-year period.
- It is estimated that ~ 60 tonnes of acid will be treated generating 10,000 m³ of AMD sludge at ESE in Year -1; and ~400 tonnes of acid will be treated generating 50,000 m³ of AMD sludge in Year 0.

Table 6: Construction Phase acidity loads and AMD sludge volumes

BPCP SUB-AREA	INDICATIVE YEAR	PROJECT STAGE	OVERBURDEN MOVED (bcm)	ACID LOAD (t/yr)	AMD SLUDGE (3 wt% SOLIDS)
MFS	FY27	Stage -1	395,600	42	4,831
MFS	FY28	Stage 0	1,394,100	147	17,023
MFS *	FY29	Stage 1	850,700	89	10,388
ESE	FY27	Stage -1	659,200	61	7,143
ESE *	FY28	Stage 0	4,348,200	404	47,114

Green cells relate to the Construction Phase.

Indicates the first year of the WLBm for MFS and ESE (MWM, 2026j,k). Data are used to determine the acidity and sludge loads for the construction phase (pro rata based on material movement).

4 PASSIVE TREATMENT AMD SLUDGE MANAGEMENT

4.1 Introduction

Studies indicate that 20 passive treatment systems are required for MFS and ESE, with six PTS being established at the ESE project sub-area and 14 PTS being established at the MFS project sub-area. Flow rates range from < 1 L/s up to ~120 L/s. Acidity loads range from ~1 t/yr up to ~ 300 t/yr.

Mussel shell bioreactors (MSR) were selected as the chosen technology for PTS based on:

- **Renewable Material:** The material used in a MSR are derived from waste mussel shells, a by-product of the seafood industry, which supports a circular economy. Furthermore, the CO₂ within the shells, that are used for neutralisation of acidity, is renewable (i.e., not fossil CO₂)
- **Treatment Performance:** MSRs have shown to consistently remove PCOC such as acidity, Fe, and Al, and to a slightly lesser extent, trace metals such Ni and Zn under both acidic and alkaline conditions. Secondary MSR treatment (polishing pond) have been proposed for further removal of residual trace metals and secondary contaminants as required. Site-specific operational field trials will be completed in the first 1-3 years of the Operational Phase of the BPCP to validate previous laboratory studies that the designs of these MSR polishing ponds are suitable to achieve closure water quality objectives in the targeted timeframe.
- **Sludge Management:** AMD sludge (predominantly Fe and Al) is generated from the treatment of acidic AMD impacted waters. Downflow MSR are an efficient process to remove Fe and Al, acting as a vertical flow reactor as well as a neutralising PTS with pH correction such that AMD sludge forms at the surface of the MSR. This sludge can effectively be removed as part of routine maintenance as demonstrated at existing operating MSRs. Higher acidity loads (i.e., higher dissolved Fe and Al loads) can be managed by increased maintenance frequencies once treatment performance decreases. When active treatment is still occurring after ELF's have been rehabilitated (i.e., Active Closure Phase), AMD sludge disposal will either be onsite at an appropriate location (e.g., AMD sludge disposal cells at ESE Coal Pad), disposal at Stockton, or by other approved methods that may be developed over the Operational Phase of the BPCP. In the Post Closure Phase similar locations will be used. A back-up option includes disposal to offsite landfills.

Noting: Other options for AMD sludge management will be evaluated during the Operational Phase. If studies indicate that the method can provide geochemical stability, containment integrity, and cost-effective handling to align with closure objectives then this may be implemented at a later date (with additional regulatory approval as required).

- **Maintenance:** For maintenance of the MSRs (e.g., desludging) the system or part of the system needs to be taken off-line. This could involve dosing of bypass water with CaO or NaOH, designing MSRs to incorporate bays such that individual bays can be bypassed and drained for desludging while others remain operating. MSR Polishing ponds could also be constructed deeper to accommodate all sludge generation or be desludged periodically, if required. Further details are provided in the AMD WMP (BRL, 2026b)

- **Spatial Requirements:** MSR can be sized for the expected flow (where ~100 m² of MSR surface area with a minimum depth of 1.5 m is needed for 1 L/s) provided sufficient surface area is available. For ESE and MFS, MSR surface area requirements have been factored into mine plans based on net percolation rates of 40% into ELF's after closure (MWM, 2026i), which drives treatment requirements. Additional space is provided for the MSR polishing ponds. Space for maintenance activities (e.g., desludging, vehicle access, etc) is also required.
- **Demonstrated Experience and Longevity:** BRL has successfully implemented MSRs, with systems operating effectively for nearly a decade while showing low maintenance requirements.

Studies indicate that the Post Closure Phase is likely to last for many decades until geochemical stability is achieved in the ELF's and seepage waters can be released without treatment. Accordingly, MSR sludge management will also be required for many decades.

4.2 Passive Treatment Efficiency

While MSRs are the preferred passive treatment technology for the BPCP, other passive treatment options are likely to be viable and should not be excluded from consideration. For instance, passive treatment technologies are advancing rapidly, e.g., enhanced passive treatment systems (Christenson et al., 2018)) and these may have application to the BPCP in the future. Likewise, there is a trend towards the use of a series of biogeochemical processes (i.e., a treatment train) to treat AMD characteristics (Nairn et al., 2023; Trumm and Ball, 2018).

MSRs will be assessed during the early stages of the BPCP by operational trials with ongoing literature review of new technologies to confirm that MSRs remain the best practicable option. Early construction of the MSR during operations will enable site-specific testing and validation, helping to address uncertainties and demonstrate the system's effectiveness.

MSR treatment efficiencies for different PCOC are shown in Table 7. The work to derive these efficiencies are provided in MWM (2026c).

Table 7: MSR treatment efficiencies.

PARAMETER	TREATMENT EFFICIENCIES (%)
SO ₄	10.4
Al	99.7
Fe	80 ¹
Ni	40.2
Mn	58.6
Cd	1.89
Co	82.8
Cu	96.6
Pb	85.8
Zn	63.7

1. A nominal efficiency of 80% is used rather than the measured 99.7% to account for the ELF being sub-oxic and some Fe(II) passing through the MSR untreated.
2. PCOC such as As, Cr, and TI were not evaluated given low concentrations in influent. Further details are provided in MWM (2026a).

Treated water from the MSR flows into a polishing pond for aerobic treatment. This promotes Fe(OH)₃ formation supporting further Ni and Zn removal and oxidation of secondary contaminants. The removal efficiencies for Ni and Zn are shown in Table 8. The work to derive these efficiencies are provided in MWM (2026c).

Table 8: MSR polishing pond treatment of MSR Stage 1 effluent

PARAMETER	TREATMENT EFFICIENCIES (%)
Fe	99.0
Zn	59.0
Ni	12.5

Studies indicate the pH of treated water from the MSR can be ~pH 8 (MWM, 2026c). This may require a pH correction or mixing/dilution with surface flows so that water quality is compliant with proposed water quality pH limits at downstream compliance monitoring locations. pH correction may use ferric chloride (FeCl₃), which will also support the removal of trace metals such as Zn and Ni if Fe concentrations in the MSR effluent are lower than expected.

AMD sludge generation from the MSR polishing pond is accounted for in the AMD sludge calculations (e.g., Fe load). The additional contribution of any FeCl₃ would need to be assessed once the MSR are operating.

4.3 AMD Sludge Volumes – Passive Treatment

MSR are proposed for the treatment of seepage from ELFs at closure of the ESE and MFS sub-areas. Projected sludge quantities generated by MSR are shown in Table 9. MSR require desludging every ~5-years. This may be a shorter duration for MSR with higher acidity loads as MSR are sized for flow, not acidity load and could be every 1-2 years (confirmation to come from field trials during the Operational Phase of the project). Desludging of MSR requires removal of a small portion of remnant shells as part of the sludge which is accounted for in the sludge volumes below. These shells remain in the sludge and will provide acid neutralisation capacity buffering any acidity during disposal.

The volume of sludge generated per tonne of acidity treated by MSRs is significantly lower than the sludge volume generated by active treatment (i.e., 1-2 m³/tonne of acidity (MSR) compared to 20-40 m³ (CaO treatment (at 3% solids))). This difference is caused by a higher sludge solids content in MSR sludge (likely to be closer to >20% solids), as opposed to an order of magnitude step change in acidity loads being treated. Overall, the change from active treatment to passive treatment is projected to decrease AMD sludge quantities by an order of magnitude.

Table 9: AMD sludge generation rates for ESE and MFS MSR

BPCP SUB-AREA	ELF	MSR ACTIVATION DATE	MSR DESIGN ACIDITY (t/yr) ¹	MSR SURFACE AREA (m ²) ¹	SLUDGE QUANTITY AFTER 5 YEARS (m ³)	SLUDGE THICKNESS AFTER 5 YEARS (mm)
-	BV-ELF	-	10	350	74.9	214
ESE	BVE	2058	38.2	1,537	286	186
ESE	CON	2058	174.4	8,339	1,308	157
ESE	NSUL	2046	5.1	1,994	39	19
ESE	PPG	2058	0.1	306	1	3
ESE	WWH	2030	299.1	12,991	2,243	173
ESE	ESC	2030	11.9	245	89	363
MFS	MSR1	2045	11.2	512	84	165
MFS	MSR2	2045	2.7	128	20	159
MFS	MSR3	2045	3.8	345	28	82
MFS	MSR4	2045	16.1	345	121	351
MFS	MSR5	2045	24.2	1,582	182	115
MFS	MSR6	2045	5.3	375	39	105
MFS	MSR7	2045	28.5	1,683	214	127
MFS	MDC1	2029	0.1	49	0.7	15
MFS	MDC2	2038	0.1	42	0.4	10
MFS	MSR8	2047	43.3	2,644	325	123
MFS	MSR9	2047	5.1	331	38	115
MFS	MSR10	2047	2.7	204	20	98
MFS	MSR11	2029	8.6	244	65	265
MFS	MSR12	2029	8.9	244	67	274
Total					5,170	

1. Data from MWM (2026c). Acidity loads are based on the activation date of the MSR as per the water and load balance models.

Data indicates (references) that the quantity of sludge generated after 5 years is highly variable and is a function of the influent acidity load (as determined by the sludge volumes to acidity loads measured at the BV ELF MSR). A total of 5,170 m³ of sludge will be generated every 5 years once all MSR are operating (although there will be a decline in loads of at least 0.62% per year) from the start date of the MSR so this is a conservative value.

5 AMD SLUDGE DISPOSAL

This section summarises the proposed approach for AMD sludge management for the BPCP over the Construction, Operational, Active Closure, and Post Closure phases. The BPCP project timeline along with water management phases is shown in Figure 25.

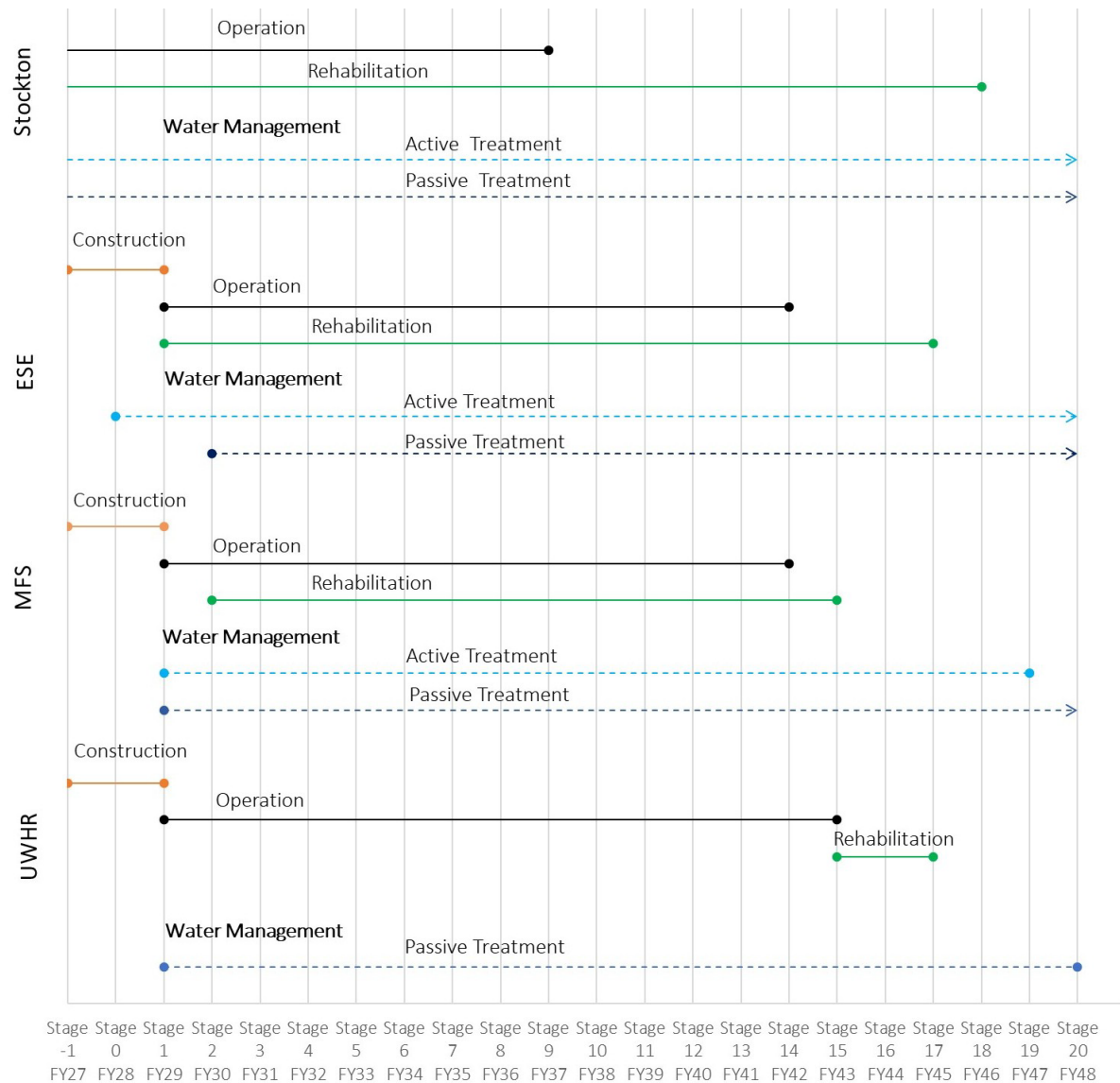


Figure 25: BPCP timelines (by stage and by indicative year).

5.1 Construction Phase

Treatment of AMD and TSS is expected during the Construction Phase prior to the commissioning of the ESE and MFS water treatment plants (Figure 25). The following is noted:

- TSS will be the dominant contributor to mine impacted water during the Construction Phase due to lesser effects from ELF AMD impacted seepage at the start of the project. This will be managed by passive treatment processes (e.g., sediment ponds, check dams, floc blocks (further details in BLR, 2026c)) or, when required, small portable treatment systems will be used to manage AMD and TSS.

- ESE: The current Escarpment Mine Pit 3 Pit Lake and other existing water treatment infrastructure (e.g., Lake Brazil) will be used to treat and settle AMD sludge (i.e., the system is in place, except for the treatment plant). Treated waters will be discharged to Cascade Creek Trib (V8 Creek). Backfill of rock will eventually bury this AMD sludge. Pit 3 has a capacity of ~200,000 m³.
- MFS: A temporary water treatment sump of 10,000 m³ will be built near the MFS Coal Storage Pad. This will be buried by rock at the end of the MFS Construction Phase once the MFS WTP is operational. The temporary water treatment sump will be operational until the MFS WTP is constructed and will manage treatment of any AMD and TSS during the Construction Phase. Treated waters will be discharged to the Waimangaroa River above W2 (Smokestack). Desludging of this sump will be required. AMD sludge will be transported to Stockton or ESE for disposal.

5.2 Operation Phase

During the operational phase, the preferred option for AMD sludge disposal is within engineered landforms (i.e., co-disposal). This will include:

- Disposal with pond fines in the pond fine disposal area (unlined cell)
- Disposal within a constructed sludge cell (unlined cell).

Laboratory and field trials undertaken by BRL (MWM, 2021) indicate that co-disposal of AMD sludge with PAF rock in ELF is an appropriate disposal option (Section 2.2.4). There remains a risk of elevated leachate contaminant concentrations (primarily Co, Mn, Ni, and Zn). However, overall, the magnitude of AMD sludge co-disposal material volumes versus PAF only material volumes stored at the landform scale is expected to make the risk of metal mobilisation relatively low. The proposed approach for the BPCP is to place AMD sludge within PAF dumps and or with PAF materials. HAF materials will be avoided.

AMD sludge will be dewatered (mechanical dewatering) prior to placement in ELF (to at least 12 wt% solids). Placement would occur in dedicated (unlined) cells within the engineered landforms.

If the PCOC contained with the AMD sludge are mobilised (as discussed earlier in Section 2.2), then these solutes will be captured by the ELF underdrain and will be directed to the active or passive treatment systems depending on mining phase. Figure 26 presents a schematic of the co-disposal encapsulation strategy. The following is noted:

- AMD sludge will be placed within cells within the ELF as they are being constructed.
- AMD sludge will not be placed in the soil cover layer, NAF layer, or lower sulfur zones (10 m ELF shells).
- AMD sludge placement will be avoided where this could compromise geotechnical stability or cause subsidence that may affect rehabilitation and revegetation.

Other options for AMD sludge disposal will be assessed during the operational phase of the BPCP including:

- Disposal to pit lakes/voids including the ESE Ex Pit Seal Pit and the SN14 Pit (~180,000 m³) at Stockton.
- The use of Geotubes on the ESE Coal Storage Pad or central infrastructure area that will be capped with NAF rock at closure.
- Disposal to landfill (offsite).

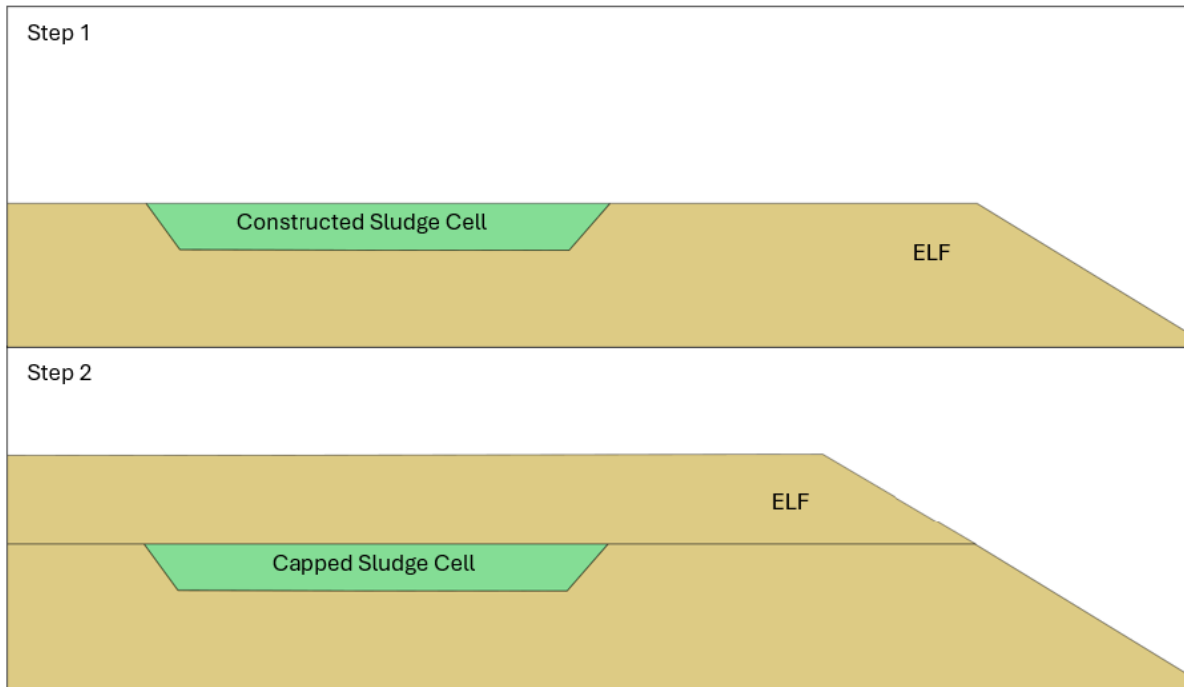


Figure 26: Intra-dump AMD sludge cells.

5.3 Active Closure Phase

During the Active Closure Phase, the ELF's have been rehabilitated and are not available for ongoing co-disposal of AMD sludge. This period starts with all rehabilitation of ELF's being completed and ends with a transition to passive treatment. AMD sludge will be managed by the following process during this phase:

- AMD sludge from MFS and ESE will be disposed into engineered cells (or other similar management processes) on the ESE Coal Infrastructure area.
- AMD sludge may also be transported to Stockton for disposal, which will have operating AMD sludge disposal facilities during this time frame.
- Other AMD sludge disposal options assessed during the Operational Phase will also be considered.

5.4 Post Closure Phase

In the Post Closure Phase there will be ~5,000 m³ of AMD sludge generated every 5 years from the MSR across the MFS and ESE project areas including:

- ~800 m³ per year at ESE

- ~250 m³ per year at MFS

AMD sludge will be disposed at Stockton (which will have ongoing AMD treatment), or by other approved methods that may be developed over the Operational Phase of the BPCP for minor quantities of AMD sludge generated in the Post Closure Phase by the MSR. Back-up options include disposal to an approved offsite landfill.

5.5 Summary

Preferred AMD sludge disposal options are summarised in Table 10.

Table 10: AMD sludge disposal summary

MINE PHASE	SELECTED OPTION	EXPLANATORY NOTES
Construction Phase	• ESE – within Pit 3 • MFS – within a temporary sump built for construction phase water management.	• Minor AMD treatment is expected in the Construction Phase (~60 t H₂SO₄/yr and 90 t H₂SO₄/yr at ESE and MFS respectively) • ESE: The existing Pit 3 Pit Lake will be used to settle sludge. Backfill of mine rock will eventually bury this AMD sludge (noting the pit lake will be drained first by pumping to Lake Brazil to drain into Cascade Creek Trib (V8)). • MFS: A temporary sump of 10,000 m³ will be built near the MFS Coal Storage Pad. This will be operational until the MFS WTP is constructed and will manage treatment (e.g., Ca(OH)₂, MgO, or NaOH) of any AMD and TSS during the Construction Phase. Once the WTP is operating this AMD sludge sump will be backfilled. The MFS facility will require periodic cleaning and removal of AMD sludge to ESE or Stockton to ensure sufficient capacity for AMD sludge settlement in this sump. • In the second year of Construction at MFS and ESE, AMD sludge will be placed in unlined cells within ELF's (BRL, 2026b). • Management processes will be developed to dewater AMD sludge prior to removal and disposal.
Operational Phase	• Placement within cells within the ELF's as they are being constructed. AMD Sludge will not be placed in cover layers, NAF⁵ layers, or lower sulfur zones (10 m	• Unlined cells within ELF's (BRL, 2026b) where high acid forming (HAF) materials are avoided. • Seepage from ELF's will be fully managed and treated by the two WTP. • AMD sludge may be disposed of with Pond Fines.

⁵ Non-acid forming

	ELF shells, i.e., within 10 m of the ELF final surface).	Other options for AMD sludge disposal will be investigated during the Operational Phase. These options are discussed in Table 1 and Section 5.2.
Active Closure Phase	Disposal of AMD sludge onsite.	- AMD sludge from MFS and ESE will be disposed into engineered cells (or other similar management processes) on the ESE Coal Infrastructure area. - AMD sludge may also be transported to Stockton for disposal, which will have operating AMD sludge disposal facilities. - Other AMD sludge disposal options assessed during the Operational Phase will also be considered.
Post Closure Phase	Disposal of AMD sludge onsite.	- AMD sludge will be disposed at Stockton (which will have ongoing AMD treatment), or by other approved methods that may be developed over the Operational Phase of the BPCP for minor quantities of AMD sludge generated in the Post Closure Phase by the MSR. - Other options include disposal to an approved offsite landfill.

6 SLUDGE MANAGEMENT SUMMARY

AMD and suspended sediment generated during construction and mining associated with the BPCP requires treatment, which produces metal and sediment-rich sludges as a by-product. Both active AMD treatment (e.g., calcium oxide dosing) and passive AMD treatment (e.g., MSR) precipitate metals predominantly iron and aluminium, forming sludge that requires management and disposal. During the construction and operational phases of the project, sludge will be heavily influenced by suspended sediment, which will decrease as rehabilitation activities are completed.

6.1 Overview

Site-specific studies (as explained in Section 2) highlight the following AMD sludge management considerations:

- Lower AMD sludge generation rates in the early years of the project that tend to be dominated by sediment rather than Fe- and Al- precipitates.
- High sludge generation volumes during the operational and active closure phases are expected (e.g., prior to transition to passive treatment and lower acidity loads).
- Fe- and Al- rich AMD sludges are sensitive to acidic conditions (higher metal leaching below pH 5–6). Data indicates that trace metals are preferentially mobilised where $Mn > Co = Zn > Ni$.
- Dewatering risks and the ability to influence disposal options (e.g., transportation of sludge material).

The existing Stockton Mine AMD sludge management experience provides a practical analogue for managing these risks and future AMD sludge management for the BPCP, demonstrating the importance of:

- Reagent selection on AMD sludge volume and stability.
- Suitable sludge dewatering processes to permit planned disposal options.
- AMD sludge disposal options.

Although quantities of AMD sludge are significant, they are low compared to the total quantity of overburden placed in the proposed Engineered Landforms (ELFs). For instance, when peak AMD sludge is generated at ESE in FY36:

- MFS: In FY37 there is 2,113,100 bank cubic metres (bcm) of rock (MWM, 2026h) placed in the MFS ELFs (i.e., 5.07 Mt, based on a density of 2.4 t/m³) and 847 t of AMD sludge (dry basis) as shown in Table 5.
- ESE: In FY36 there is 9,802,600 bcm of rock (MWM, 2026h) placed in the ESE ELFs (i.e., 23.5 Mt, based on a density of 2.4 t/m³) and 4,353 t of AMD sludge (dry basis) as shown in Table 5.

Across MFS and ESE this equates to 0.02% AMD sludge in FY36.

Greatest quantities of AMD sludge will be generated in the Operational and Active Closure phases of the project when acidity loads are highest. Contributors to AMD sludge quantity include TSS and AMD (Fe, Al, calcium carbonate (CaCO_3)) as shown in Table 11.

Table 11: Mine Phases and AMD treatment sludge quantities for MFS and ESE

PHASE	TREATMENT METHOD	TSS CONTRIBUTION	AMD CONTRIBUTION	AMD SLUDGE QUANTITIES (WET)
Construction Phase	Portable active treatment systems	Moderate	Low	Moderate (10,000 to 20,000 m ³ /yr) ¹
Operational Phase	Active water treatment	High	High	High (~40,000 m ³ /yr) ²
Active Closure Phase	Active and passive water treatment	Moderate to low	High decreasing to moderate	High decreasing to moderate (~16,000 m ³ /yr decreasing) ³
Post Closure Phase	Passive water treatment	Low	Moderate	Moderate (~1,000 m ³ /yr) ⁴

Note:

Note: Estimates of sludge quantities are provided from the water and load balance models (WLBMs) for BPCP sub-areas ESE and MFS (MWM, 2026a,b) for the Operational, Active Closure, and Post Closure phases. AMD sludge estimates for the Construction Phase are based on material movements and sludge estimates from the first year of the WLBMs (pro rata based on material quantities).

1. Based on 3 wt% solids for the 2-year Construction Phase (Table 6 of this report).

2. Based on 12 wt% solids for the Operational Phase (Table 5 on this report).

3. Based on 12% solids for FY2045 (Table 5 on this report).

4. Passive treatment estimated to be >20% solids.

6.2 AMD Sludge Management Risks

The contribution to sludge volume by trace metals is not significant with regards to volume effects as explained below:

- Al and Fe hydroxides contribute to ~ 95% of the sludge volume (dry weight basis).
- Major trace metals (Manganese (Mn), Nickel (Ni), Zinc (Zn) hydroxides) contribute ~5% of the sludge volume (1.6%, 0.5%, 2.9% respectively).
- All other trace metals contribute to < 0.5% of the sludge volume (dry weight basis).
- During the Construction Phase the ratio of TSS to Al + Fe load is low with Al + Fe contributing to ~5% of the total sludge volume (dry weight basis) for ESE Year 2028; at the end of the Active Treatment Phase Fe + Al load contributes to ~42% of the total sludge volume (dry weight basis) for ESE Year 2057.

However, studies indicate that trace metals that are preferentially mobilised from sludge (Mn > Cobalt (Co) = Zn > Ni) are also more difficult to remove by passive treatment using MSR (Mn – 58.6%; Co – 82.8%, Zn, 63.7%, Ni – 40.2%). A higher trace metal load may require a longer active treatment period

6.3 AMD Sludge Management

The following management processes are proposed:

- Develop a management process for AMD sludge disposal that is supported by performance monitoring and adaptive management. This should include recording of AMD sludge volumes and disposal locations within any landforms.
- Performance water quality monitoring of ELF basal seepage should be undertaken to detect any increase in PCOC concentrations due to AMD sludge disposal. This would be identified by an increasing trend in trace metals such as Zn and might require a longer active treatment phase.
- Other AMD sludge disposal options may be assessed throughout Operational Phase for implementation in Active and Post Closure phases.

6.4 Other Studies

The following additional studies are recommended to support and improve AMD sludge management utilising adaptive management processes:

- Pit lake stratification studies need to be undertaken to confirm whether disposal of AMD sludge into pit lakes is acceptable in the long term if pit lakes stratify on a seasonal basis. There may be long term benefits for the project if AMD sludge can be disposed to pits in the closure phases.
- AMD sludge generation from the MSR polishing pond is accounted for in the AMD sludge calculations (e.g., Fe load). The additional contribution of any FeCl_3 will need to be assessed once the MSR are operating.
- Further studies should be undertaken on the need to remove shells in the MSR from below the Al- and Fe- hydroxide layers with time. If a slow buildup of precipitates occurs, then these materials may require disposal as AMD sludge, which could increase AMD sludge quantities.
- Further assessment of the AMD sludge is required to confirm that the AMD sludge will meet landfill disposal criteria if this is selected as the long-term Post Closure Option for AMD sludge disposal. This includes:
 - Analysis of total metal concentration of the AMD sludge (e.g., mg/kg)
 - Toxicity Characteristic Leaching Procedure (TCLP) testing as proposed by the US EPA laboratory test method (Method 1311).

Such testing needs to be undertaken on MSR AMD sludge that is low in TSS to be representative.

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8 LIMITATIONS

Attention is drawn to the document “Limitations”, which is included in Appendix A of this report. The statements presented in this document are intended to provide advice on what the realistic expectations of this report should be, and to present recommendations on how to minimise the risks associated with this project. The document is not intended to reduce the level of responsibility accepted by Mine Waste Management, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in doing so.

APPENDIX A LIMITATIONS

This Document has been provided by Mine Waste Management Ltd (MWM) subject to the following limitations:

This Document has been prepared for the particular purpose outlined in MWM's proposal and no responsibility is accepted for the use of this Document, in whole or in part, in other contexts or for any other purpose.

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Conditions may exist which were undetectable given the limited nature of the enquiry MWM was retained to undertake with respect to the site. Variations in conditions may occur between investigatory locations, and there may be special conditions pertaining to the site which have not been revealed by the investigation, and which have not therefore been considered in the Document. Accordingly, additional studies and actions may be required.

In addition, it is recognised that the passage of time affects the information and assessment provided in this Document. MWM's opinions are based upon information that existed at the time of the production of this Document. It is understood that the services provided allowed MWM to form no more than an opinion of the actual conditions of the site at the time the site was reviewed and cannot be used to assess the effect of any subsequent changes in the quality of the site, or its surroundings, or any laws or regulations.

Any assessments made in this Document are based on the conditions indicated from published sources and the investigation described. No warranty is included, either express or implied, that the actual conditions will conform exactly to the assessments contained in this Document.

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MWM acknowledges that this report will be relied on by a Panel appointed under the Fast-track Approvals Act 2024 and these disclaimers do not prevent that reliance.



MINE WASTE MANAGEMENT

GREENROAD GROUP

APPENDIX Q MFS - GROUNDWATER TECHNICAL REPORT

Mount Frederick South Sub-Area

Groundwater Technical Report

20 July 2026

J-NZ0377-004-R-FINAL



**MINE WASTE
MANAGEMENT**
GREENROAD GROUP



BATHURST
RESOURCES LIMITED

Mount Frederick South Sub-Area

Groundwater Technical Report

Document Number: J-NZ0377-004-R-FINAL

Document Date: 20 July 2026

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REVISION	DATE	AUTHOR	RECORD OF REVIEW
J-NZ0377-004-R-FINAL	20/07/2026	LM / RB	RB / PW

EXECUTIVE SUMMARY

Bathurst Resources Limited (BRL) is seeking to obtain authorisation through the Fast-track Approvals Act (FTAA) to progress development and mining of the coal resources across the wider Buller Plateaux. This project is referred to as the Buller Plateaux Continuation Project (BPCP or Project). Mine Waste Management Limited (MWM) has developed this report for BRL to support the permitting of the Mount Frederick South (MFS) sub-area, a component of the BPCP.

This report was prepared to assess potential environmental effects related to groundwater for MFS. Potential effects to groundwater quantity and quality were identified, including changes to:

- Groundwater levels, mainly from pit excavation.
- Groundwater flow, mainly from pit excavation.
- Groundwater quality, mainly from seepage from ex-pit and in-pit engineered landforms (ELFs).

Potential effects were assessed conceptually, with supporting calculations where appropriate. Findings from the assessment are summarised below:

Groundwater Quantity

- Groundwater levels
 - Pit excavation and dewatering will intercept the water table, with the degree of drawdown differing between the East Pit and West Pit. During operations and post-closure, the passive drainage of backfilled pit voids will mean this condition likely remains.
 - On the eastern side of MFS, the East Pit void is typically deeper and the water table shallower, resulting in localised lowering of the water table by approximately 30 m in the long term, with the cone of depression close to the pit walls given the low permeability geological units intercepted.
 - On the western side of MFS, the West Pit void is shallower, and in areas the water table is deeper, meaning that while the pit voids will intercept the groundwater system, the magnitude of drawdown will be lower (e.g., 5 m or less) than at the East Pit void.
- Groundwater flows
 - A number of factors indicate changes to the amount of groundwater discharging to streams are likely to be low, including (i) pit voids positioned above adjacent stream levels, (ii) lower hydraulic conductivity (K) rock with a localised cone of depression, and (iii) sealing of intercepted underground workings as required to prevent uncontrolled discharge.
 - The MFS water and load balance model (WLBm) accounts for reduction in groundwater discharge to streams by reductions in natural catchment areas reporting to streams (MWM, 2026c). Other inputs to streams, such as treated water, are also included. Overall, the modelling results suggest an increase in lower flow conditions in the long term (i.e., post-closure) compared to baseline. The discharge of treated water from mussel shell bioreactors (MSRs) greatly offsets any reduction in groundwater discharge.

Groundwater Quality

ELF seepage poses the largest potential risk to groundwater quantity:

- The lower K in situ rock compared to the higher K backfill material, coupled with basal and perimeter drainage systems, will promote ELF seepage to collection locations and subsequent treatment. Performance monitoring will be required to confirm ELF seepage is not being transported via groundwater pathways to surface water receptors (e.g., streams).
- At the MFS coal handling area (Coal Transfer Pad, Coal Stockpile Area), the data available suggests a thin soil/unconsolidated deposit profile (~ 3-4 m) underlain by mudstone bedrock. These conditions coupled with basal drainage systems would promote effective collection of any sub-surface seepage.

Runoff from pit floors that remain post-closure is also a risk to groundwater quality should a portion infiltrate to the groundwater system. The lower K pit floor would behave hydrologically in a similar manner to exposed bedrock surfaces, where the majority of rainfall is translated to surface runoff. Infiltration would therefore be a lower proportion of rainfall, potentially in the order of 5% of annual average rainfall based on regional recharge estimates. Performance monitoring is required to confirm pit floor runoff does not impact groundwater quality.

Known groundwater users are over 4 km away, located on the coastal flats and unlikely to be impacted by the MFS sub-area activities. Any potential effect would be negligible.

Forward Works

Although the data currently available suggests favourable conditions for subsurface seepage collection at the Coal Transfer Pad, further investigations to confirm assumptions, including the installation of groundwater monitoring wells, are recommended to be completed during the Construction Phase.

Performance Monitoring

The existing groundwater monitoring network will be impacted by the MFS sub-area, with all except three wells (DC33, DC45, and DC46) likely to be decommissioned. As such, additional groundwater monitoring wells should be installed in key locations. Areas for long term performance monitoring are recommended to target locations positioned between potential sources (e.g., ELF) and receptors (e.g., streams), and in close proximity to sources to provide warning of potential seepage impacting groundwater. Timing of new well installation should occur as far ahead of mining disturbance as is practicable. Hydrogeological testing of wells (e.g., slug tests) would be beneficial to improve the site-specific K dataset.

Efficient collection of in-pit ELF seepage is predicated on maintaining a lower phreatic surface within the backfilled material than that external to the pit (i.e., pit acts as a hydraulic sink to maintain hydraulic containment of seepage). Although the higher K backfill material (compared to in situ rock) and use of underdrains will act to lower the phreatic surface within the in-pit ELFs, high rainfall conditions could theoretically counteract this leading to a higher in-pit phreatic surface than anticipated (and the pit no longer being a hydraulic sink everywhere). Therefore, to complement groundwater monitoring external to the pit, the phreatic surface within the ELF should be monitored to confirm the basal drainage network is performing adequately and the pit remains a hydraulic sink, thereby minimising the potential for ELF seepage to reach surface water receptors. This can be achieved by installing nested vibrating wire

piezometers following rehabilitation. In addition, periodic seepage surveys should be completed following rehabilitation to identify any unexpected seepage emerging through the rehabilitation surface. Collection of recommended data will support management processes.

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1 **INTRODUCTION**

Bathurst Resources Limited (BRL) is seeking to obtain authorisation through the Fast-track Approvals Act 2024 (FTAA) to progress development and mining of the coal resources across the wider Buller Plateaux. This project is referred to as the Buller Plateaux Continuation Project (BPCP or Project).

1.1 **Background**

The purpose of the BPCP is to secure the existing infrastructure and mining operations associated with the Stockton Mine and provide access to additional mining areas as the coal resources in the current operations are depleted. The Project proposes to mine 20 million tonnes of coking coal utilising existing infrastructure facilities over a 25-year timeframe to support and extend the mine life of the current Stockton Mine operations.

There are four key Project areas (also referred to as sub-areas) that make up the BPCP:

- Stockton.
- Mount Frederick South (MFS).
- Escarpment Extended (ESE).
- Upper Waimangaroa Haul Road.

This report relates to MFS only.

1.2 **Scope and Objectives**

This report documents the assessment of potential environmental effects related to groundwater for the MFS sub-area of the Project.

This report was prepared to achieve the following objectives:

- Develop a Hydrogeological Conceptual Model for the MFS sub-area to develop an understanding of the system in regard to groundwater and interaction with other environmental receptors.
- Assess potential effects of the MFS sub-area on the environment via groundwater effect pathways during operations and post-closure.

1.3 **Project Description**

This assessment was based on the Project as described in the BPCP Assessment of Environmental Effects.

The MFS sub-area is located approximately 1 km southwest of the existing Mount Frederick mining area at the Stockton Mine. This area will be accessed off the proposed UWHR, with a haul road being constructed from the UWHR up into the MFS mine area.

There are historic underground mines in this area, dating back to the late 1800's.

MFS will be mined in two pits: West Pit and East Pit. Coal within this targeted resource is a key component of the future export market blend requirements following the forecasted depletion of the Stockton coal resources.

Mining in this area will largely be integrated with the Stockton and ESE mining activities and operations, with minimal semi-permanent infrastructure located at the site. There will also be a coal transfer stockpile and water management infrastructure.

The MFS sub-area involves the following major activities (Figure 1):

- Open-cast mining of the East and West Pits.
- Construction of Engineered Landforms (ELFs) to place waste rock. The majority of the ELFs will be placed within the mined-out pit shells. Ex-pit ELFs will be used for waste rock storage prior to in-pit disposal being available. All ELFs will be progressively rehabilitated with cover systems as part of the mine closure activities. The Coal Transfer Pad is also considered an ELF.
- Construction of an active water treatment plant (WTP) to treat mine affected waters on site during operation and into the closure phase.
- Construction of Mussel Shell Reactors (MSRs) and polishing ponds, to passively treat ELF seepage water prior to discharge to the receiving environment. Some MSRs will be established at the start of ELF placement while others will be established at mine closure / after mine closure following the transition from active treatment to passive treatment.

Figure 2 shows the disturbance schedule over time, where mining activities start on the west and advance over Billo Stream to the west.

1.3.1 Water Management Overview

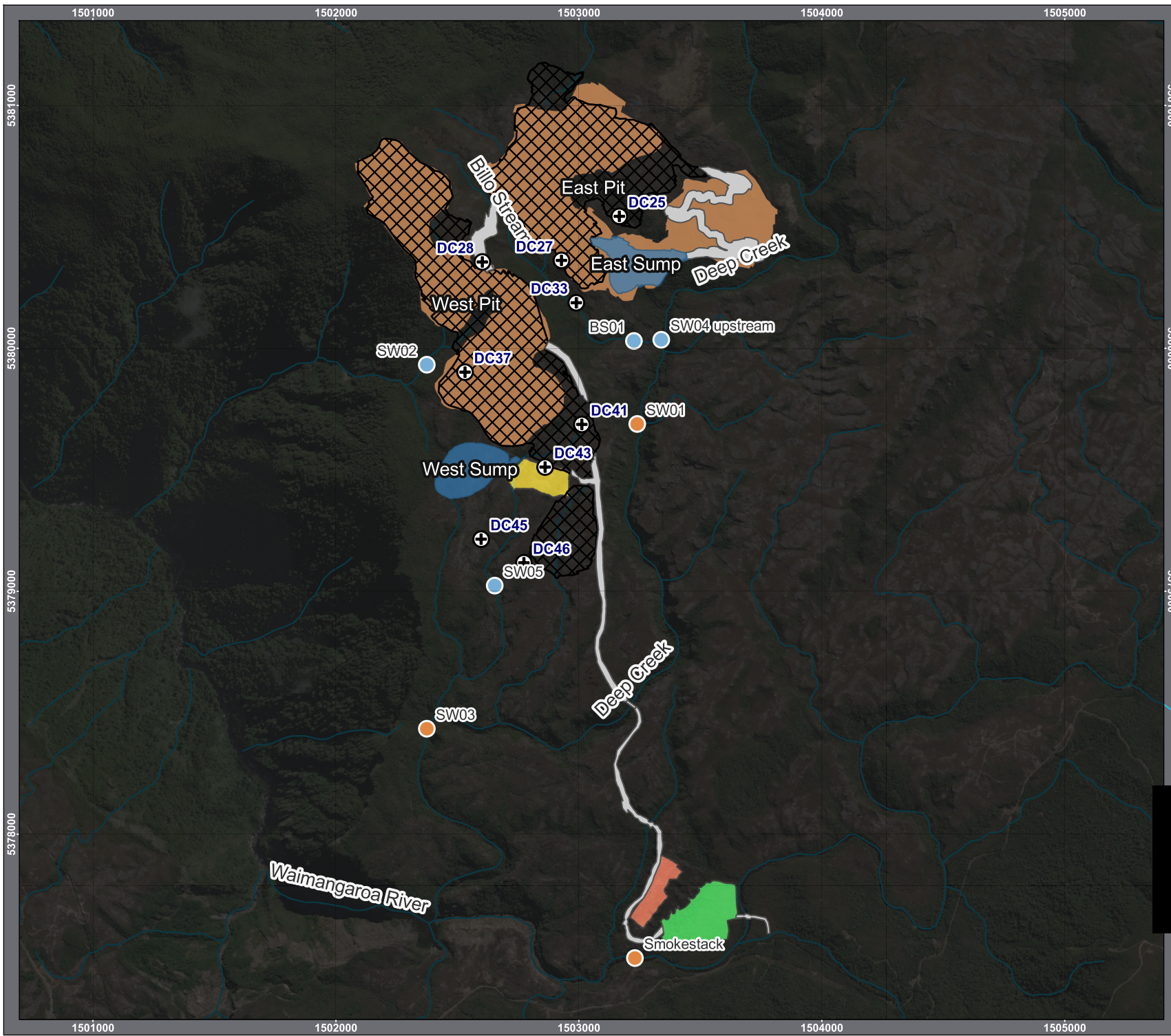
General water management practices have been summarised for the operational and post-closure phases of the MFS sub-area within this section.

Operational phase water management will comprise:

- In-pit dewatering, involving collection of in-pit water within sumps and pumping to the WTP (active treatment). Treated water will be discharged to the Waimangaroa River upstream of Smokestack.
- Construction of bypass mechanisms to divert higher flows (e.g., >95th percentile flows) from mine sumps to receiving catchments into Deep Creek and its tributaries.
- Construction of sub-ELF basal and perimeter drainage systems to direct ELF seepage to passive water treatment systems, each comprising a MSR and a polishing pond. Timing of MSR activation will vary by ELF based on the rehabilitation schedule.
- Construction of clean water diversion drains to direct clean water away from the pits.

Post-closure water management will comprise:

- Continuation of active treatment and associated operational water management infrastructure until discharge water quality meets compliance criteria.
- Ongoing passive water treatment.
- Cessation of dewatering associated with active treatment, and subsequent filling of sumps.



LEGEND

- Monitoring Wells
- Sumps
- Haul Road
- ELF
- Pits
- Coal Transfer Pad
- Infrastructure Pad
- WTP Pad
- Waterways
- Monitoring Site**
 - Proposed Compliance Location
 - Proposed Performance Location

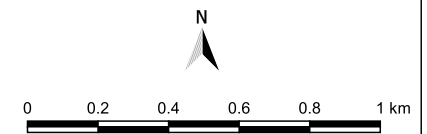


Figure 1: Site Overview
Mt. Fred South

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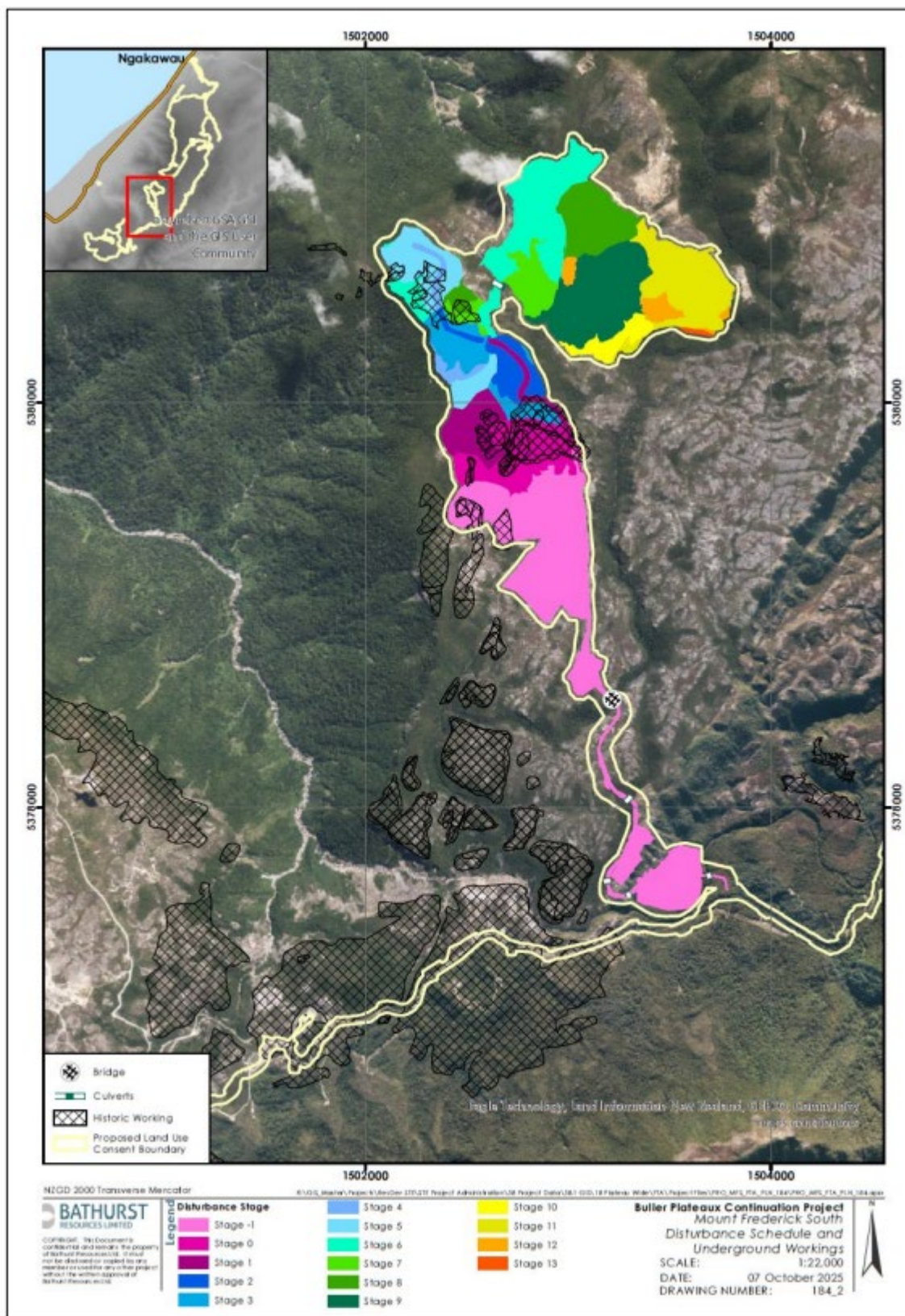


Figure 2: MFS sub-area disturbance schedule.

Source: BPCP FTA Assessment of Environmental Effects.

2 HYDROGEOLOGICAL CONCEPTUAL MODEL

2.1 Overview

A Hydrogeological Conceptual Model (HCM) can be described as a descriptive representation of a groundwater system that incorporates an interpretation of the geological and hydrological conditions. It consolidates the understanding of the key processes of the groundwater system, including the influence of stresses, and assists in the understanding of possible future changes (Barnett et al., 2012). The HCM presented within this section is based on available data from the site and studies from other sites on the Buller Plateaux. A summary of the HCM is presented in Section 2.8.

2.2 Topography and Land Use

The MFS sub-area is located on the Denniston Plateau, on the West Coast of the South Island. The Denniston Plateau is typically elevated at 600 – 1,100 m above sea level (asl) and hosts several current and former coal mining operations. The MFS sub-area encompasses 216 ha and is characterised by gentle to moderately sloping, hilly terrain with deeply incised drainage channels. The sub-area has an overall slope towards the south and elevation of the pit and ELF locations generally ranges between 650 and 920 m asl.

The MFS sub-area is host to a network of historical underground mine workings, of which water has been observed draining from adits into Deep Creek. Collapse of these underground mine workings has altered the surface topography in some locations via subsidence.

2.3 Climate and Hydrology

2.3.1 Climatic Records

To date there has been no monitoring of weather parameters within the MFS sub-area itself. However, there are meteorological stations within 6 km to the northeast (Stockton Office Met, 790 m altitude) and Cypress Met, 725 m altitude), and within 6 km to the south-west (James Weather Station 645 m altitude) and (Lake Brazil Weather Station, 640 m altitude). There is also a rain gauge on Mt Frederick itself at an altitude of 1,056 m (Chater, 2024a).

General rainfall depths for the sub-area were derived from Lake Brazil Weather Station rainfall records, situated at an elevation of 640 m. Chater (2024b) developed a relationship between Lake Brazil Weather Station and elevation which is considered applicable for estimating rainfall on the Denniston Plateau (Figure 3). The current mine plan indicates mining activities will occur in the upper extents of the catchment. Based on this, a mean elevation of 812 m has been adopted to estimate average conditions on-site. Using the relationship developed by Chater (2024b), a multiplication factor of 1.084 was applied to the Lake Brazil Weather Station record.

The Lake Brazil weather record contains data from 2010 – 2023. The data records lack continuity and contain numerous data gaps. In such cases, data was patched using climatic data from the Stockton Office Met Station, which is located at the Stockton mine at a similar elevation (Chater, 2024b). The patched dataset is herein referred to as the MFS sub-area climate dataset.

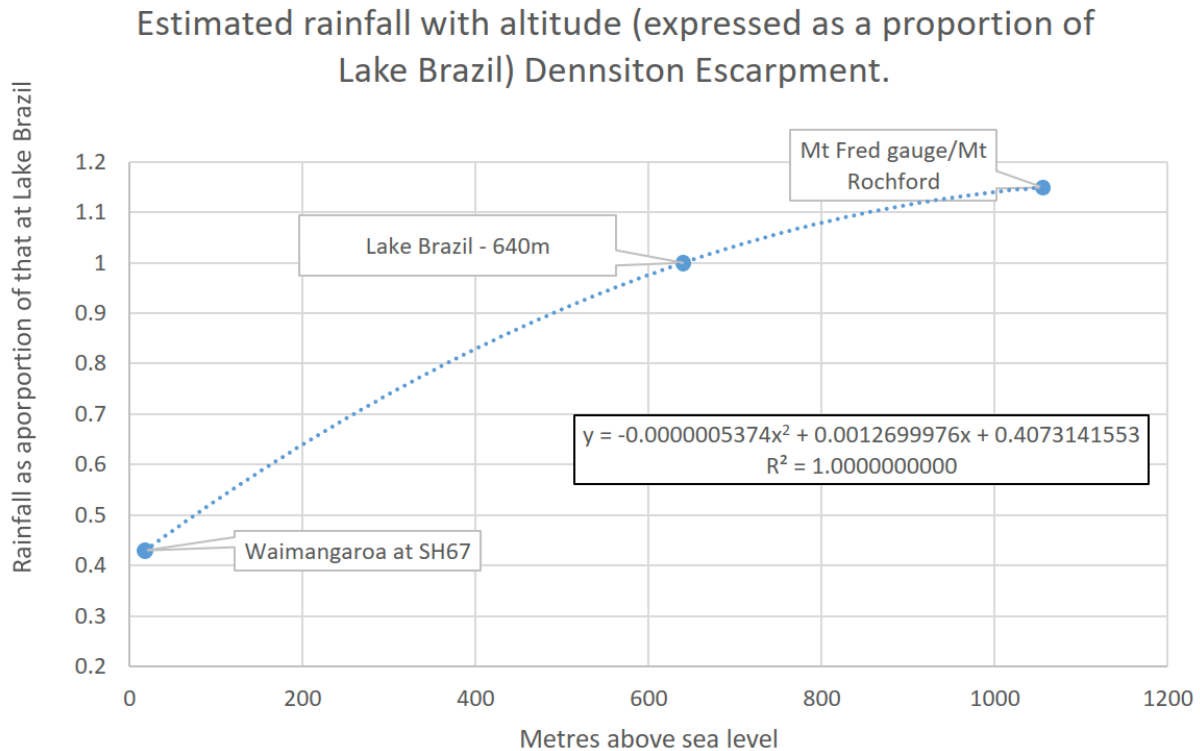


Figure 3: Derived rainfall elevation relationship.

Source: Chater (2024a)

2.3.2 Rainfall

The West Coast of the South Island is characterised by high rainfall and is the wettest region in New Zealand. High rainfall is attributed to the region's exposure to moisture laden air masses passing over the Tasman Sea, with typical annual rainfall in coastal areas of 2,000 – 3,000 mm/year (Macara, 2016). However, rainfall is significantly higher in elevated areas such as on the Denniston Plateau.

Figure 4a presents rainfall records from 2011 to 2023 from the MFS sub-area climate dataset. Average seasonal rainfall is presented in Figure 4b. The following is noted regarding the figures:

- Mean rainfall is approximately 5,900 mm/year.
- Annual rainfall is variable, with a range of 4,711 mm/year (2018) to 6,895 mm/year (2021).
- Rainfall is comparable between summer, autumn, and winter, with an average of approximately 1,400 mm/year for each season.
- Spring is the wettest season with an average of 1,674 mm.

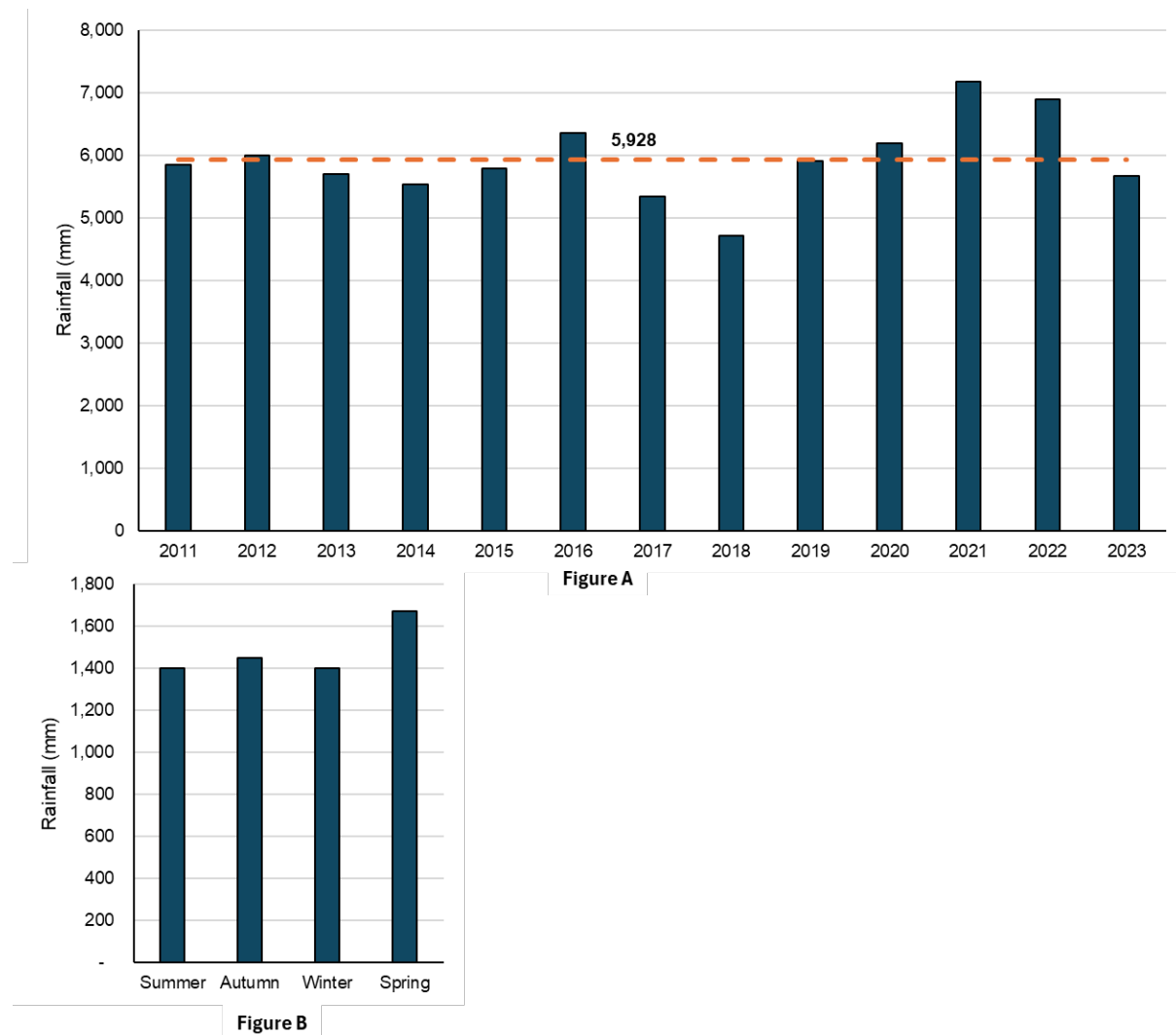


Figure 4: Rainfall data summary

(a) MFS sub-area climate dataset records from 2011-2023.

(b) Seasonal average rainfall from the MFS sub-area climate dataset spanning 2011-2023.

2.3.3 Air Temperature and Evaporation

Air temperature differences across site are anticipated to be minor and therefore Lake Brazil has also been used as a surrogate for the upper MFS sub-area. Air temperature records from Lake Brazil recorded between 2011 and 2023 are illustrated in Figure 5. The temperature is considered mild, with peak temperatures occurring in February and minimum temperatures occurring in June.

Potential evaporation (PE) has also been estimated utilising the MFS sub-area climate dataset record (see MWM, 2026a). Monthly estimates of potential evaporation are illustrated in Figure 6. As indicated, potential evaporation is anticipated to be highest in December, and lowest in June. An energy deficit is apparent throughout all months, provided monthly rainfall always exceeds PE. Annual PE has been estimated as 840 mm, which is approximately 14% of mean annual rainfall.

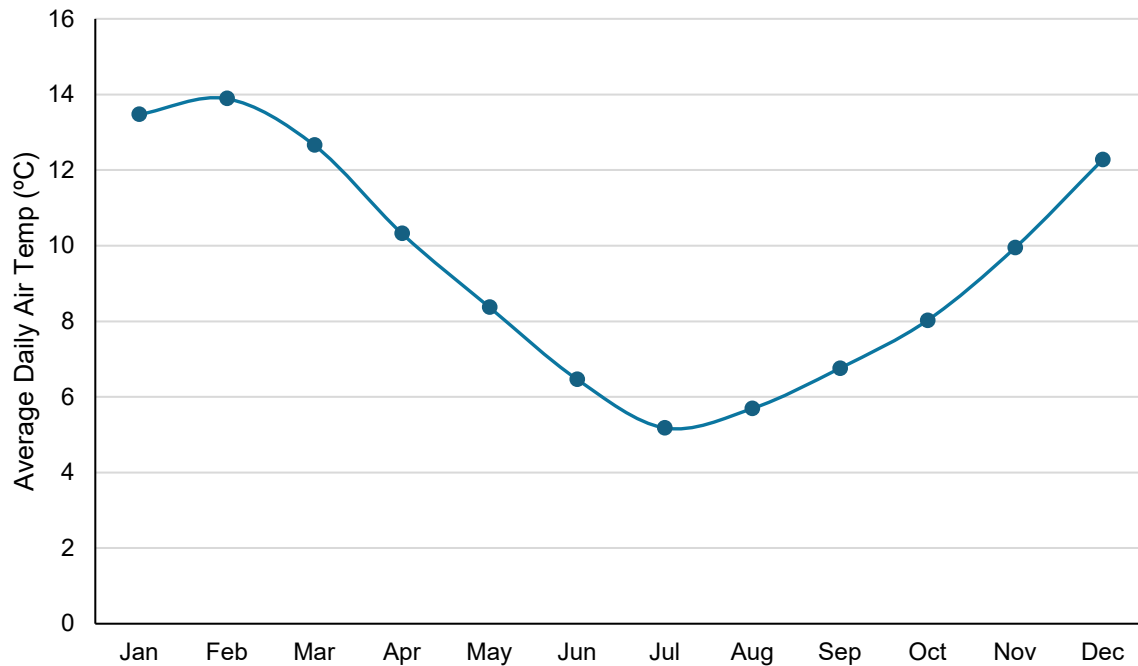


Figure 5: Average daily air temperature

Note: from MFS sub-area climate dataset between 2011 and 2023.

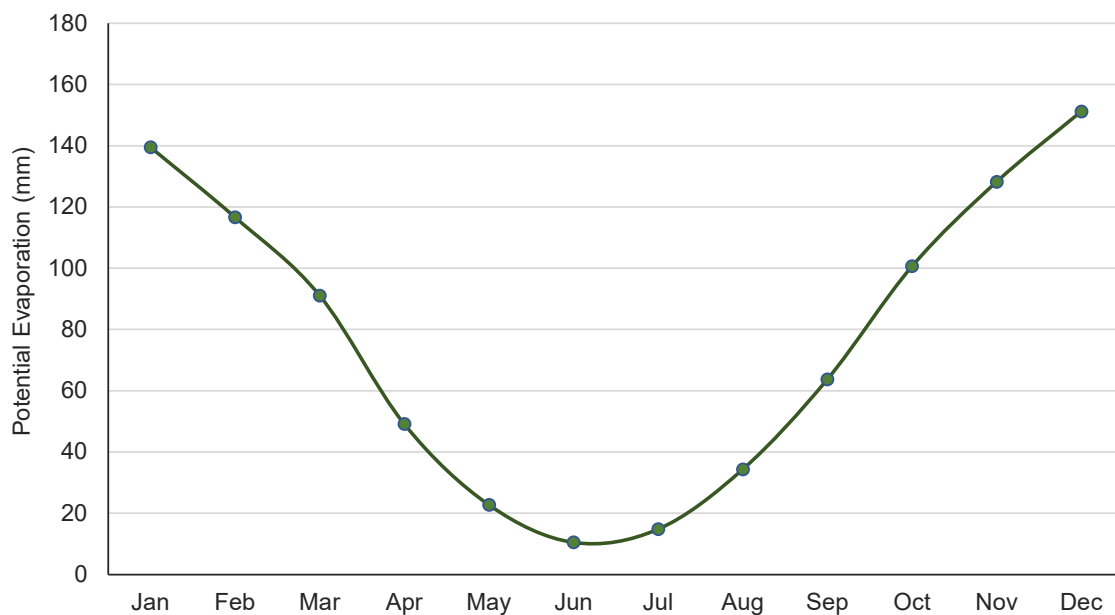


Figure 6: Estimated monthly potential evaporation

Source: MWM (2026a)

2.3.4 Hydrology

The Buller Plateaux are characterised by high rainfall, elevated topography and thin soils with limited soil moisture holding capacity. Infiltration to ground is therefore minor in comparison to runoff with a large proportion of rainfall expected to reach streams and rivers via surface run-off rather than via groundwater baseflow (Golder 2012a).

The main drainage feature is Deep Creek (also known as Deep Stream) which flows south outside the north east and eastern boundaries of the MFS sub-area, discharging to the Waimangaroa River approximately 2 km south of the ELFs (see Figure 1). Several valleys make up the headwaters of the Waimangaroa River on the western boundary of the MFS sub-area, these tributaries collect runoff from the surrounding topography and drain south and discharge into the Waimangaroa River. Available flow data for SW01 (see Figure 1 for location) is shown in Figure 7. Extremely flashy responses are apparent, with low baseflow rates. Mean flow for the record shown was 371 L/s and low flows (95th percentile) were only 2.6 L/s for a catchment area of 3.61 km² (MWM, 2026b). Flow data suggest MFS sub-area streams/creeks are runoff dominated, with low contribution from groundwater.

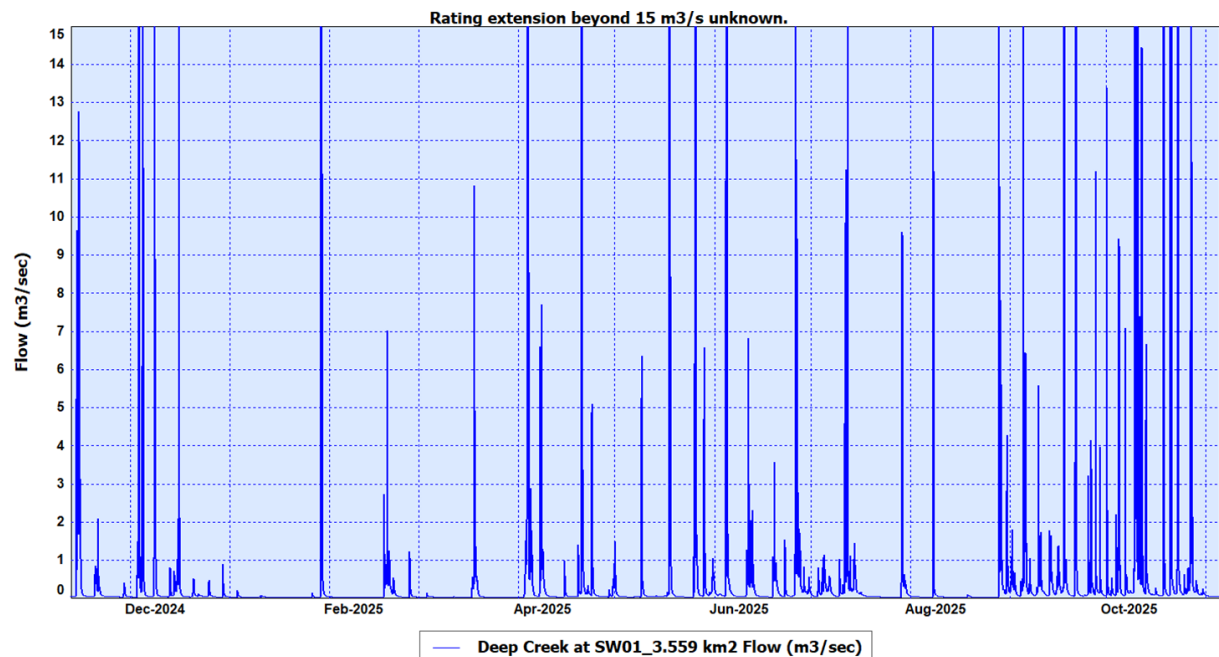


Figure 7: SW01 flow record.

Source: MWM (2026b).

2.4 Hydrogeological Site Investigations

BRL conducted a drilling programme at MFS sub-area, beginning in 2023, primarily to evaluate the coal resource and to develop a geological model of the site. A total of nine groundwater monitoring wells were installed in select boreholes on-site. Five of these monitoring wells have since been used to establish baseline conditions, including:

- Groundwater quality sampling
- Groundwater level monitoring
- Hydraulic testing

The data collected using these monitoring wells have informed the HCM within this report, particularly regarding site hydrostratigraphy and the groundwater flow regime. A summary of the monitoring wells and the groundwater monitoring programme are provided in Table 1. Locations of all nine monitoring wells are shown in Figure 1.

Table 1: Monitoring well summary.

MONITORING WELL	SCREENED INTERVAL (m bgl)	HYDROSTRATIGRAPHIC UNIT (HSU)	SCREENED GEOLOGY	GROUND ELEVATION (m RL)	PRESSURE TRANSDUCER	MANUAL GWL MEASUREMENTS
DC25	11.6 – 14.6	BCM	Sandstone	793.8	No	Yes
DC27	18.5 – 24.5		Conglomerate	791.6	No	Yes
DC28	6 – 9		Main Coal Seam	813.1	Yes	Yes
DC33	1.3 – 4.3	Contact: BCM / BSM	Coal, Argillite, Greywacke	742.5	Yes	Yes
DC41	9.2 – 12.2	BSM	Undifferentiated GG	740.7	Yes	Yes

BCM – Brunner Coal Measures.

BSM – Basement.

GG – Greenland Group Basement.

GWL – Groundwater Level.

bgl – below ground level

2.5 Geological Setting

2.5.1 Regional Geology

The following description of regional geology has been summarised from the work of Flores & Sykes (1996).

The Buller Coalfield in the West Coast Basin-and-Range Province has undergone subsidence and extension since the Late Cretaceous. The Brunner Coal Measures (BCM), deposited from the middle Eocene to Oligocene, form the foundational layer of a transgressive sequence, which comprise succession of estuarine high sulfur sedimentary rocks consisting of clastic rocks and coal seams. The BCM unconformably overlie the basement rocks comprising Greenland Group turbidite sequences, intruded by granites and porphyries. The BCM are dominated by sandstones inter-layered with siltstones, mudstones, carbonaceous mudstones, and coal seams. The sequence is 70 – 130 m thick and was deposited in a fluvio-paralic environment consisting of braided and meandering streams within a deltaic, barrier, tidal environment. The BCM unconformably overlie Greenland Group, Karamia Batholith, Berlins Porphyry, and Hawks Crag Breccia (Golder, 2012a). Weathering below the unconformity is highly variable but has been observed to extend to approximately 15 m depth.

2.5.2 Site Geology

The soil thickness within the MFS sub-area area is typically thin (<300 mm) to absent, with tussock root mass comprising a significant portion of the surface soil (Golder, 2012a).

Underlying the soil and exposed across much of the MFS sub-area, is typically indurated coarse sandstone of the BCM. Other BCM units (e.g., siltstone and coal) were visible along drainages and collapsed historic mine workings, some relatively shallow (<2 m). In some areas of the site, basement outcrops at the surface. Geological logs provided by BRL indicate basement rocks are greywacke and argillite of the Greenland Group or undifferentiated. An indicative stratigraphic column of the geology within the MFS sub-area has been developed from BRL bore logs and is illustrated in Figure 8. The main coal seam, and additionally the target coal seam for mining, is the Mangatini Seam. The general site geology is indicated in Figure 8 along with mapped major faults. The illustrations indicate that surface cover consists of BCM across the areas of planned mine infrastructure. Greenland Group Basement is exposed immediately to the north and west. It should be noted that this map does indicate minor instances of basement outcropping at the surface, which have been observed in some areas of the MFS sub-area.

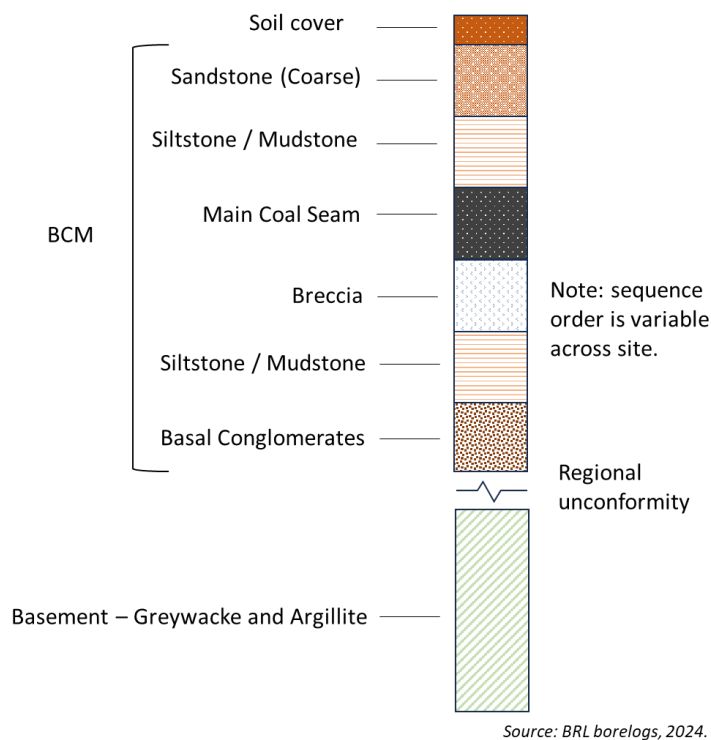


Figure 8: MFS stratigraphy.

Note: Stratigraphic column is indicative only and spatial variability occurs across the site.

The thickness of the BCM is variable across the site. Data from bore logs associated with the 2023 drilling programme (Table 2) indicate the BCM sequence is thinner at the northern end of the site and thickens toward the south; see Figure 1 for location of data. The thickness of the BCM at the northern end of the site is variable depending on topography, ranging from 0 – 36 m. Further south, the basement was not intercepted during drilling despite drilling to greater depths. BCM depths here are likely to range between 50 m and 100 m.

Table 2: Thickness of BCM intercepted in drillholes.

MONITORING WELL	BCM THICKNESS	COMMENT
DC25	36 m	-
DC27	21.5 m	-
DC28	10 m	-
DC33	0 m	Basement exposed at surface
DC37	27.5 m	-
DC41	>43.5 m	Basement rock not intercepted
DC43	>50 m	Basement rock not intercepted
DC45	>62 m	Basement rock not intercepted
DC46	>50 m	Basement rock not intercepted

The Coal Transfer Pad (Figure 1) will be positioned on a swampy floodplain of the Waimangaroa River with the potential for a deeper soil profile in this area. Detailed soil lithology data for this area are not available, but limited historic drillhole data suggest soil/unconsolidated deposit thickness is in the region of 3 - 4 m thick overlying mudstone bedrock.

2.5.3 Structural Geology

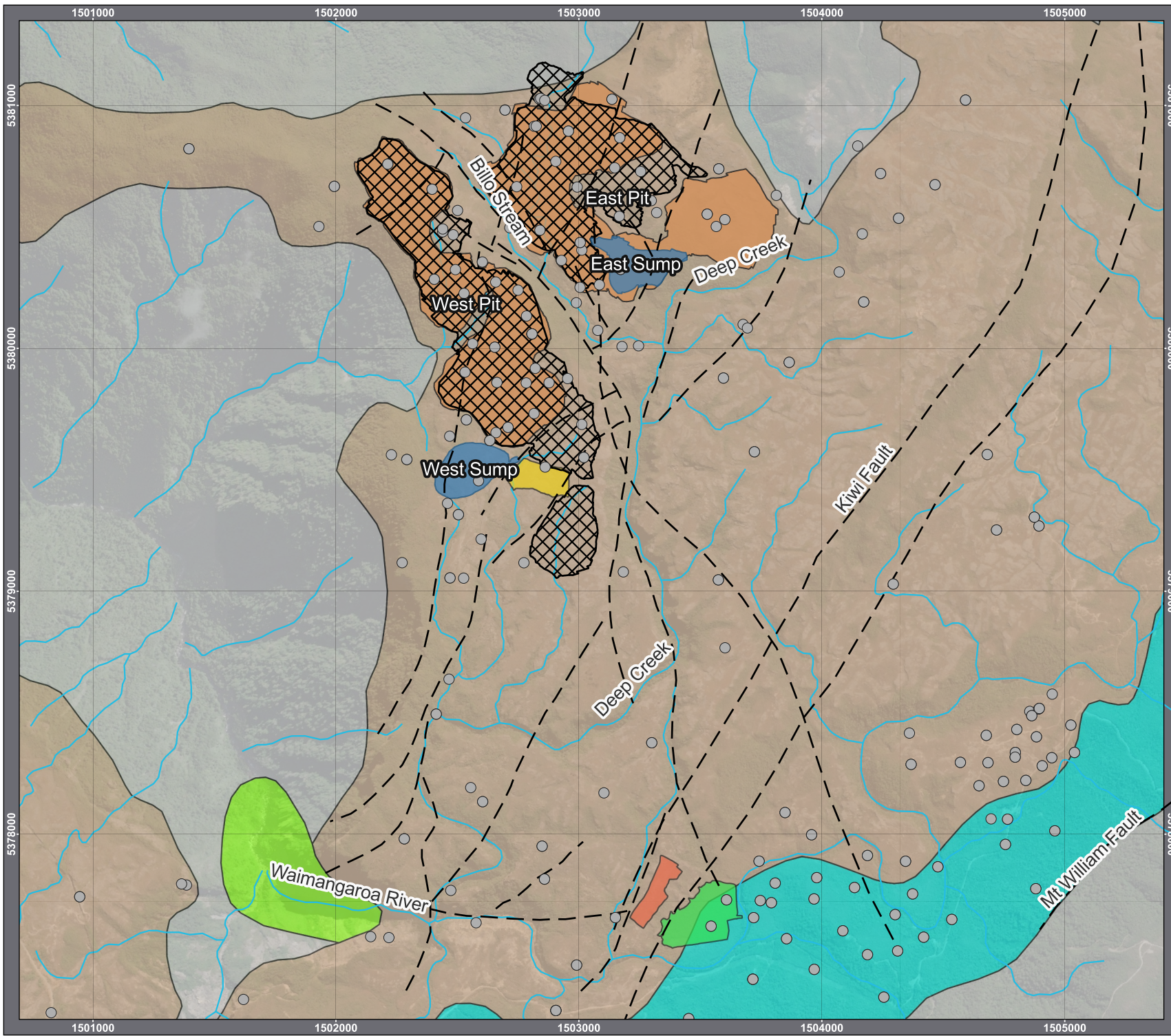
PDP (2025) reviewed the structural geological setting for geotechnical purposes. The following section is adapted from that work¹, except where alternative references are made:

The structural geology of the MFS sub-area is complex and predominantly fault controlled with some drag faulting. There are no significant regional structural folds within the MFS sub-area, with coal seam deformation directly related to faulting. Fault traces were provided by BRL and shown in Figure 9. The following is noted:

- Within the MFS sub-area, slopes are deeply incised and offset by NNE and NW trending fault scarps. The predominant fault set trends NNE, with fault planes deeply dipping at 60° to 80°. A number of the drainage features across the area appear to have been formed from faulting.
- Faults across the MFS sub-area have vertical displacements of 10 to 20 m, but there is no evidence of strike slip movement.
- The 'major' roughly north-south trending faults are part of the reactive normal faults for the current compressional phase, and the transverse faults have taken up the differential stress between the faults. These transverse faults could be very large structures in basement and have in places crosscut the 'main' north-south trending faults. Similar observations have been made at Stockton.
- The topography of the MFS sub-area comprises a series of dip slopes which generally dip southwest at 8° to 10°. Bedding in the BCM generally dip between 5° to 20°.
- Review of core logging within BRL's drillhole database did not provide a strong correlation between logged fault zones and mapped fault traces (shown in Figure 9). It should be noted that not all drill core was subjected to geotechnical logging.
- Review of drill core from three drillholes indicated structural damage (i.e., 'crush zones') to be present in the West Pit, with zones 0.8 to 1.3 m thick.

Structural jointing is likely variable across the MFS sub-area. Elsewhere on the Buller Plateaux, Golder (2012a) describes subvertical joints orthogonal to bedding being common in BCM sandstones and mudstones, with generally wide to very wide joint spacing within the main rock mass. Sometimes these joints were observed to be infilled with silicate or soil materials. Gaps of up to 1 m were measured closer to steep slopes where movement of large blocks resulted in opening of joints.

¹ The reader is directed to PDP (2025) for further information.



LEGEND

- | | |
|----------------------|-------------------------|
| — Faults | ● Drillholes |
| ■ Sumps | Geological Units |
| ▤ ELF | ■ Berlins |
| ■ Pit | ■ Porphyry |
| ■ Coal Transfer Pad | ■ Brunner |
| ■ Infrastructure Pad | ■ Coal Measures |
| ■ WTP Pad | ■ Greenland Group |
| — Waterways | ■ Kaiata Formation |

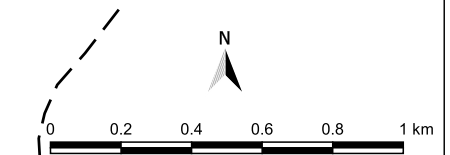


Figure 9: Geology and Structures

Mt Fred South

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2.6 Hydrostratigraphy

The main geological units encountered on-site are reported in detail in Section 2.5. These units are regionally extensive and have been identified at several mine sites (e.g., Stockton Mine). The key hydrostratigraphic units (HSU) at MFS are the BCM and Basement Rock.

Although BCM comprise various lithologies including sandstone, siltstone, conglomerate, and coal seam units of varying hydraulic properties, they are interpreted to form one HSU at the scale of the MFS area. The primary porosity of BCM and Basement Rock is anticipated to be low, such that secondary porosity associated with fracturing is the dominant mechanism for groundwater flow (Golder, 2012a). Where present, underground workings also provide a significant control on groundwater flow.

Hydraulic conductivity (K) estimates are available for the same HSUs at nearby sites from across the Buller Plateaux (e.g., Fergusson, 1995; Kingett Mitchell, 1999; MWH, 2003; Kingett Mitchell, 2005; URS, 2010; Stockton Alliance, 2014; Golder, 2012b). K estimates vary by approximately three orders of magnitude from these sources, but can be summarised as follows:

- BCM ranging between 2×10^{-8} m/s to 1×10^{-5} m/s, with a geometric average of 5×10^{-7} m/s.
- Basement ranging between 9×10^{-10} m/s to 4×10^{-6} m/s, with a geometric average of 4×10^{-7} m/s.

Calibration of numerical groundwater flow models has generally led to lower estimates of K for Basement ($< 1 \times 10^{-7}$ m/s) and higher K for BCM ($\geq 1 \times 10^{-6}$ m/s) for the Cypress Mine (e.g., Golder, 2010; GHD, 2021). This would suggest the BCM has a higher degree of lateral connectivity between fracture zones, potentially related to continuous bedding contacts, compared to Basement where these continuous structures are less prevalent. However, fractured damaged zones associated with the Mt William Fault at the Cypress Mine could also explain the higher K inferred by modelling.

Site specific K values for the various units have been estimated from analysis of slug testing undertaken in monitoring wells installed as part of the previously described site investigations (see Section 2.4). These data are tabulated in Table 3. Further detail on the slug testing and subsequent analysis is presented in Appendix A (MWM, 2026c).

Table 3: Site specific estimated hydraulic conductivity of HSUs at MFS.

MW ID	HSU	GEOLOGY	HYDRAULIC CONDUCTIVITY (m/s)
DC25	BCM	Sandstone	4.0×10^{-7}
DC28		Conglomerate	2.4×10^{-7}
DC41		Main Coal Seam	1.2×10^{-6}
DC27	Contact: BCM / BSM	Coal, Argillite, Greywacke	3.4×10^{-7}
DC33	BSM	Undifferentiated GG	2.3×10^{-6}

MW – Monitoring well.

BCM – Brunner Coal Measures.

BSM – Basement.

GG – Greenland Group Basement.

m/s – metres per second.

Source: MWM, 2026c.

The following key observations are noted:

- All K values are within an order of magnitude, indicating limited variability across the site.
- General K is considered low to moderate, and consistent with regional estimates.
- Higher K estimates were made in monitoring wells screened in coal and shallow basement rock.
- Analysis of wells screened in the sandstone, conglomerate, and the BCM-basement contact indicated lower K for these units.

2.7 Groundwater Flow Regime

2.7.1 Groundwater Levels

Groundwater level monitoring has been undertaken in five monitoring wells since April 2024. Pressure transducers with automatic dataloggers were installed in three monitoring wells (DC28, DC33, DC41) to record groundwater levels at intervals of up to 1 hour, whilst a barometric logger was installed on-site to correct groundwater levels for the effects of barometric pressure. Data downloads were undertaken approximately every three months by BRL, which coincided with measurement of manual groundwater levels in all five monitoring wells. Manual measurements are undertaken to validate pressure transducer data.

Groundwater levels for the three monitoring wells with pressure transducer data compared to rainfall records are illustrated in Figure 10 below. The following observations from the graph are noted:

- Groundwater levels within DC33 can be observed to increase and decrease approximately 0.5 m corresponding to rainfall events. The fast response to rainfall is typical of fractured basement rock due to small storage and moderate transmissivity. DC33 is shallow (<5 m deep) and screened within the basement where it is exposed within the valley of Billo Stream. DC33 is approximately 10 m east of Billo Stream, and groundwater within the well is recorded at approximately 3.5 m below ground level (bgl) indicating a hydraulic gradient towards the channel of Billo Stream.
- Groundwater levels within DC28 and DC41 can be observed to reflect seasonal rainfall trends, with higher levels during wetter periods and lower levels during drier periods.
- Annual fluctuations in groundwater levels are within 1 m for all monitoring wells.

In general, groundwater levels are relatively shallow in the East Pit area of the MFS sub-area in the vicinity of the pits, within approximately 15 m bgl. Groundwater levels are significantly deeper south of the West Pit with measured groundwater levels at depths greater than 40 m bgl. Groundwater levels were between 40 and 50 m bgl in monitoring wells DC43, DC45, and DC46², however these wells were not included in the continuous groundwater level monitoring programme, partly due to access difficulties. The cause of these deeper groundwater levels is not fully understood but could be related to factors such as structural controls like faults or the presence of underground workings. Alternatively, the deeper levels could be reflective of the deeper regional water table while shallower groundwater levels (e.g., at DC41) could be representative of perched coal seam systems.

² Based on repeated post well installation manual measurements.

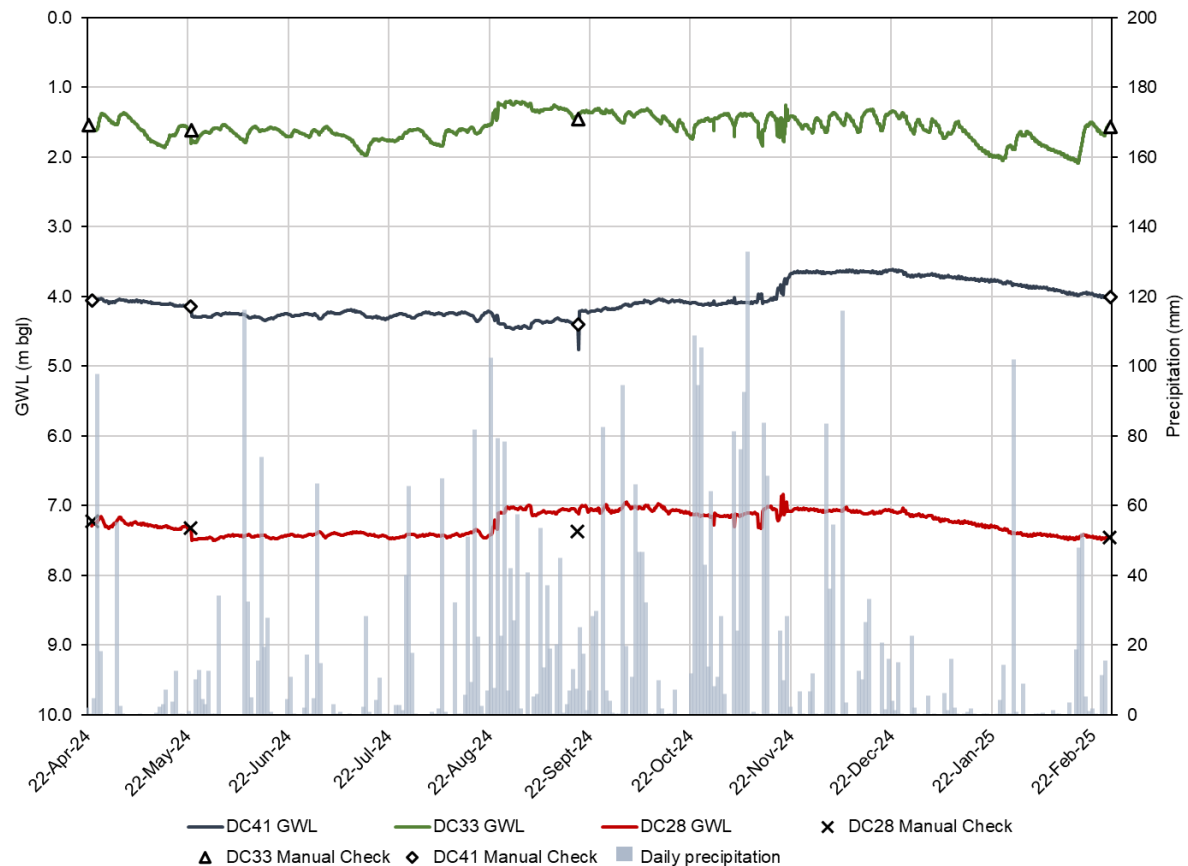


Figure 10: Groundwater levels and precipitation.

Note: Illustrated precipitation records were taken from Stockton office met station, located at a similar elevation although approx. 9 km to the north.

Groundwater level data provided by BRL.

2.7.2 Groundwater Recharge

As discussed in Section 2.3.4, groundwater recharge via infiltration and percolation of rainfall is considered to be minimal due to the low permeability of the BCM and thin overlying soils (where present). The majority of precipitation is understood to run off into the streams and drain from the catchment. As discussed in Section 2.7.1, groundwater level data reflect seasonal trends but with limited response to rainfall events.

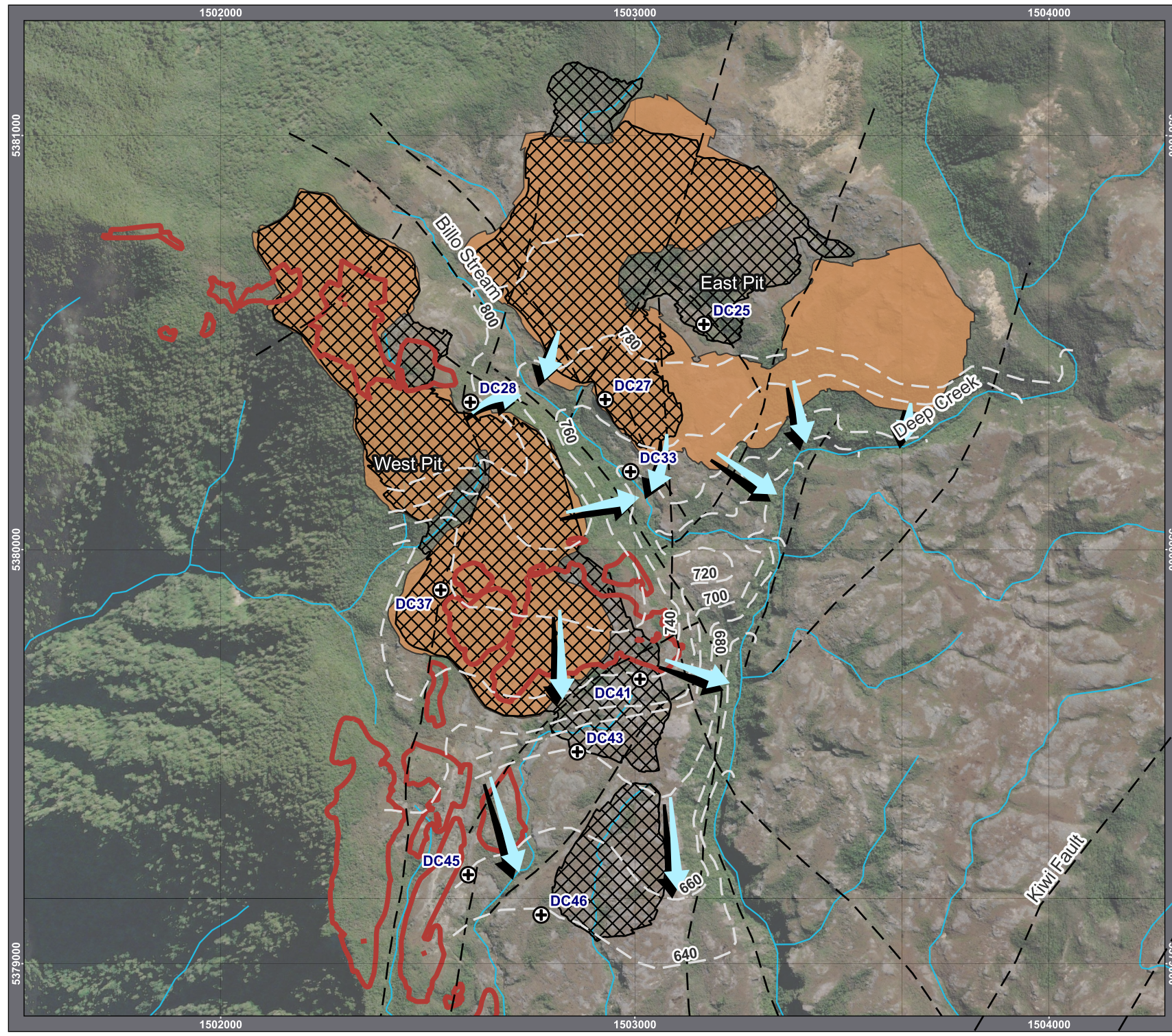
Recharge estimates are not available for the aquifers on-site. However, steady state aquifer recharge estimates for the Cypress Mine, part of the nearby Stockton Mine, are between 5 – 7% of mean annual rainfall (GHD, 2021). Recharge estimates on-site are expected to be similar due to the mine sites having a similar climate and stratigraphy.

2.7.3 Groundwater Flow

Groundwater flow directions have been inferred from measured groundwater levels and stream elevations, with guidance from topographic contours. These are presented in Figure 11. It is noted that limited groundwater data are available for the MFS sub-area, and therefore inferences on groundwater level are considered approximate, and are largely based on professional judgement in areas of the sub-area where no groundwater level data are available.

The following is noted regarding baseline groundwater flow conditions:

- Groundwater flow is broadly southwards with hydraulic gradients reflective of topographic relief.
- Within the valleys of Billo Stream and Deep Creek, localised groundwater flow converges towards the respective channels indicating groundwater discharge conditions.
- DC33 was installed approximately 10 m from Billo Stream and screens the water table within the weathered zone approximately 3 m bgl. Groundwater levels are elevated with respect to the base of the stream channel indicating a hydraulic gradient into the creek, supporting conceptualisation of groundwater discharge conditions.
- Deep Creek is significantly more incised and is therefore expected to receive groundwater contributions.
- Groundwater flow in the southern portion of the MFS sub-area flows in a general southerly direction, following the slope of the terrain.
- Underground workings are known to discharge into Deep Creek tributaries via a number of adits (Figure 11). The exact influence of workings on the groundwater flow regime is unknown, however, some workings will be near surface and above the water table, and some below the water table.



- LEGEND**
- Monitoring Wells
 - Faults
 - Groundwater Flow Direction (inferred)
 - Groundwater Level Contours (mRL)
 - Underground Workings
 - ELF
 - Pits
 - Waterways

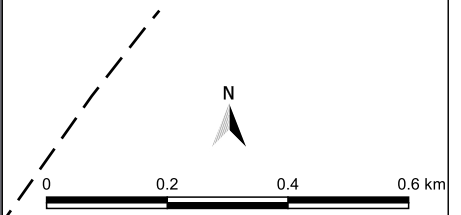
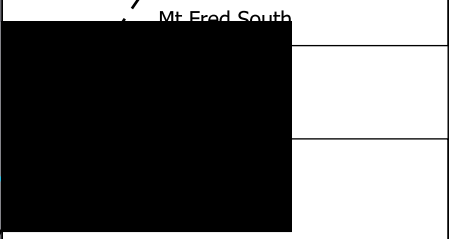


Figure 11: Groundwater Flow Regime



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2.8 Groundwater Quality

Groundwater sampling within the MFS sub-area has occurred roughly quarterly since December 2023, with four sampling events completed.

Average groundwater quality data are summarised in Table 4, with laboratory certificates provided in Appendix B. A metal ecotoxicity quotient (MEQ) is used in this report to identify constituents that may be elevated with respect to water quality guidelines, or trigger values (Weber and Olds, 2016). For this report, the following water quality reference values (WQ Ref Values) were used:

- The historic consent conditions from Escarpment Mine (RC010193) (Table 5).
- 95% ANZG (2018) Default Guideline Values.
- Where appropriate, other guideline values were applied:
 - ANZECC Livestock Drinking Water Guidelines (2000) for sulfate: 1,000 mg/L.
 - Guidelines from the NPS³ for Freshwater Management (MFE, 2020) for nitrate-N at 2.4 mg/L.
- No hardness modifications⁴ were applied as this was conducted as a screening assessment to determine the potential for exceedances.

The following observations are noted:

- pH is typically slightly acidic, typically below a pH of 5.5, except for DC25, which has a higher average pH. DC25 pH has been slowly decreasing over time, suggesting it may still be recovering following installation (pH of 6.89 in February 2025). As such, data from this well may not be representative of formation water.
- Conductivity ranged between 3 and 24 mS/m.
- Dissolved oxygen concentrations suggest oxic conditions prevail.
- Constituents close to or above the MEQ were copper, iron, manganese, and zinc.

³ NPS = National Policy Statement

⁴ Hardness correction algorithms used to convert chronic toxicity data for Cd, Cr, Pb, Ni, and Zn at a given test water hardness to a hardness of 30 mg CaCO₃/L (ANZG, 2018).

Table 4: Average groundwater quality data.

CONSTITUENT	UNITS	DC25	DC27	DC28	DC33	DC41	MAX MEQ
Field pH	pH units	7.95	5.15	4.93	5.38	4.63	-
Field Temp	°C	12.1	12.2	13.1	11.8	13.2	-
Field DO	mg/L	3.35	1.89	4.51	3.56	3.82	-
Acidity	mg CaCO ₃ /L	8.25	52.8	81.0	73.0	27.3	-
Total Alkalinity	mg CaCO ₃ /L	78.5	3.50	7.50	20.3	3.00	-
Conductivity	mS/m	24.0	3.00	8.65	15.1	3.35	-
Total Hardness	mg CaCO ₃ /L	65.0	3.00	27.0	22.0	2.00	-
Total Dissolved Solids	mg/L	134.0	20.0	46.3	80.8	18.8	-
Turbidity	NTU	9.43	3.16	40.9	46.5	8.28	-
Total Suspended Solids	mg/L	<6.0	<6.0	78.0	151.0	16.8	-
Ammonia (NH ₃ -N)	mg/L	0.080	<0.01	0.020	0.010	0.095	0.40
Nitrate (NO ₃ -N)	mg/L	<0.01	0.015	0.017	<0.01	0.103	0.04
Nitrite (NO ₂ -N)	mg/L	<0.01	<0.01	0.010	<0.01	<0.01	-
Total Nitrogen	mg/L	0.218	0.046	0.556	0.077	0.081	-
D(NP)OC	mg/L	4.95	8.25	0.400	2.45	0.350	-
Aluminium (Al)*	mg/L	0.108	0.016	0.181	0.074	0.041	0.36
Arsenic (As)*	mg/L	0.0048	0.002	<0.001	<0.001	<0.001	0.37
Boron (B)*	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	0.00
Cadmium (Cd)*	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.00
Calcium (Ca)*	mg/L	23.2	0.458	4.63	2.44	0.300	-
Chromium (Cr)*	mg/L	0.006	<0.001	<0.001	<0.001	<0.001	0.03
Chloride (Cl)	mg/L	5.88	4.21	5.09	5.61	4.83	-
Cobalt (Co)*	mg/L	0.0008	<0.0005	0.012	0.007	<0.0005	0.07
Copper (Cu)*	mg/L	0.001	0.001	0.009	0.006	0.0007	6.96
Iron (Fe)*	mg/L	0.037	0.993	0.061	0.031	0.024	0.90
Lead (Pb)*	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.00
Magnesium (Mg)*	mg/L	0.525	0.308	1.06	0.783	0.335	0.97
Manganese (Mn)*	mg/L	0.039	0.011	0.096	0.099	0.003	-
Mercury (Hg)*	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.00
Nickel (Ni)*	mg/L	0.0006	0.0007	0.03	0.01	0.0005	0.49
Potassium (K)*	mg/L	5.15	0.503	0.908	0.613	1.14	-

CONSTITUENT	UNITS	DC25	DC27	DC28	DC33	DC41	MAX MEQ
Silica (SiO ₂)*	mg/L	11.4	3.05	6.68	5.35	4.74	-
Sodium (Na)*	mg/L	19.9	2.32	5.80	27.2	2.51	-
Sulfate (SO ₄)	mg/L	26.9	0.813	16.0	35.5	1.40	0.04
Thallium (Tl)*	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.00
Zinc (Zn)*	mg/L	0.005	0.014	0.119	0.016	0.009	2.21

Italics: Average calculated value reported as less than the Laboratory Limit of Reporting.

Metals and metalloids are presented as dissolved.

- indicates no measurement available or not applicable.

** indicates parameter is reported as dissolved fraction.*

D(NP)OC = Dissolved (non-purgeable) Organic Carbon.

DO is dissolved oxygen.

Average data from four sampling events for each well.

Table 5: Receiving waters median concentration compliance limits from RC010193.

PARAMETER	ESCPARMENT CONSENT CONDITIONS	
pH (pH units)	4.5 – 6.5	
MEDIAN CONCENTRATIONS		
Total suspended solids (mg/L)	15	
Turbidity (NTU)	15	
Iron + manganese (mg/L)	1.1	
Aluminium (mg/L)	0.5	
Median pH	pH > 5.5	pH < 5.5
Cadmium (mg/L)	0.0003	0.0012
Chromium (mg/L)	0.05	0.20
Cobalt (mg/L)	0.044	0.18
Copper (mg/L)	0.002	0.0013
Lead (mg/L)	0.0065	0.026
Nickel (mg/L)	0.017	0.068
Zinc (mg/L)	0.012	0.054

Associated with the consent obtained for the Escarpment Mine. Limits for cadmium, copper, chromium, lead, nickel, and zinc are based on a median water hardness of 50 mg CaCO₃/L.

2.9 Groundwater Users

Review of publicly available West Coast Regional Council data⁵ shows all known non-BRL groundwater bores and permitted groundwater takes are located on the coastal flats, over 4 km from the MFS sub-area (Figure 12). Two permitted groundwater takes associated with the permit number AUTH-RC02239-7 are owned by Buller Coal Limited (a subsidiary of BRL).

⁵ Data source (accessed 15 July 2025):

<https://gis.westcoast.govt.nz/WestMapView/?map=f00edc0d875f4508b76c89e321c64f1a>

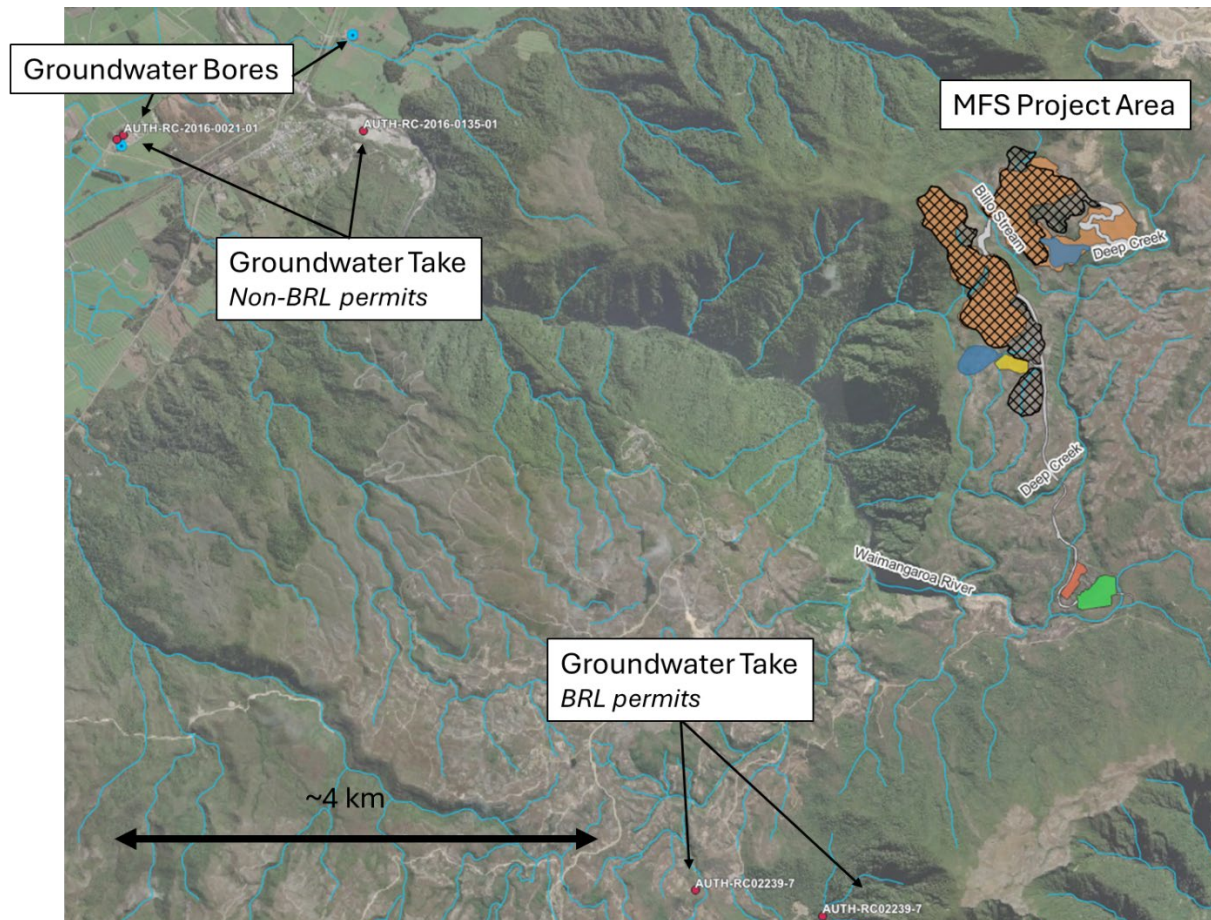


Figure 12: Nearby groundwater bores and permitted takes.

Permit and bore data source: West Coast Regional Council⁶.

2.10 Hydrogeological Conceptual Model Summary

The HCM provided in this section summarises information provided in Sections 2.2 to 2.7 relating to baseline conditions at the MFS sub-area. The baseline groundwater flow regime is represented by cross sections indicated in Figure 13 to Figure 15.

The MFS sub-area is characterised by low to moderately sloping terrain towards the south with a number of deeply incised drainage channels. Deep Creek is the major drainage feature within the catchment and drains into the Waimangaroa River beyond the southern extent of the MFS sub-area.

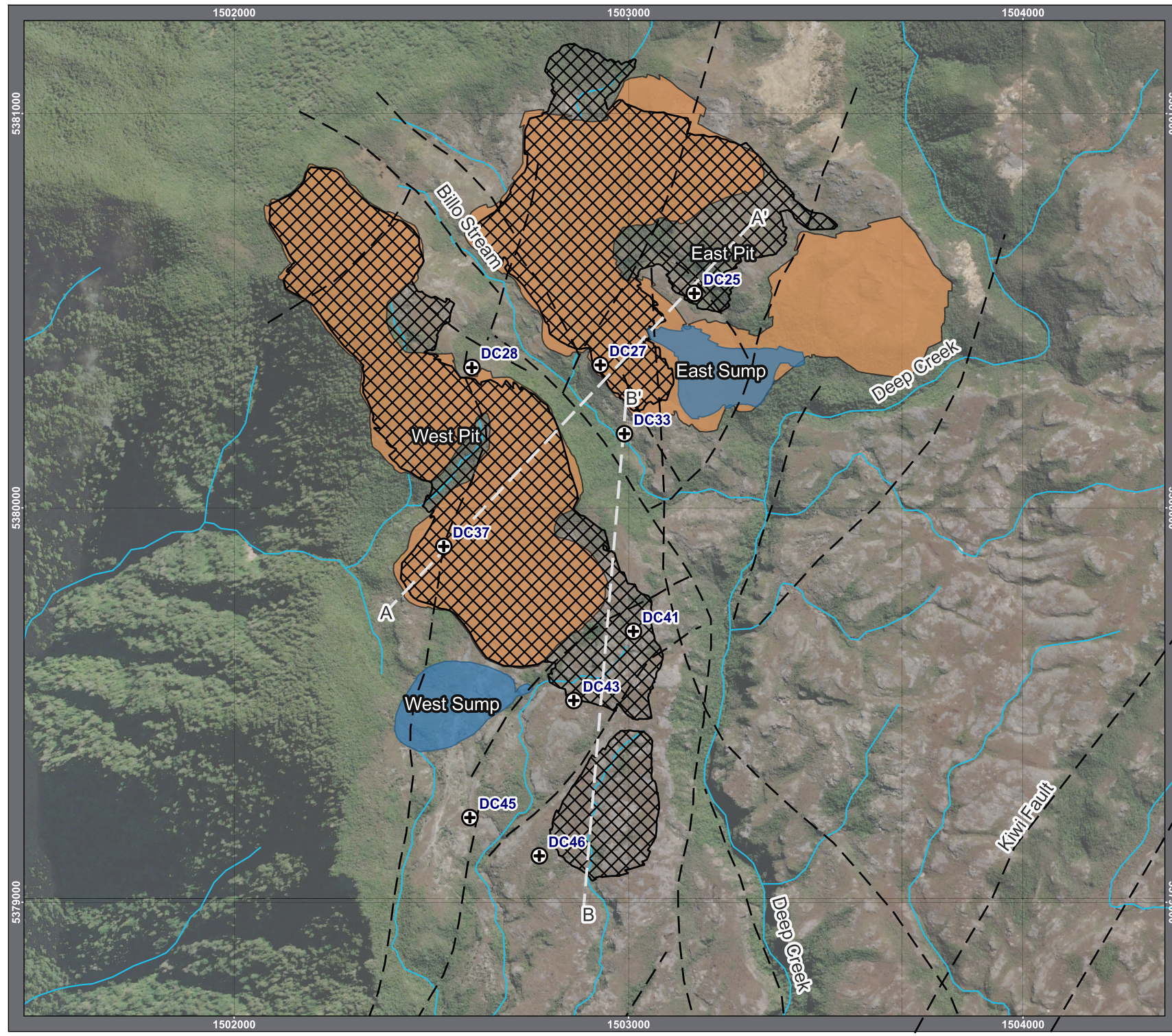
The two main geological formations on-site (BCM and Basement Rock) are considered to form two separate HSUs. Secondary permeability is the primary control on permeability in both units via connected fracture networks where underground workings are not present. Where these workings are present and roof collapse has occurred, permeability is likely enhanced. Within the MFS sub-area, hydraulic testing suggests that coal seams and near surface, weathered, basement have K elevated above other units (e.g., sandstone, deeper basement), although the sample size is small making definitive conclusions difficult. Overall, based on site specific testing and regional estimates, representative bulk K for each HSU are interpreted to range between:

- BCM 10^{-7} m/s to 10^{-6} m/s. Where mine roof collapse has occurred, K could be even higher.
- Basement 10^{-8} m/s to 10^{-7} m/s.

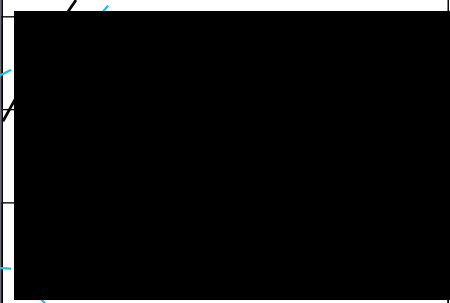
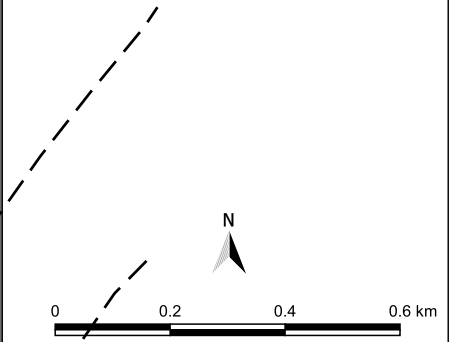
In the northern MFS area, the phreatic surface is shallow (e.g., at DC27 and DC28 < 10 m bgl), but deepens significantly south of DC41 (e.g., >30 m bgl at DC43). The cause of the sudden drop south of DC41 is not certain, but coincides with thicker BCM units (i.e., deeper basement contact). Potential causes could be related to faulting impeding flow between DC41 and DC43, or DC41 representative of a perched groundwater system that represents a shallow coal seam unit(s).

Groundwater flow is broadly south with localised flow in the upper catchment towards the channels of Billo Stream and Deep Creek. Groundwater within the upper reaches is conceptualised to discharge to surface water features. Downstream the connection to surface water is less clear. The deeper groundwater level data at DC43, DC45, and DC46 suggests a local disconnection between surface and groundwater. Overall, the groundwater system will discharge to Deep Creek or the Waimangaroa River given their deep incision into the land surface.

Groundwater quality data indicates pH is typically below 5.5, the groundwater system is oxic, and certain metals are elevated with respect to adopted WQ Ref Values, including copper, iron, manganese, and zinc.



- LEGEND**
- Cross Sections
 - ⊕ Monitoring Wells (Groundwater Level Indicated)
 - Sumps
 - ▨ ELF
 - Pits
 - Waterways



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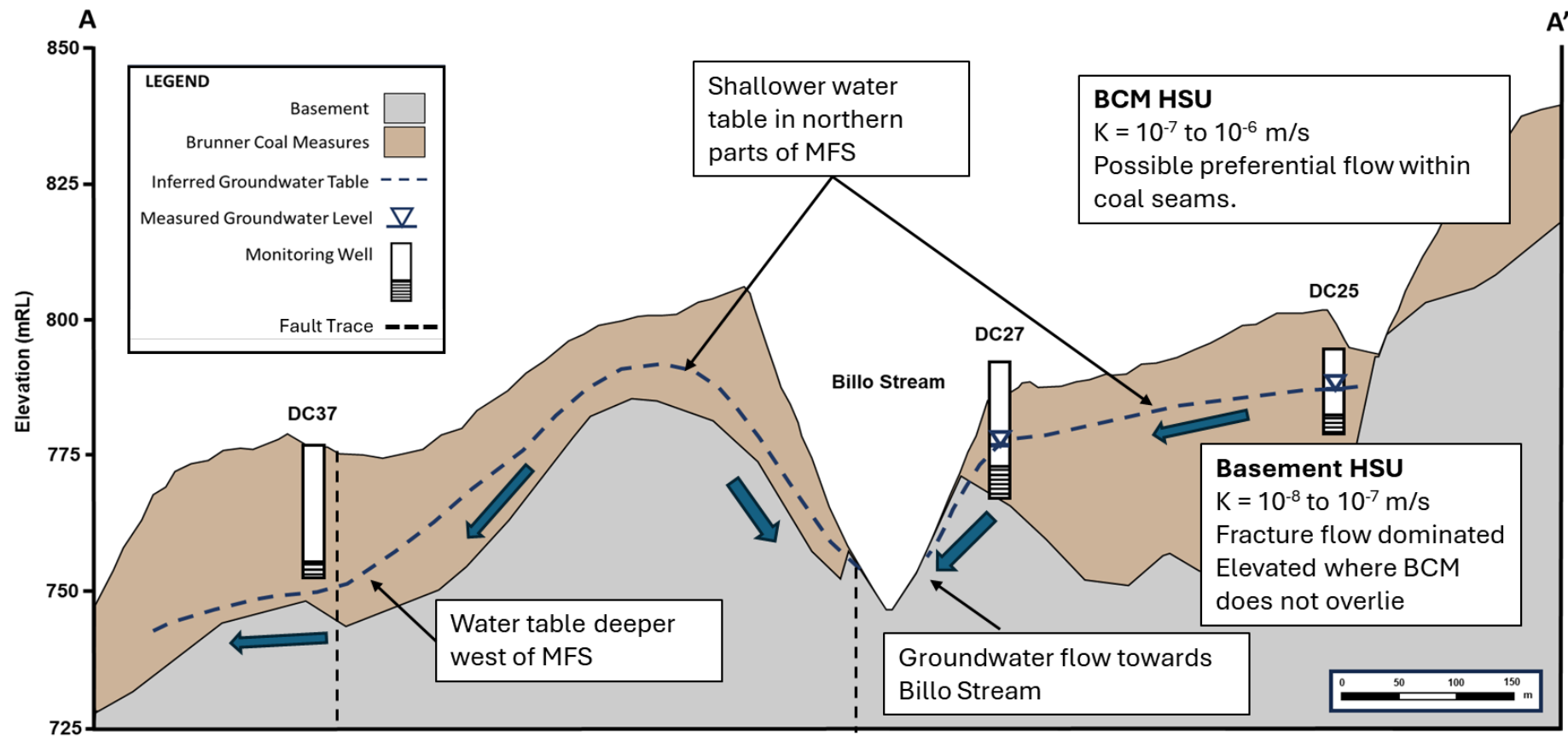


Figure 14: Cross Section A-A' indicating baseline groundwater flow regime.

Note 5x vertical exaggeration.

Geological units based on surface provided by BRL from their MFS Geological Model.

See Figure 13 for section location.

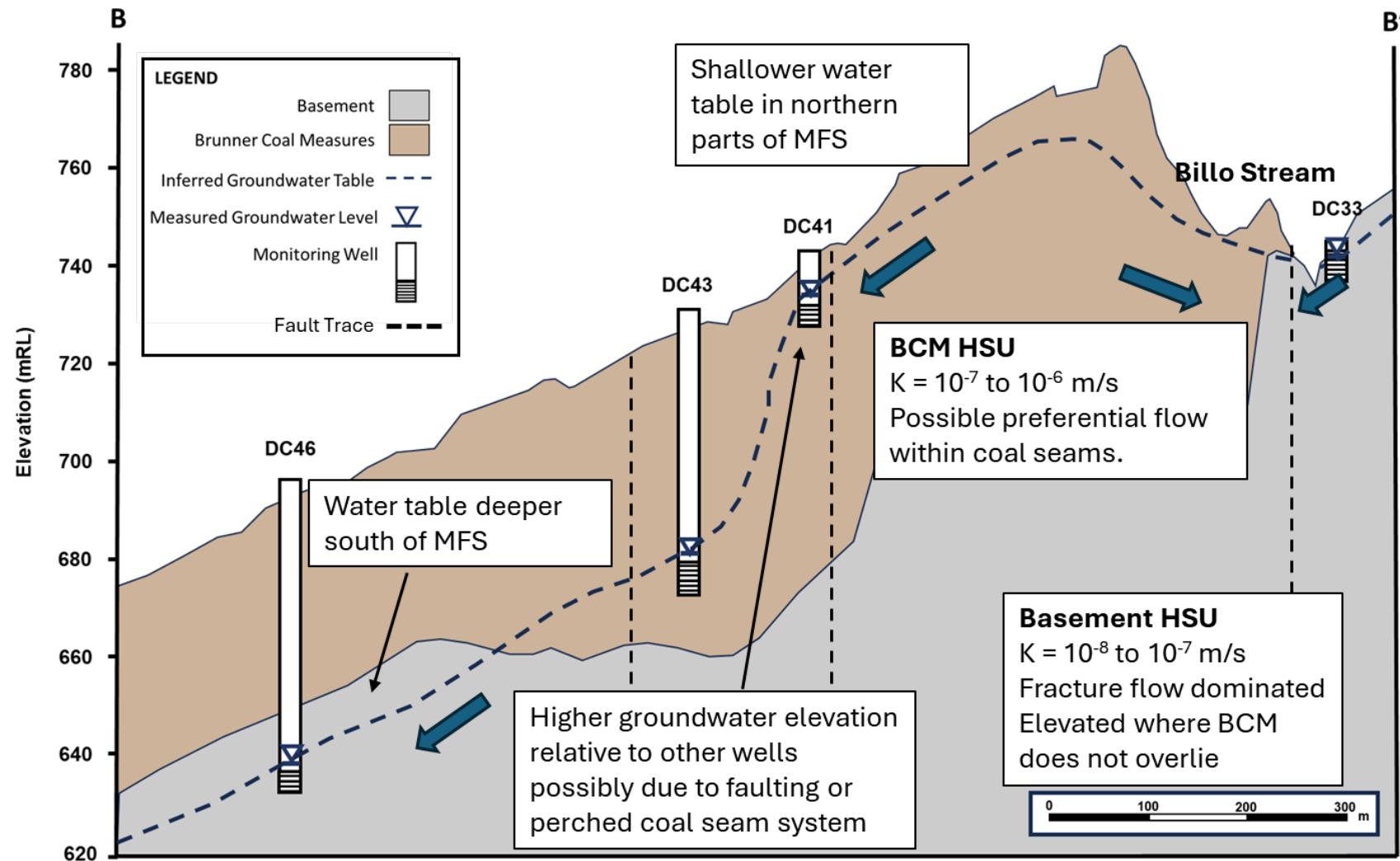


Figure 15: Cross Section B-B' indicating baseline groundwater flow regime.

Note 5x vertical exaggeration. Geological units based on surface provided by BRL from their MFS Geological Model. See Figure 13 for section location.

3 GROUNDWATER EFFECTS ASSESSMENT

The effects assessment presented in this section focusses on groundwater-related effects that could occur during the operational and post-closure phases of the MFS sub-area. These effects are presented in terms of groundwater quantity and groundwater quality.

A HCM for post-closure conditions is shown in Figure 16 and Figure 17. Note that the MFS sub-area will involve backfilling of pit voids as the pit expands laterally along with progressive rehabilitation. As such, hydrogeological potential effects will be transient, but are expected to be greatest and similar for operations and closure/post-closure conditions.

MFS has the potential to interact with groundwater in the following ways:

- Groundwater Quantity: open pit mining below the water table may alter the groundwater flow regime.
- Groundwater Quality: development of ELFs and associated AMD seepage may alter groundwater quality. Pit floor runoff may also alter groundwater quality.

Known groundwater users are over 4 km away, located on the coastal flats (see Section 2.8) and are unlikely to be impacted by the mining activities undertaken at the MFS sub-area. Any potential effect would be negligible. As such, they are not considered further in this assessment.

Potential effects are described further below based on the HCM and supporting calculations.

3.1 Groundwater Quantity

During operations, passive dewatering (i.e., with in-pit sumps) will be required within the MFS pits given the lower bulk K of the rock mass. This practice is consistent with experience at Stockton where the high rainfall environment means pit dewatering is dominated by rainfall/runoff inflow rather than groundwater inflows.

3.1.1 Groundwater Levels

MFS pit voids will intercept the water table, and along with passive dewatering, alter the groundwater flow regime by lowering the phreatic surface as the pit void acts as a groundwater sink. The degree of change will vary across the site:

- On the eastern side of MFS sub-area, the pits are typically deeper resulting in localised lowering of the water table by approximately 30 m (see Figure 16).
- On the western side, the pit voids are shallower and in areas the water table is deeper meaning the pit voids will intercept the groundwater system to a lesser degree (i.e., drawdown of 5 m or less).

Review of ELF mine rock properties by MWM (2026a), found K to range between 10^{-6} and 10^{-5} m/s, implying the ELFs are likely to be free draining for the most part, enhanced by basal drainage systems (BPCP AEE). As a result, development of in-pit ELFs is not interpreted to substantially change the groundwater levels near an open pit void once it is backfilled (i.e., they will remain depressed post-closure).

Given the relatively low K rock and high rainfall environment, the cone of depression is expected to remain relatively close to the pit voids.

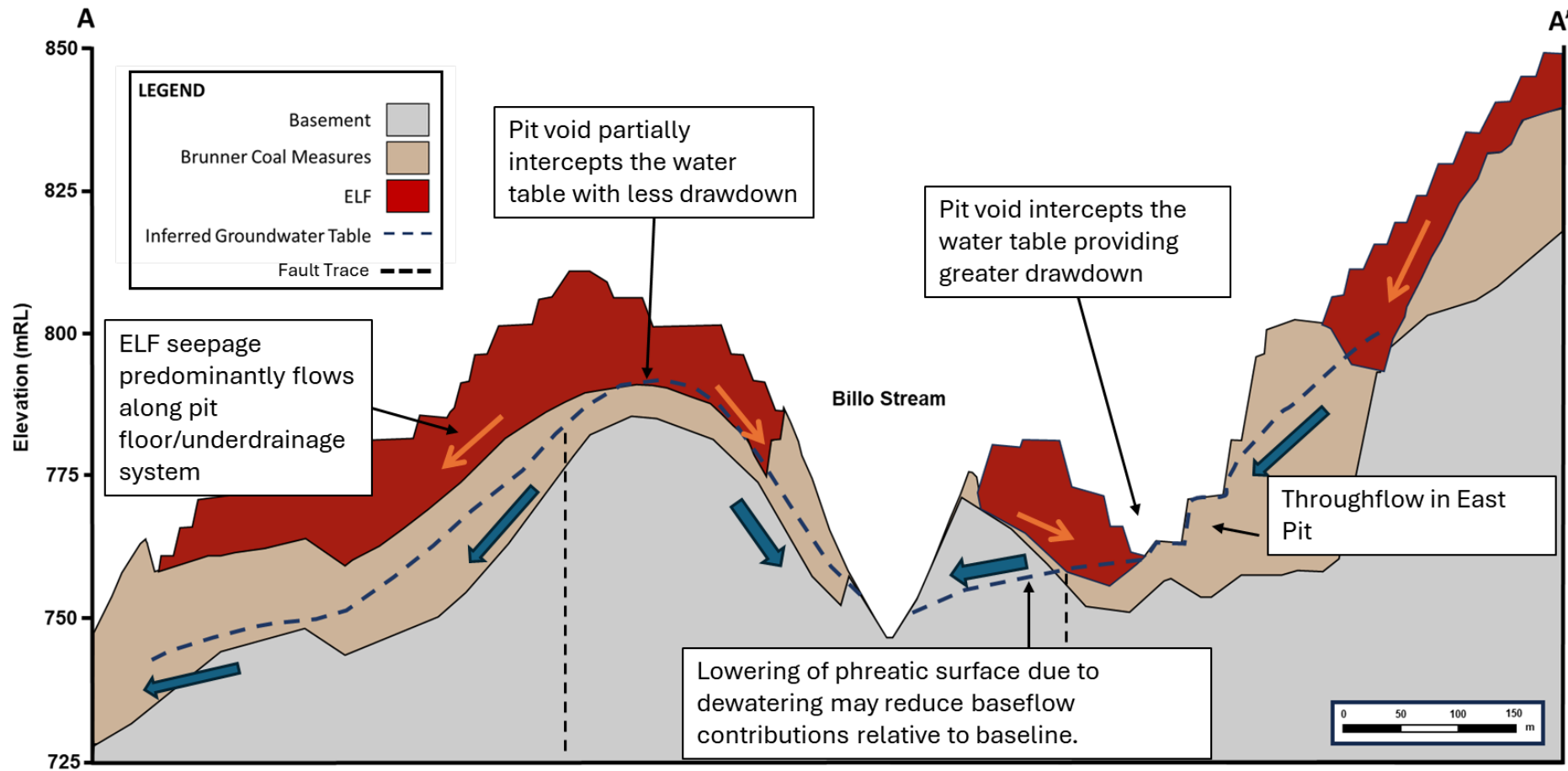


Figure 16: Cross Section A-A' indicating post-closure groundwater flow regime.

Note 5x vertical exaggeration.

Geological units based on surface provided by BRL from their MFS Geological Model. See Figure 13 for section location.

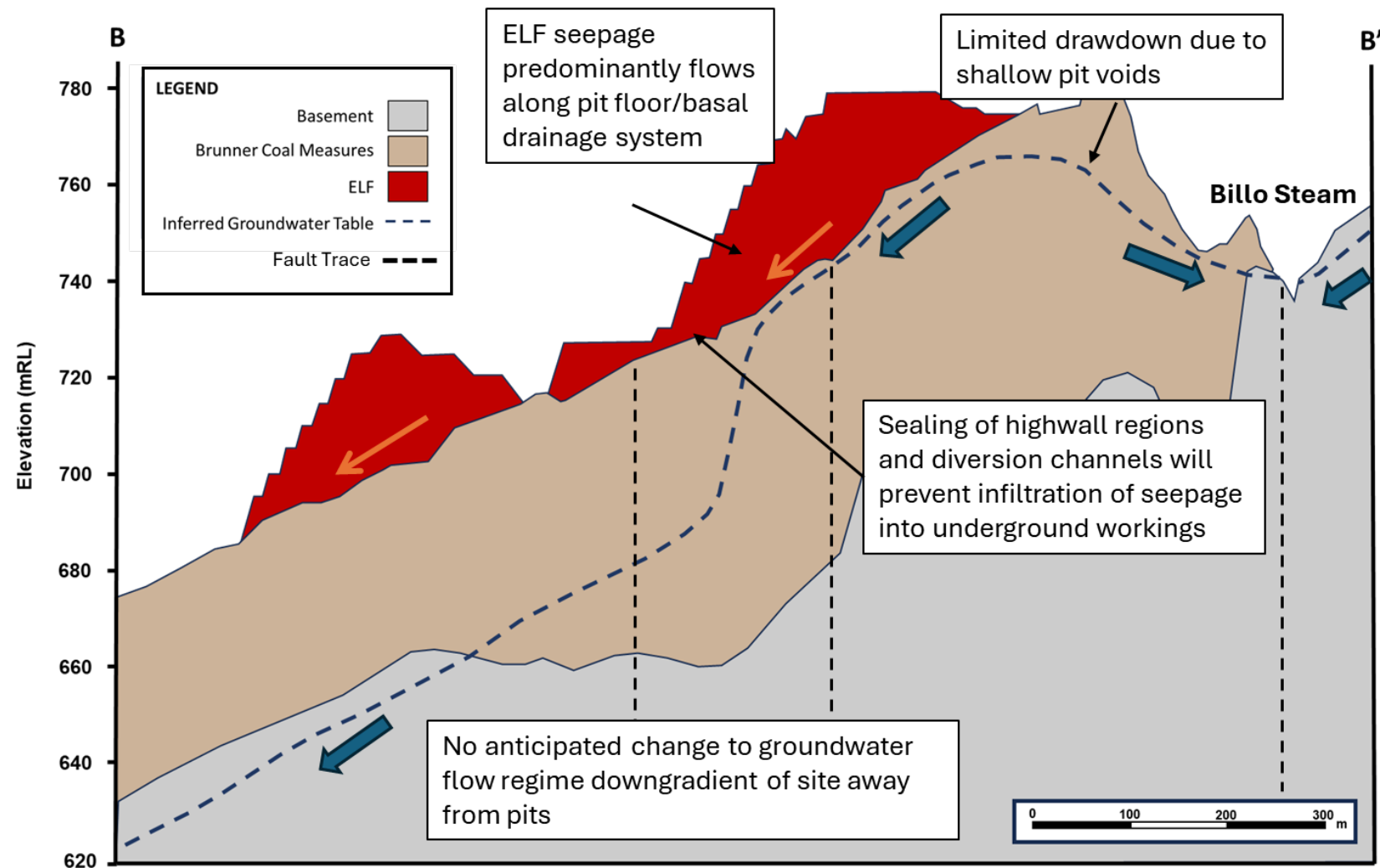


Figure 17: Cross Section B-B' indicating post-closure groundwater flow regime.

Note 5x vertical exaggeration. Geological units based on surface provided by BRL from their MFS Geological Model. See Figure 13 for section location.

3.1.2 Groundwater Flows

Changes to the amount of groundwater discharging to creeks in the MFS sub-area are likely to be low given the following:

- Pit voids bottoms are typically positioned above adjacent stream levels, meaning discharge gradients may be lowered, but not reversed.
- Lower K HSUs will act to limit hydraulic connection between pit voids and streams.
- Underground workings intercepted by the pit voids will be sealed off with lower K material (BPCL AEE).
- Discharge of (passively) treated mine-impacted water to streams during operations would act to increase stream flow rates during lower flow conditions as ELF's will have steadier flows than the baseline undisturbed catchment.

Reduction in groundwater discharge to streams is assessed in the MFS Water and Load Balance Model (WLBm) (MWM, 2026d) based on a reduction in undisturbed areas contributing baseflow to a given stream at proposed compliance locations. Other inputs to streams, such as treated water, are also included in this modelling.

For Deep Creek, WLBm results (MWM, 2026d) suggest:

- At SW01 (see Figure 1 for location), a slight decrease in the 7-day mean annual low flow (7D MALF) statistic of ~2% during the Operations and Active Closure Phase, transitioning to a >500% increase in the Post-closure Phase.
- At SW03, increases in 7D MALF of ~30% and ~900% for the Operations and Active Closure Phase, and the Post-closure Phase, respectively.

Overall, the WLBm results suggest a potential slight decrease in groundwater discharge to surface water compliance sites during the Operations and Active Closure Phase. Then in the Post-closure Phase, discharge of MSRs greatly offsets any reduction in groundwater discharge at proposed compliance locations.

Billo Stream will have a relatively significant proportion of the contributing catchment disturbed and water routed away from pre-mining channels. MWM (2026b) estimated the proportion of Billo Stream catchment that would no longer report to the existing stream channel (part of the channel will also be mined out), with calculations suggesting 40-50% of the pre-mining Billo Stream flow could be routed to Deep Creek and the Waimangaroa River. The proportion of groundwater discharge to this creek would potentially reduce by a similar amount.

3.2 Groundwater Quality

3.2.1 ELF Seepage

ELF seepage poses the largest potential risk to groundwater quality. The position of ELF's is typically up hydraulic gradient of streams, providing a potential pathway if ELF seepage were to infiltrate to the groundwater system. Seepage flow paths from ELF's are shown in Figure 18, and are interpreted as follows:

- At the base of in-pit ELF, the lower K in situ rock mass will likely promote seepage to preferentially flow along the coal floor/pit floor surface. In addition, sub-ELF basal drains and perimeter drains will be cut into bedrock to control seepage flow paths.
- Ex-pit ELF seepage flow paths will either follow pre-mining topography or perimeter drains. In both cases, ex-pit ELF seepage will be predominantly directed either back into the backfilled pit void, or to collection and treatment locations.
- At the Coal Transfer Pad, the data available suggest a thin soil/unconsolidated deposit profile (~ 3-4 m) underlain by Kaiata mudstone bedrock. These conditions coupled with basal and perimeter drainage systems would promote effective collection of any sub-surface seepage.

Underground workings intercepted will be sealed (BPCP AEE) to minimise the potential for transport via these conduits.

In summary, ELF seepage will be collected and conveyed for treatment before being discharged to the receiving surface water environment. Performance monitoring (discussed further in section 5.2) will be required to confirm ELF seepage is not being transported via groundwater pathways to surface water receptors (e.g., streams).

3.2.2 Pit Floors

Runoff from pit floors that remain post-closure is also a potential risk to groundwater quality should a portion infiltrate to the groundwater system. The lower K pit floor would behave hydrologically in a similar manner to exposed bedrock surfaces, where the majority of rainfall is translated to surface runoff. Infiltration would therefore be a lower proportion of rainfall, potentially in the order of 5% of annual average rainfall based on regional recharge estimates (see Section 2.7.2). Performance monitoring is required to confirm pit floor runoff does not impact groundwater quality.

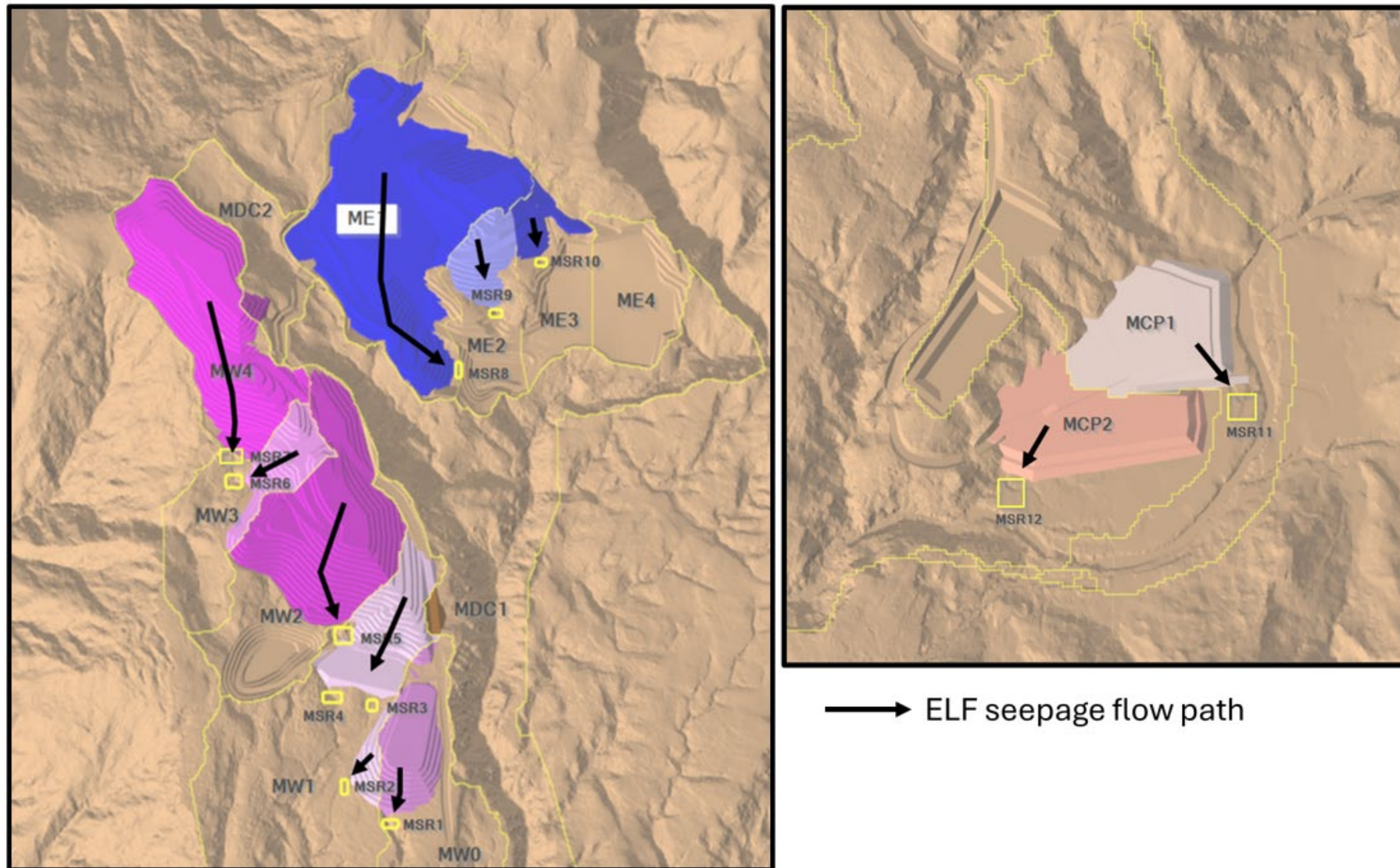


Figure 18: Sub-ELF seepage flow paths and indicative MSR locations.

4 **CONCLUSIONS**

Findings from the assessment are summarised below:

4.1 **Groundwater Quantity**

4.1.1 *Groundwater Levels*

- Pit excavation and dewatering will intercept the water table, with the degree of drawdown differing between the East Pit and West Pit. During operations and post-closure, the passive drainage of backfilled pit voids will mean this condition likely remains.
- On the eastern side of MFS, the East Pit void is typically deeper and the water table shallower, resulting in localised lowering of the water table by approximately 30 m.
- On the western side of MFS, the West Pit void is shallower, and in areas the water table is deeper, meaning that while the pit voids will intercept the groundwater system, drawdown will be to a lesser degree.

4.1.2 *Groundwater Flows*

- A number of factors indicate changes to the amount of groundwater discharging to streams are likely to be low, including (i) pit voids positioned above adjacent stream levels, (ii) lower K rock with a localised cone of depression, and (iii) sealing of intercepted underground workings as required to prevent uncontrolled discharge.
- The MFS WLBM (MWM, 2026d) accounts for reduction in groundwater discharge to streams by reductions in natural catchment areas reporting to streams. Other inputs to streams, such as treated water, are also included. Overall, the modelling results suggest an increase in lower flow conditions in the long term (i.e., post-closure) compared to baseline. The discharge of MSRs greatly offsets any reduction in groundwater discharge.

4.2 **Groundwater Quality**

ELF seepage poses the largest potential risk to groundwater quality:

- The lower K in situ rock (e.g., BCM) compared to the backfill material, coupled with basal and perimeter drainage systems, will promote ELF seepage to collection locations and subsequent treatment. Performance monitoring will be required to confirm ELF seepage is not being transported via groundwater pathways to surface water receptors (e.g., streams).
- At the Coal Transfer Pad, the data available suggest a thin soil/unconsolidated deposit profile (~ 3-4 m) underlain by mudstone bedrock. These conditions coupled with basal and perimeter drainage systems would promote effective collection of any sub-surface seepage.

Runoff from pit floors that remain post-closure is also a risk to groundwater quality should a portion infiltrate to the groundwater system. The lower K pit floor would behave hydrologically in a similar manner to exposed bedrock surfaces, where the majority of rainfall is translated to surface runoff. Infiltration would therefore be a lower proportion of rainfall, potentially in the order of 5% of annual average rainfall based on regional recharge estimates. Performance monitoring is required to confirm pit floor runoff does not impact groundwater quality.

Known groundwater users are over 4 km away, located on the coastal flats and unlikely to be impacted by any groundwater associated effect caused by the MFS sub-area.

5 RECOMMENDATIONS

5.1 Forward Works

Although the data currently available suggests favourable conditions for subsurface seepage collection at the Coal Transfer Pad, further investigations, including the installation of monitoring wells are recommended to be completed during the Construction Phase to confirm assumptions.

5.2 Performance Monitoring

The existing groundwater monitoring network will be impacted by the MFS sub-area (see Figure 1), with all except three wells (DC33, DC45, and DC46) likely to be decommissioned. As such, additional groundwater monitoring wells should be installed in key locations to confirm ELF seepage is not migrating via groundwater pathways. Areas for long term performance monitoring to target are shown in Figure 19. These are positioned between potential sources (e.g., ELFs) and receptors (e.g., streams), and in close proximity to sources to provide the earliest possible warning of potential seepage impacting groundwater. Timing of new well installation should occur as far ahead of mining disturbance as is practicable. Hydrogeological testing of wells (e.g., slug tests) would be beneficial to improve the site-specific K dataset.

Efficient collection of in-pit ELF seepage is predicated on maintaining a lower phreatic surface within the backfilled material than that external to the pit. Although the higher K backfill material (compared to in situ rock) and use of underdrains will act to lower the phreatic surface within the in-pit ELFs, high rainfall conditions could theoretically counteract this leading to higher in-pit phreatic surface than anticipated. Therefore, to compliment groundwater monitoring external to the pit, the phreatic surface within the ELF should be monitored to confirm the basal drainage network is performing adequately and the pit remains a hydraulic sink, thereby minimising the potential for ELF seepage to reach surface water receptors. This can be achieved by installing nested vibrating wire piezometers into the ELFs following rehabilitation. Final locations should be evaluated as mine and closure plans evolve. In addition, periodic seepage surveys should be completed following rehabilitation to identify any unexpected seepage emerging through the rehabilitation surface. Collection of recommended data will support management processes.

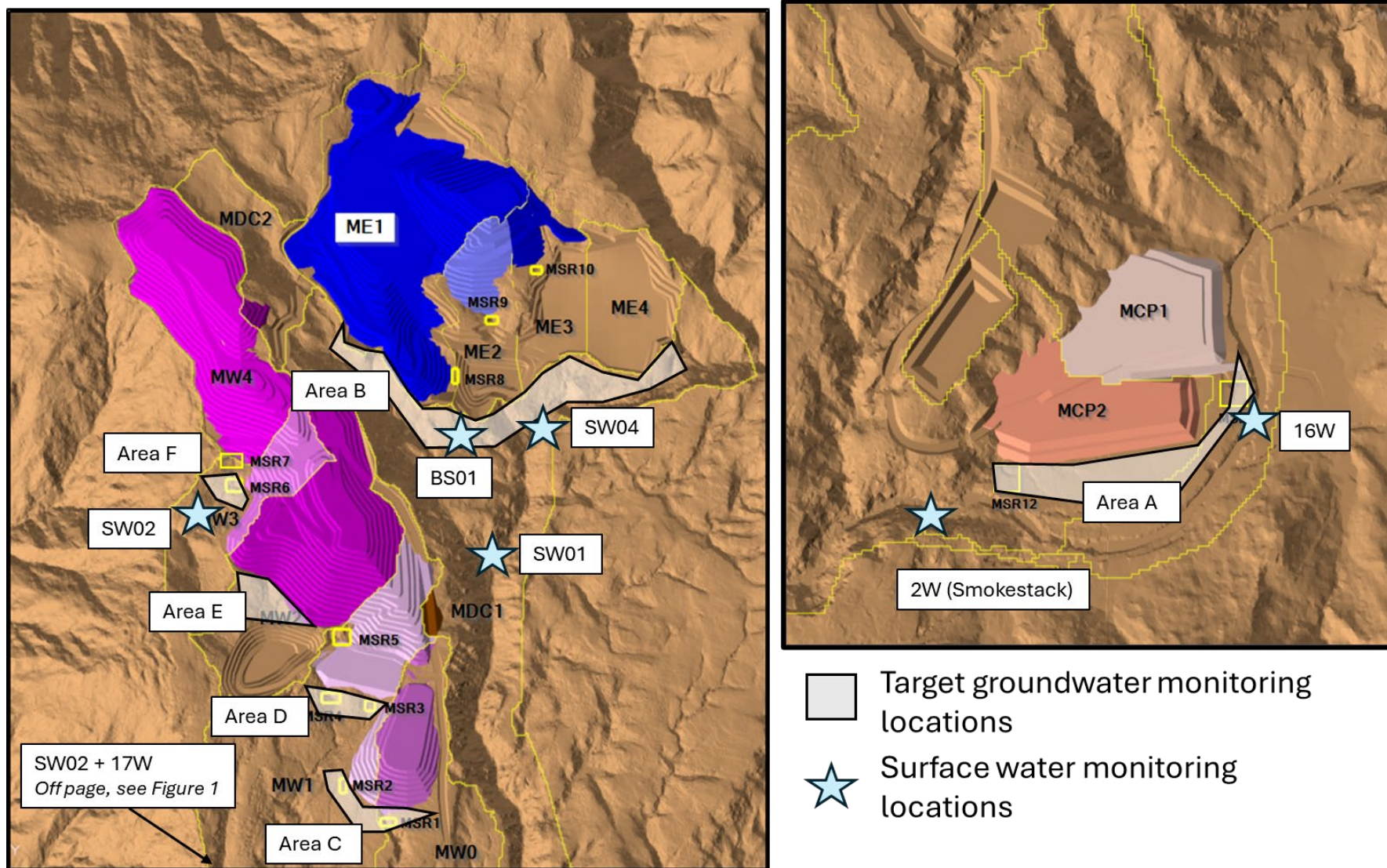


Figure 19: Target groundwater monitoring locations.

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7 LIMITATIONS

Attention is drawn to the document “Limitations”, which is included in Appendix D of this report. The statements presented in this document are intended to provide advice on what the realistic expectations of this report should be, and to present recommendations on how to minimise the risks associated with this project. The document is not intended to reduce the level of responsibility accepted by Mine Waste Management Limited, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in doing so.

APPENDIX A SLUG TESTING ANALYSIS

MEMO

From: [REDACTED]
Date: 21 July 2026
Cc: [REDACTED]
Document Number: J-NZ0377-007-M-FINAL
Document Title: Mount Fredrick South Slug Testing and Analysis

Mine Waste Management Limited (MWM) was retained by Bathurst Resources Limited (BRL) to characterise Mount Fredrick South (MFS) baseline groundwater conditions. Characterisation works included a field program involving slug testing of developed monitoring wells at MFS to provide site specific estimates of hydraulic conductivity.

This factual memorandum documents the slug testing fieldwork completed, methodology, and analysis results and interpretation.

BACKGROUND AND SCOPE

BRL are advancing baseline studies to support environmental approvals for their Mount Fredrick South Extension project. A resource drilling program was recently completed, including the installation of nine monitoring wells (MW). The MWs were constructed with 50 mm diameter PVC casing with 0.5 mm slotted screens, targeting the Brunner Coal Measure (BCM) sequence and the basement rock hydrostratigraphic units (HSU).

The MWs facilitate the following:

- Monitoring of long-term groundwater levels
- Groundwater quality sampling
- Estimation of hydraulic conductivity of the screened lithologies

The estimation of hydraulic conductivity (K) was facilitated through slug testing, a method that involves displacing the water column within the MWs and observing the rate of recovery to its static water level. These tests were carried out in MWs that had undergone well development to minimise drilling induced well skins that could potentially affect estimates of K. Details of these wells can be found in Table 1. Additionally, three groundwater pressure transducers and one barometric pressure transducer were deployed within select MWs for the purpose of long-term groundwater level monitoring. These select wells are also indicated within Table 1.

Table 1: Summary of MWs used for hydraulic testing.

MW	COLLAR COORDINATES ¹		GROUND ELEVATION (m RL) ²	DEPTH (m bgl)	TOP OF SCREEN (m bgl)	BOTTOM OF SCREEN (m bgl)	WATER LEVEL (m btoc)	SCREENED LITHOLOGY
	X	Y						
DC25	1503167.0	5380544.1	793.83	16.6	11.6	14.6	17.24	BCM: Sandstone
DC27	1502928.7	5380362.6	791.57	24.5	18.5	24.5	15.44	Contact: BCM/BSM
DC28 ³	1502603.0	5380356.0	813.11	9	6	9	8.10	BCM: Pebble conglomerate
DC33 ³	1502990.0	5380188.3	742.53	4.3	1.3	4.3	2.49	BSM (Greenland Group)
DC41 ³	1503012.6	5379687.2	740.66	12.2	9.2	12.2	4.45	BCM: Main Coal Seam

Notes: ¹Coordinates presented in New Zealand Transverse Mercator Projection (NZTM) 2000.

²Elevations presented in New Zealand Vertical Datum (NZVD) 2016.

³Pressure transducer deployed in well to monitor long-term groundwater levels.

MW – Monitoring Well

M RL – meters above reference level.

m bgl – metres below ground level.

BCM - Brunner Coal Measures.

BSM – Basement.

FIELD WORK METHODOLOGY

The slug testing fieldwork was undertaken on the 22nd and 23rd April 2024 by an HGG hydrogeologist and accompanied by a BRL representative. A detailed summary of the slug testing methodology is outlined in the Monitoring Well Development and Testing Workplan (HGG, 2023). The general slug testing methodology is presented as follows:

1. Measure and record static water level prior to conducting test.
2. Set up and deploy pressure transducer into water column, allowing for sufficient space for mechanical slug (solid cylindrical slug) above pressure transducer.
3. Measure mechanical slug cable so that the slug will be fully submerged within the water column without striking suspended pressure transducer, and secure top of cable to solid object so that the slug does not move during test.
4. Initiate falling head test by fully submerging the mechanical slug (near-instantaneously) below the static water. This will displace the water by increasing the water level within the MW.
5. Measure water level recovery using pressure transducer and manual water level measurements until it has recovered to at least 90% of recovery has occurred.
6. Following recovery to at least 90%, initiate rising head slug test by removing solid slug (near-instantaneously) to displace the water by reducing the water level within the MW.
7. On completion of falling head test (and rising head test where applicable) remove pressure transducer, upload and review data to confirm quality of test data.

ANALYSIS AND INTERPRETATION

Slug test data were analysed to derive a representative estimate of (K) for the HSU screened within each MW. Slug test data were analysed using AQTESOLV® for Windows Version 4.50, an industry standard software for interpretation of aquifer tests including options for a range of analytical solutions. For the purposes of this analysis, the Bouwer & Rice Method (1976) was selected as the analytical solution, as it is applicable for slug tests undertaken in partially penetrating wells. The following assumptions are included in the use of this solution in relation to the interpretation (Duffield, 2007):

- The aquifer has infinite areal extent.
- The aquifer is homogeneous and of uniform thickness.
- The aquifer potentiometric surface is initially horizontal.
- The control well is partially penetrating.
- A volume of water is injected or discharged instantaneously from the control well.
- The aquifer is unconfined.
- Flow is steady.

Application of the analytical solution involves curve matching of the solution to the slug test data within the AQTESOLV® graphic user interface. The software outputs a hydraulic conductivity estimate. In

cases where more than one test was completed within a MW, one test was selected that was considered representative hydraulic conductivity estimate for the MW. Considerations for selecting a representative hydraulic conductivity estimate include:

- Quality of the test data (lack of data noise, smoothness of recovery curve etc.)
- Tests that appear to be outliers
- Comparison of normalised test responses in relation to the other repeat tests.

Analysis was also completed with the Hvorslev Method (1951) as a check on analysis results, finding little difference between analysis methods.

The results of the analysis are summarised in Table 2. AQTESOLV outputs illustrating curve matching are provided in Attachment A.

Table 2: Summary of hydraulic testing results.

BORE	SCREENED LITHOLOGY	TEST	TEST TYPE	K ESTIMATE (BOUWER-RICE, 1976) ¹		REPRESENTATIVE K ESTIMATE (m/s)	COMMENT
				m/d	m/s		
DC25	BCM: Sandstone	1	Falling Head	0.035	4.0E-07	4.0E-07	-
		2	Rising Head	0.02	2.3E-07		-
DC27	Contact: BCM/BSM	1	Falling Head	0.029	3.4E-07	3.4E-07	-
DC28	BCM: Pebble Conglomerate	1	Falling Head	0.021	2.4E-07	2.4E-07	Screened across water table. Correction for effective casing radius applied. ²
DC33	BSM: (Greenland Group)	1	Falling Head	0.247	2.9E-06	2.3E-06	Screened across water table. Correction for effective casing radius applied. ²
		2	Rising Head	0.139	1.6E-06		
		3	Falling Head	0.195	2.3E-06		
DC41	BCM Main Coal Seam	1	Falling Head	0.070	8.1E-07	1.2E-06	-
		2	Rising Head	0.100	1.2E-06		-
		3	Falling Head	0.079	9.1E-07		Dual slug test (well skin test).
		4	Rising Head	0.092	1.1E-06		Dual slug test (well skin test).

m/d - metres per day.

m/s - metres per second.

BCM – Brunner Coal Measures.

BSM – Basement.

BLUE = Test selected for representative K estimate.

1. Bouwer & Rice (1976) assumptions include:

- Aquifer has infinite areal extent.
- Aquifer is homogeneous and of uniform thickness.
- Aquifer potentiometric surface initially horizontal.
- Control well is partially penetrating.
- A volume of water is injected or discharged instantaneously from the control well.
- Flow is steady.

2. Effective casing radius calculated assuming filter pack effective porosity (n_e) = 0.3

The following observations are noted regarding Table 2:

- All hydraulic conductivity estimates occur within an order of magnitude.
- Hydraulic conductivity is highest within DC33, screening the BCM siltstone.
- Hydraulic conductivity is lowest in DC28, screening the BCM pebble conglomerate.
- Hydraulic conductivity is generally considered moderate for all tested lithologies, and within the range expected for fractured sedimentary rock (Freeze & Cherry, 1979).
- Two dual slug tests were undertaken in DC41 to test for the potential presence of a drilling-induced well skin. The test compares K estimates derived from using a single slug and then a double slug, with significant difference in results potentially indicating the presence of a well skin. Due to the results being comparable with not significant variation, no evidence of a significant well skin is noted.

CONCLUSIONS

Slug testing was successfully completed in five recently installed MWs at Mt Fredrick South to estimate hydraulic conductivity of the various lithologies screened by the MWs. Analysis results indicated moderate hydraulic conductivity, with values ranging between approximately 1×10^{-7} to 1×10^{-6} m/s. All MWs were developed prior to conducting the slug tests. Dual slug tests undertaken in one MW confirmed that the development had successfully removed any well skin that may have formed from drilling activities.

CLOSING REMARKS

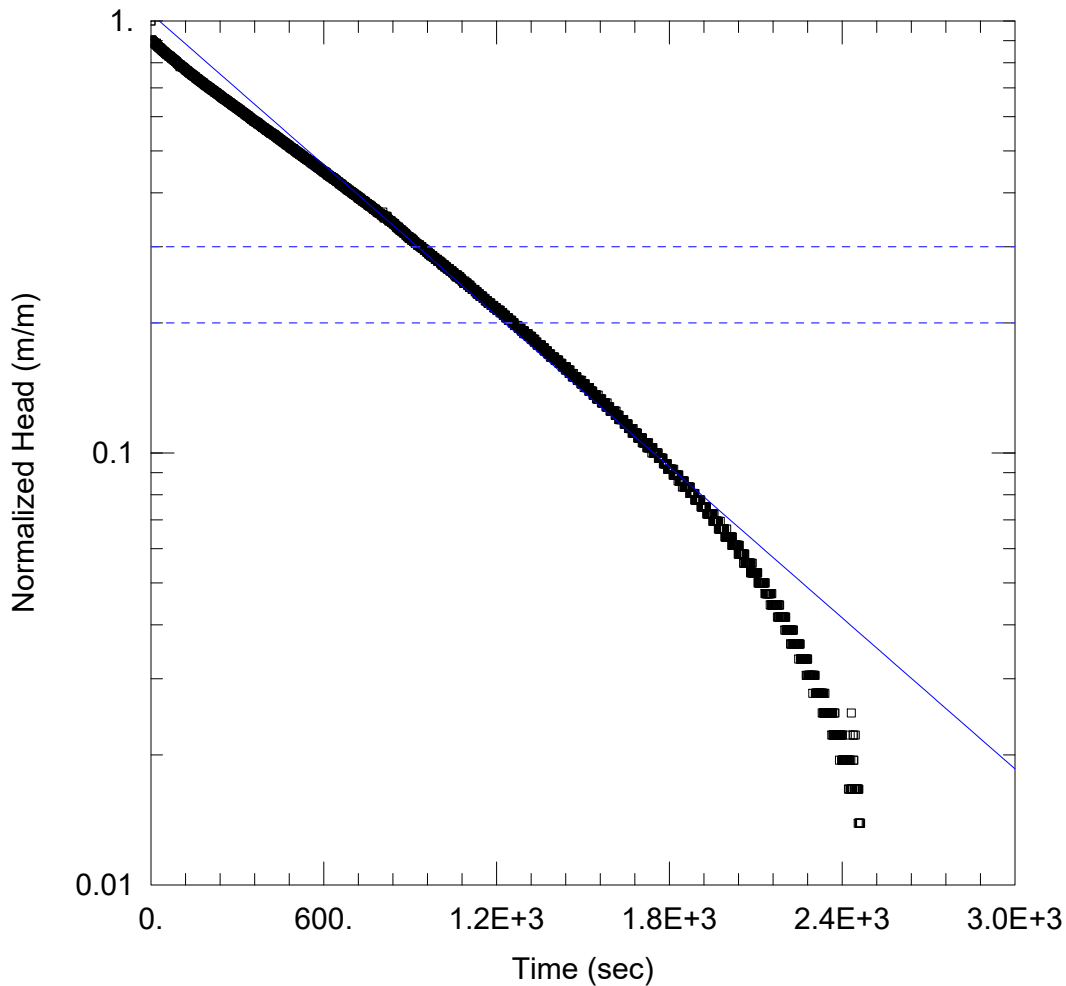


Attachments: Attachment A – AQTESOLV Output

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ATTACHMENT A – AQTESOLV OUTPUT



WELL TEST ANALYSIS

Data Set: C:\...\DC25 Test 1.aqt

Date: 05/20/24

Time: 11:52:29

PROJECT INFORMATION

Company: Hydro Geochem Group

Client: Bathurst Resources Ltd

Project: J-H-HZ0184

Location: Mt Fred South

Test Well: DC25

Test Date: 22/04/2024

AQUIFER DATA

Saturated Thickness: 36. m

Anisotropy Ratio (K_z/K_r): 1.

WELL DATA (DC25)

Initial Displacement: 0.36 m

Static Water Column Height: 7.825 m

Total Well Penetration Depth: 7.825 m

Screen Length: 3. m

Casing Radius: 0.025 m

Well Radius: 0.061 m

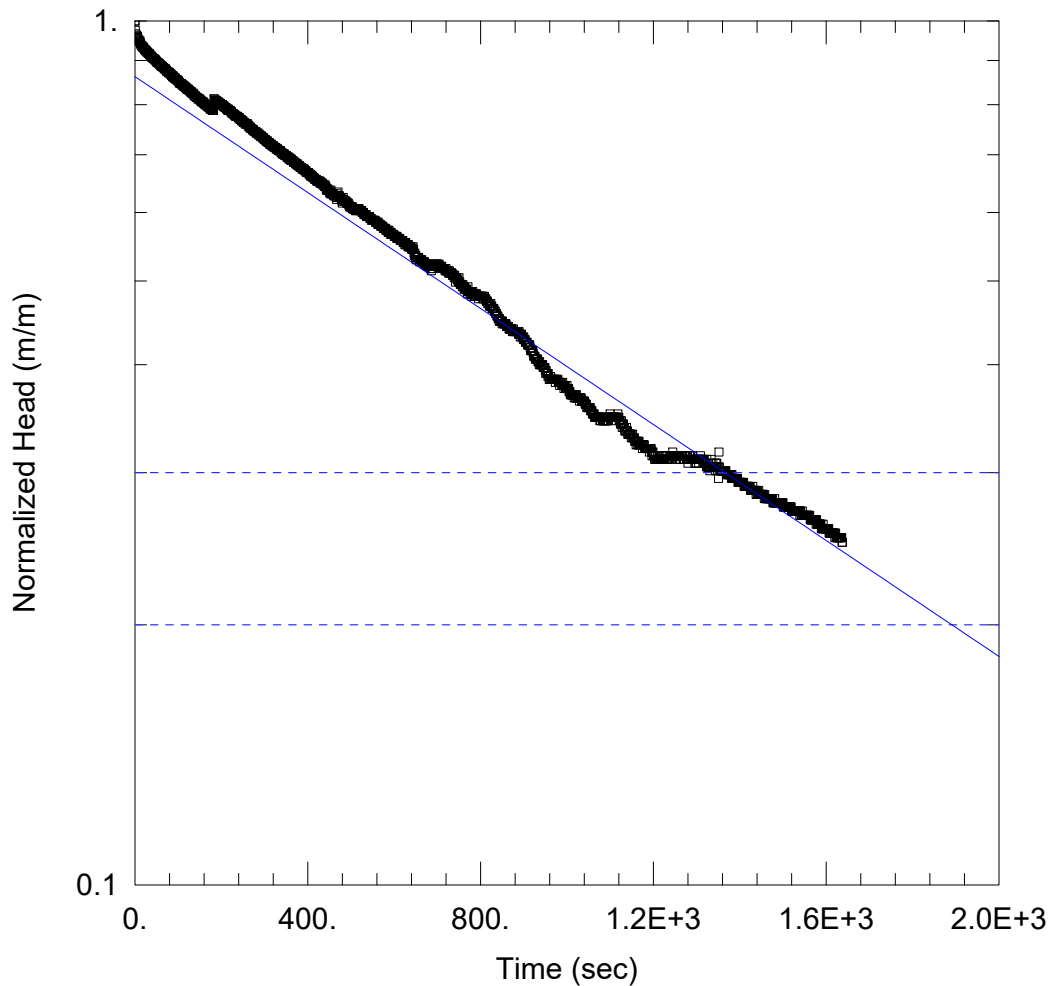
SOLUTION

Aquifer Model: Unconfined

Solution Method: Bouwer-Rice

$K = 0.03465$ m/day

$y_0 = 0.3741$ m



WELL TEST ANALYSIS

Data Set: C:\...\DC25 Test 2.aqt
 Date: 05/20/24

Time: 11:53:51

PROJECT INFORMATION

Company: Hydro Geochem Group
 Client: Bathurst Resources Ltd
 Project: J-H-HZ0184
 Location: Mt Fred South
 Test Well: DC25
 Test Date: 22/04/2024

AQUIFER DATA

Saturated Thickness: 36. m

Anisotropy Ratio (K_z/K_r): 1.

WELL DATA (DC25)

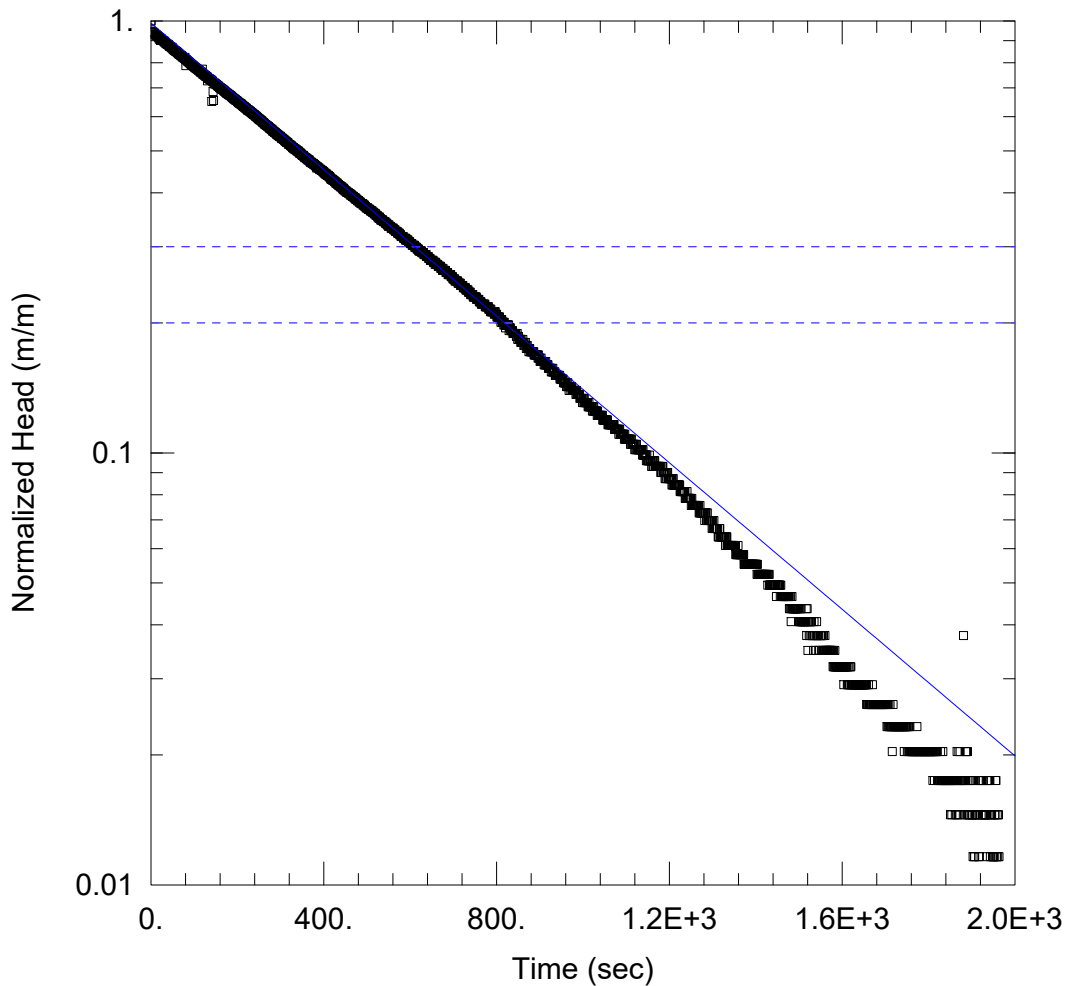
Initial Displacement: 0.325 m
 Total Well Penetration Depth: 7.825 m
 Casing Radius: 0.025 m

Static Water Column Height: 7.825 m
 Screen Length: 3. m
 Well Radius: 0.061 m

SOLUTION

Aquifer Model: Unconfined
 $K = 0.01996$ m/day

Solution Method: Bouwer-Rice
 $y_0 = 0.2802$ m



WELL TEST ANALYSIS

Data Set: C:\...\DC27 Test 1.aqt

Date: 05/20/24

Time: 11:56:08

PROJECT INFORMATION

Company: Hydro Geochem Group

Client: Bathurst Resources Ltd

Project: J-H-HZ0184

Location: Mt Fred South

Test Well: DC27

Test Date: 22/04/2024

AQUIFER DATA

Saturated Thickness: 20. m

Anisotropy Ratio (K_z/K_r): 1.

WELL DATA (DC27)

Initial Displacement: 0.344 m

Static Water Column Height: 9.83 m

Total Well Penetration Depth: 9.83 m

Screen Length: 6. m

Casing Radius: 0.025 m

Well Radius: 0.061 m

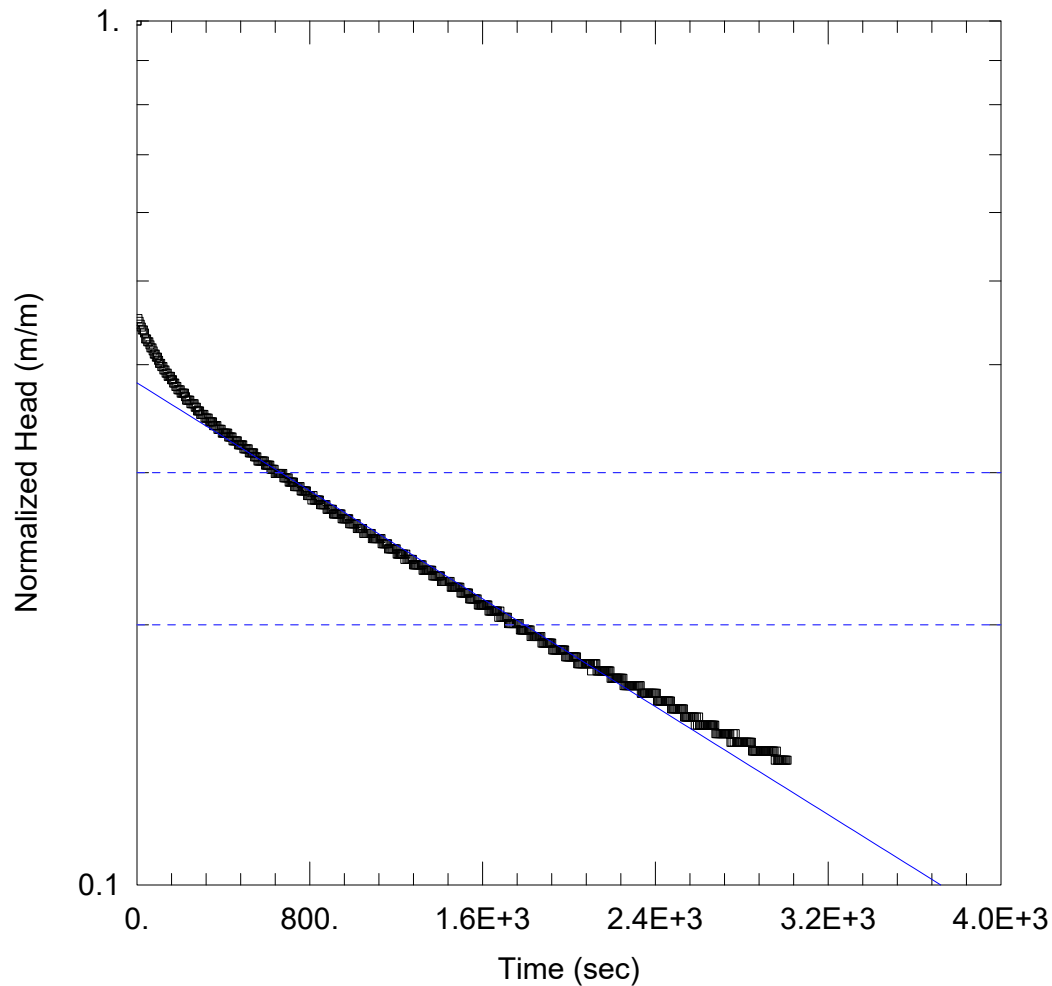
SOLUTION

Aquifer Model: Unconfined

Solution Method: Bouwer-Rice

$K = 0.02949$ m/day

$y_0 = 0.3401$ m



WELL TEST ANALYSIS

Data Set: C:\...\DC28 Test 1.aqt

Date: 05/20/24

Time: 12:01:52

PROJECT INFORMATION

Company: Hydro Geochem Group

Client: Bathurst Resources Ltd

Project: J-H-HZ0184

Location: Mt Fred South

Test Well: DC28

Test Date: 22/04/2024

AQUIFER DATA

Saturated Thickness: 10. m

Anisotropy Ratio (K_z/K_r): 1.

WELL DATA (DC28)

Initial Displacement: 0.294 m

Total Well Penetration Depth: 3. m

Casing Radius: 0.025 m

Static Water Column Height: 1.47 m

Screen Length: 3. m

Well Radius: 0.061 m

Gravel Pack Porosity: 0.3

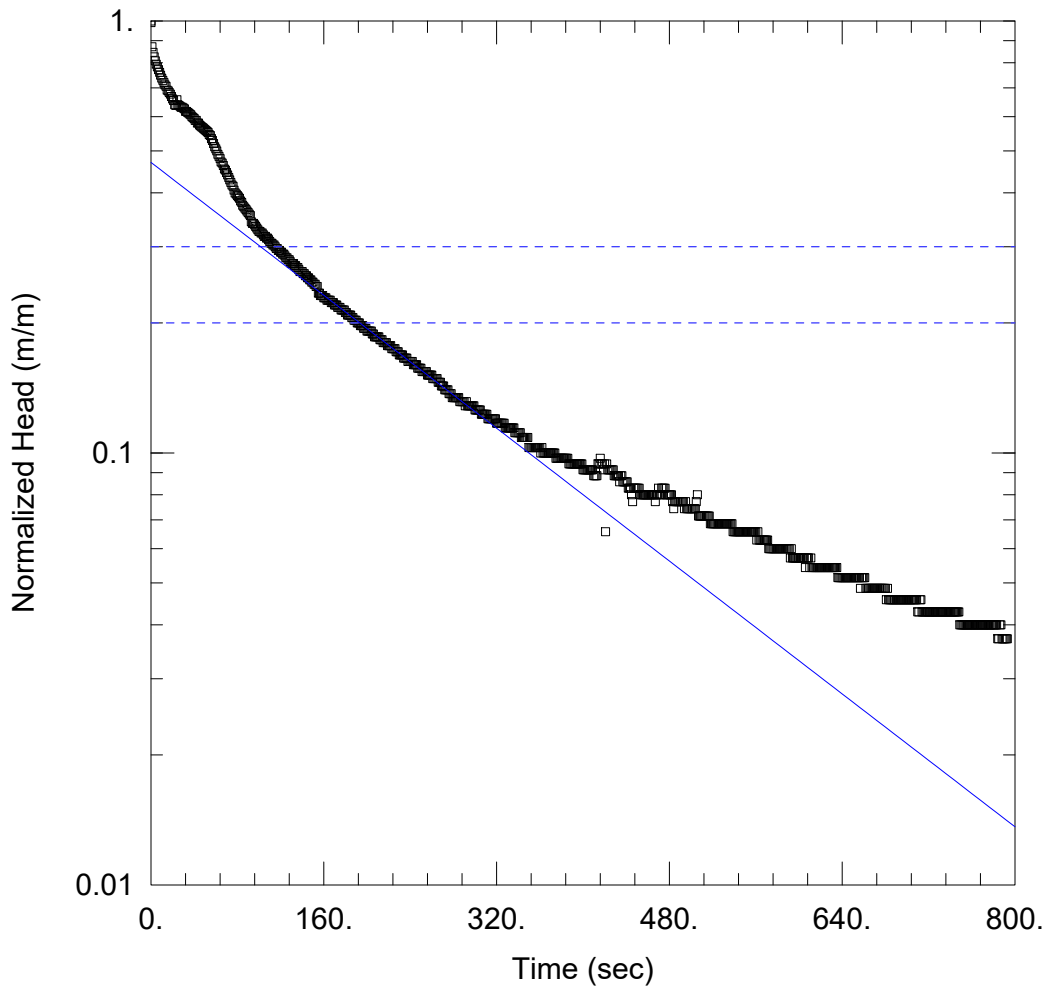
SOLUTION

Aquifer Model: Unconfined

$K = 0.02054$ m/day

Solution Method: Bouwer-Rice

$y_0 = 0.1121$ m



WELL TEST ANALYSIS

Data Set: C:\...\DC33 Test 1.aqt

Date: 05/20/24

Time: 12:02:32

PROJECT INFORMATION

Company: Hydro Geochem Group

Client: Bathurst Resources Ltd

Project: J-H-HZ0184

Location: Mt Fred South

Test Well: DC33

Test Date: 22/04/2024

AQUIFER DATA

Saturated Thickness: 20. m

Anisotropy Ratio (K_z/K_r): 1.

WELL DATA (DC33)

Initial Displacement: 0.35 m

Total Well Penetration Depth: 3. m

Casing Radius: 0.025 m

Static Water Column Height: 2.335 m

Screen Length: 3. m

Well Radius: 0.061 m

Gravel Pack Porosity: 0.3

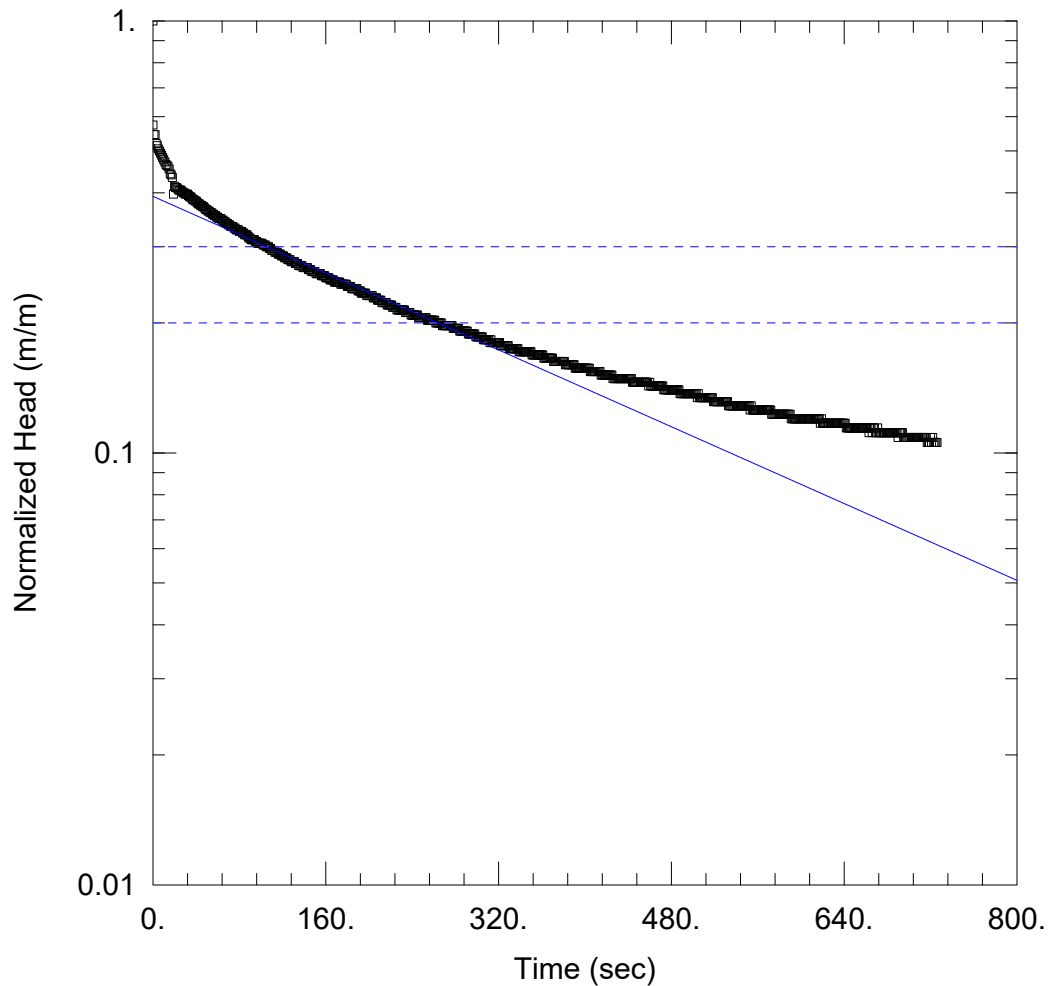
SOLUTION

Aquifer Model: Unconfined

$K = 0.2473$ m/day

Solution Method: Bouwer-Rice

$y_0 = 0.1646$ m



WELL TEST ANALYSIS

Data Set: C:\...\DC33 Test 2.aqt

Date: 05/20/24

Time: 12:03:38

PROJECT INFORMATION

Company: Hydro Geochem Group

Client: Bathurst Resources Ltd

Project: J-H-HZ0184

Location: Mt Fred South

Test Well: DC33

Test Date: 22/04/2024

AQUIFER DATA

Saturated Thickness: 20. m

Anisotropy Ratio (K_z/K_r): 1.

WELL DATA (DC33)

Initial Displacement: 0.35 m

Total Well Penetration Depth: 3. m

Casing Radius: 0.025 m

Static Water Column Height: 2.335 m

Screen Length: 3. m

Well Radius: 0.061 m

Gravel Pack Porosity: 0.3

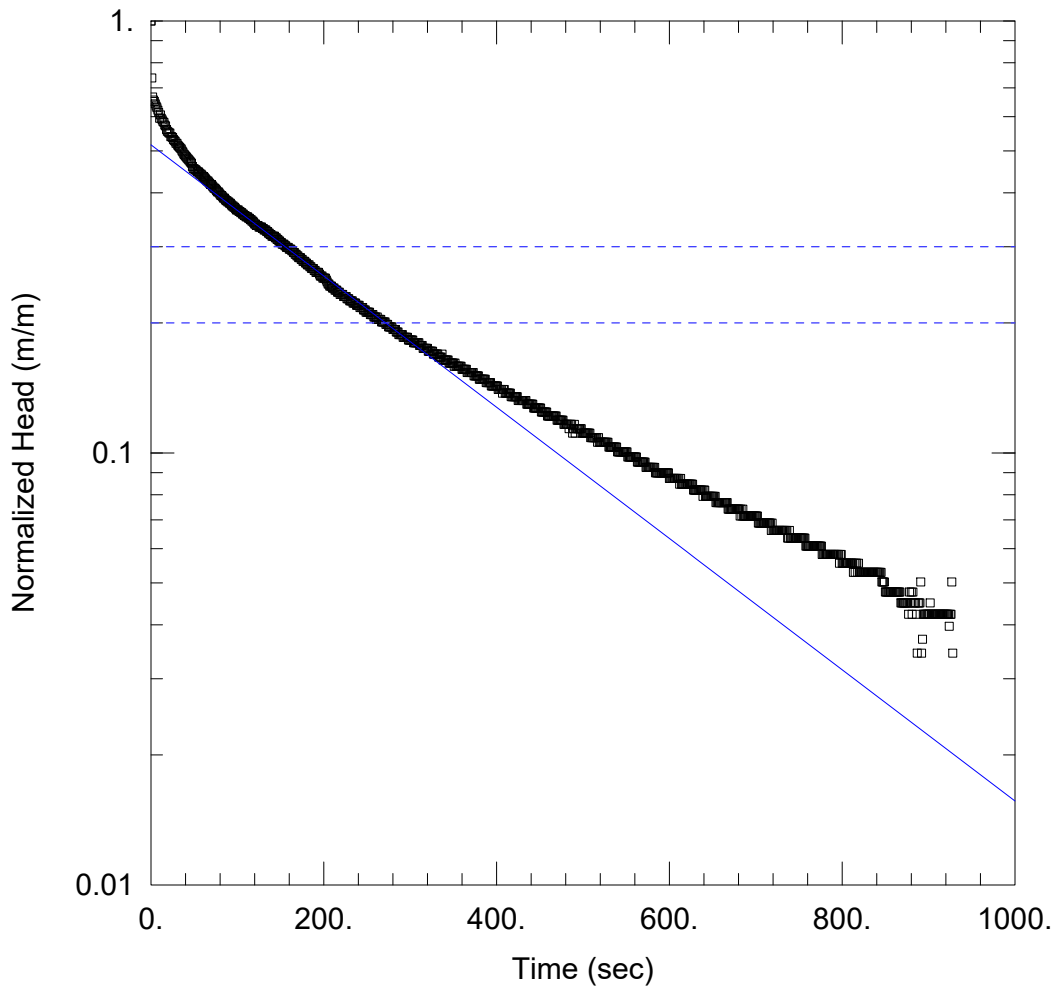
SOLUTION

Aquifer Model: Unconfined

$K = 0.1429$ m/day

Solution Method: Bouwer-Rice

$y_0 = 0.1374$ m



WELL TEST ANALYSIS

Data Set: C:\...\DC33 Test 3.aqt

Date: 05/20/24

Time: 12:49:54

PROJECT INFORMATION

Company: Hydro Geochem Group

Client: Bathurst Resources Ltd

Project: J-H-HZ0184

Location: Mt Fred South

Test Well: DC33

Test Date: 22/04/2024

AQUIFER DATA

Saturated Thickness: 20. m

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (DC33)

Initial Displacement: 0.378 m

Total Well Penetration Depth: 3. m

Casing Radius: 0.025 m

Static Water Column Height: 2.335 m

Screen Length: 3. m

Well Radius: 0.061 m

Gravel Pack Porosity: 0.3

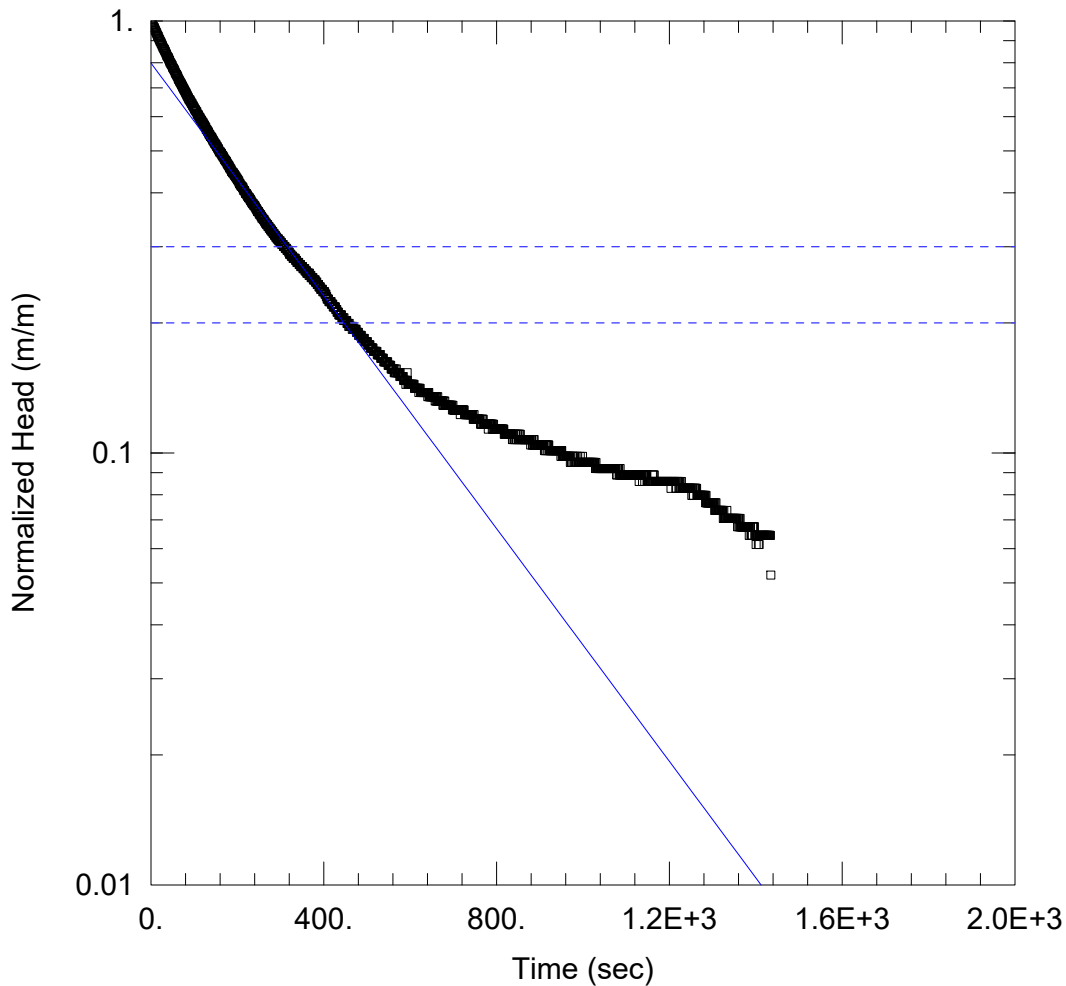
SOLUTION

Aquifer Model: Unconfined

K = 0.1954 m/day

Solution Method: Bouwer-Rice

y0 = 0.1953 m



WELL TEST ANALYSIS

Data Set: C:\...\DC41 Test 1.aqt

Date: 05/20/24

Time: 12:50:53

PROJECT INFORMATION

Company: Hydro Geochem Group

Client: Bathurst Resources Ltd

Project: J-H-HZ0184

Location: Mt Fred South

Test Well: DC41

Test Date: 22/04/2024

AQUIFER DATA

Saturated Thickness: 20. m

Anisotropy Ratio (K_z/K_r): 1.

WELL DATA (DC41)

Initial Displacement: 0.326 m

Static Water Column Height: 7.76 m

Total Well Penetration Depth: 3. m

Screen Length: 3. m

Casing Radius: 0.025 m

Well Radius: 0.061 m

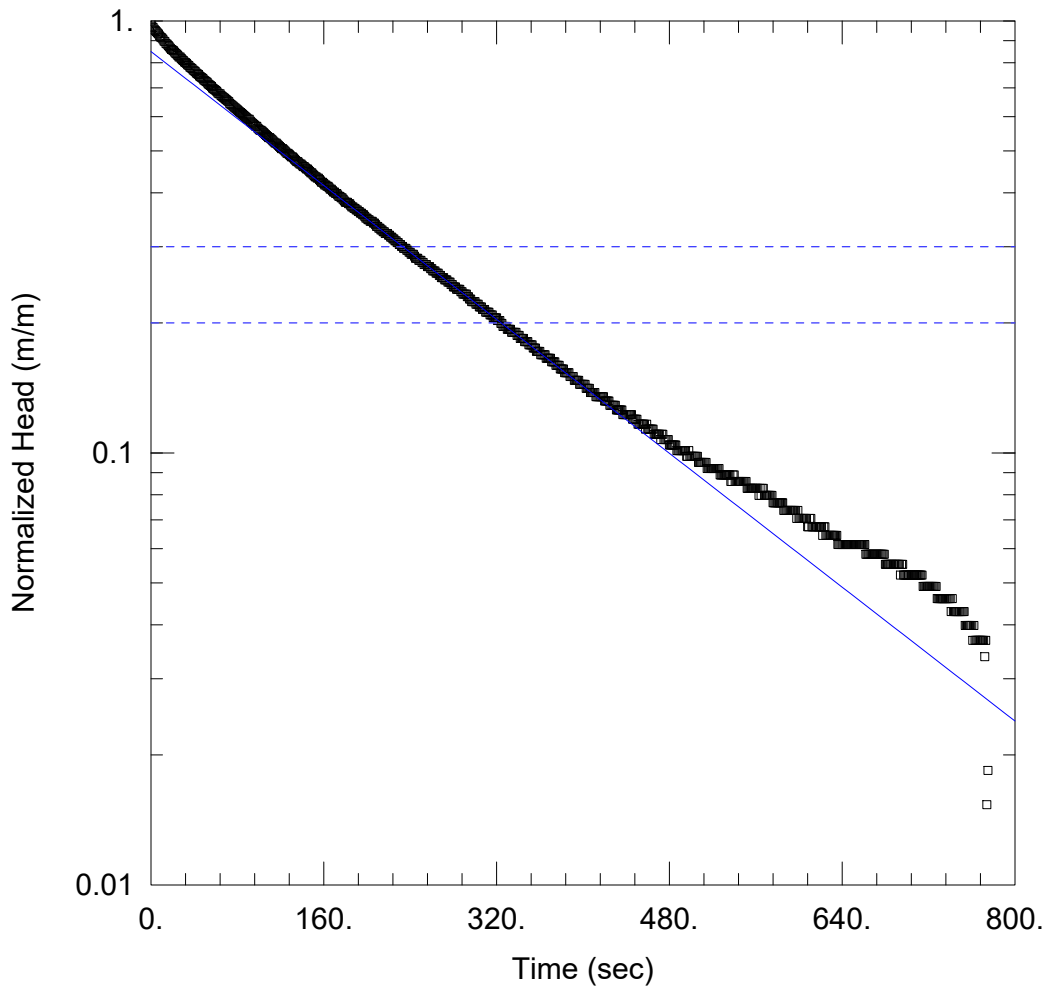
SOLUTION

Aquifer Model: Unconfined

Solution Method: Bouwer-Rice

$K = 0.0697$ m/day

$y_0 = 0.2604$ m



WELL TEST ANALYSIS

Data Set: C:\...\DC41 Test 2.aqt

Date: 05/20/24

Time: 12:51:59

PROJECT INFORMATION

Company: Hydro Geochem Group

Client: Bathurst Resources Ltd

Project: J-H-HZ0184

Location: Mt Fred South

Test Well: DC41

Test Date: 22/04/2024

AQUIFER DATA

Saturated Thickness: 44. m

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (DC41)

Initial Displacement: 0.326 m

Static Water Column Height: 7.76 m

Total Well Penetration Depth: 3. m

Screen Length: 3. m

Casing Radius: 0.025 m

Well Radius: 0.061 m

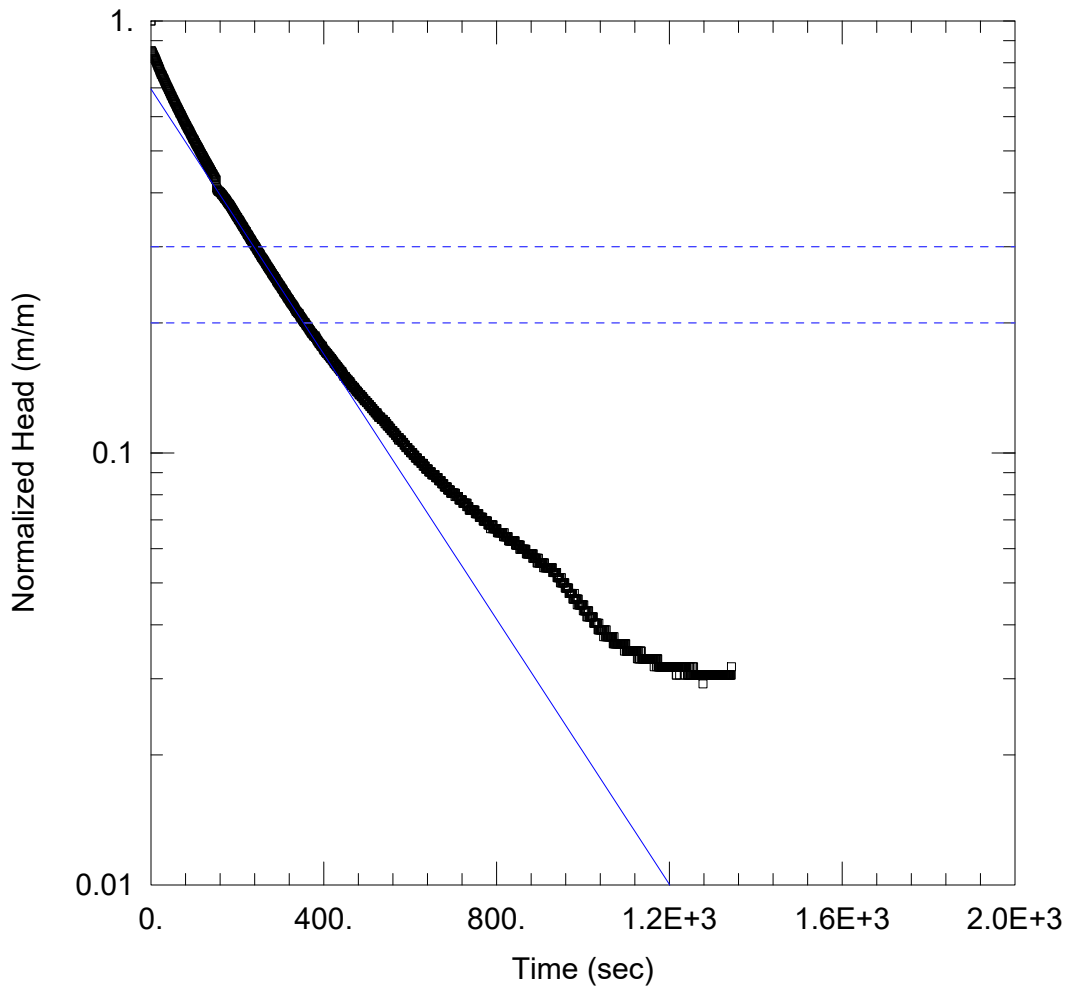
SOLUTION

Aquifer Model: Unconfined

Solution Method: Bouwer-Rice

K = 0.09931 m/day

y0 = 0.2768 m



WELL TEST ANALYSIS

Data Set: C:\...\DC41 Test 3.aqt

Date: 05/20/24

Time: 12:53:02

PROJECT INFORMATION

Company: Hydro Geochem Group

Client: Bathurst Resources Ltd

Project: J-H-HZ0184

Location: Mt Fred South

Test Well: DC41

Test Date: 22/04/2024

AQUIFER DATA

Saturated Thickness: 44. m

Anisotropy Ratio (K_z/K_r): 1.

WELL DATA (DC41 (dual slug))

Initial Displacement: 0.719 m

Static Water Column Height: 7.76 m

Total Well Penetration Depth: 3. m

Screen Length: 3. m

Casing Radius: 0.025 m

Well Radius: 0.061 m

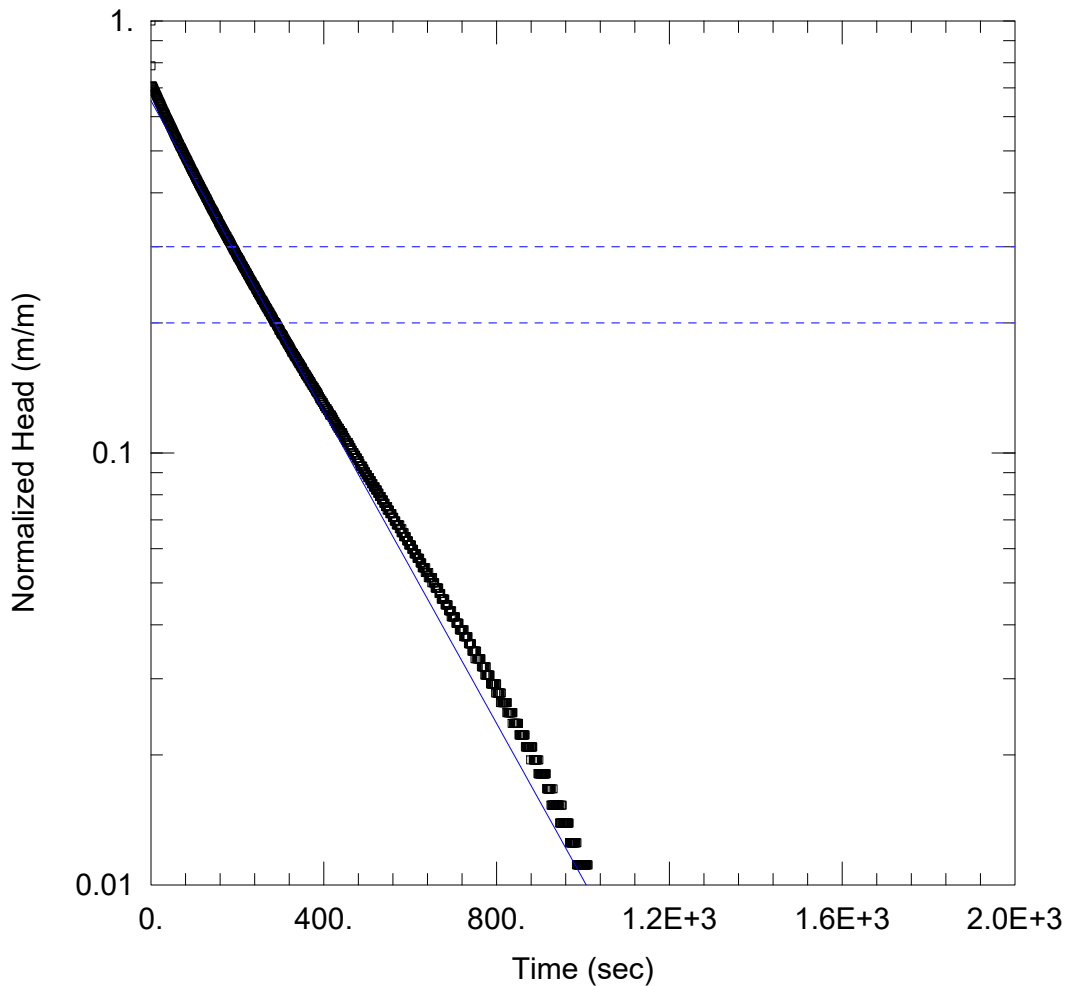
SOLUTION

Aquifer Model: Unconfined

Solution Method: Bouwer-Rice

$K = 0.07866$ m/day

$y_0 = 0.5003$ m



WELL TEST ANALYSIS

Data Set: C:\...\DC41 Test 4.aqt

Date: 05/20/24

Time: 12:54:00

PROJECT INFORMATION

Company: Hydro Geochem Group

Client: Bathurst Resources Ltd

Project: J-H-HZ0184

Location: Mt Fred South

Test Well: DC41

Test Date: 22/04/2024

AQUIFER DATA

Saturated Thickness: 44. m

Anisotropy Ratio (K_z/K_r): 1.

WELL DATA (DC41 (dual slug))

Initial Displacement: 0.719 m

Static Water Column Height: 7.76 m

Total Well Penetration Depth: 3. m

Screen Length: 3. m

Casing Radius: 0.025 m

Well Radius: 0.061 m

SOLUTION

Aquifer Model: Unconfined

Solution Method: Bouwer-Rice

$K = 0.09237$ m/day

$y_0 = 0.4698$ m

APPENDIX B GROUNDWATER QUALITY DATA

Food & Water Testing

ANALYTICAL REPORT

REPORT CODE

AR-23-NC-036189-01

REPORT DATE

30/12/2023

Attention BT Mining Ltd

PO Box 79151

Chistchurch

Phone

Email

Submission Reference:

wmw initial samples Dec 23

Order code:

EUNZCH-00161264

Purchase Order Number:

PO 535466

SAMPLE CODE

817-2023-00140037

Client Reference: DC25

Reception Date & Time: 19/12/2023 8:45

Reception temperature: 14.1 °C

Analysis Start Date & Time: 19/12/2023 14:18

Analysis Ending Date: 30/12/2023

Sampling date 2023-12-18

RESULTS

LOQ

②NW345 Acidity to pH 8.3

Acidity

<1

mg CaCO3/l

1

②NW179 Ammonia Nitrogen

Ammoniacal nitrogen (N)

0.05

mg/l

0.01

②NW075 Calcium - Acid Soluble

Calcium (Ca)

27.5

mg

0.1

②NW007 Chloride

Chloride (Cl)

6.25

mg/l

0.02

②NW023 Conductivity

Conductivity

25.2

mS/m

0.1

③NW671 Dissolved (NP) Organic Carbon

Carbon

6.3

mg/l

0.1

②NW098 Dissolved Aluminium

Aluminium

0.216

mg/l

0.002

②NW583 Dissolved Arsenic

Arsenic (As)

0.007

mg/l

0.001

②NW103 Dissolved Boron

Boron (B)

<0.03

mg/l

0.03

②NW104 Dissolved Cadmium

Cadmium (Cd)

<0.0002

mg/l

0.0002

②NW105 Dissolved Calcium

Calcium (Ca)

25.3

mg/l

0.1

②NW106 Dissolved Chromium

Chromium (Cr)

0.011

mg/l

0.001

②NW107 Dissolved Cobalt

Cobalt (Co)

<0.0005

mg/l

0.0005

②NW108 Dissolved Copper

Copper (Cu)

0.0009

mg/l

0.0005

②NW109 Dissolved Iron

Iron (Fe)

0.02

mg/l

0.01

Food & Water Testing

	RESULTS		LOQ
②NW110	Dissolved Lead		
	Lead (Pb)	<0.0005	mg/l
			0.0005
②NW112	Dissolved Magnesium		
	Magnesium (Mg)	0.29	mg/l
			0.01
②NW113	Dissolved Manganese		
	Manganese (Mn)	0.0005	mg/l
			0.0005
②NW114	Dissolved Mercury		
	Mercury (Hg)	<0.0005	mg/l
			0.0005
②NW116	Dissolved Nickel		
	Nickel (Ni)	0.0005	mg/l
			0.0005
②NW117	Dissolved Potassium		
	Potassium (K)	6.35	mg/l
			0.01
②NW472	Dissolved Silica		
	Sand/silica	11.9	mg/l
			0.02
②NW120	Dissolved Sodium		
	Sodium (Na)	22.4	mg/l
			0.01
②NW584	Dissolved Thallium		
	Thallium (Tl)	<0.0005	mg/l
			0.0005
②NW125	Dissolved Zinc		
	Zinc (Zn)	<0.002	mg/l
			0.002
②NW082	Magnesium - Acid Soluble		
	Magnesium (Mg)	0.27	mg/l
			0.01
②NW010	Nitrate-N		
	Nitrate-N	<0.01	mg/l
			0.01
②NW008	Nitrite-N		
	Nitrite Nitrogen as N	<0.01	mg/l
			0.01
②NW195	pH (Tested beyond 15 minute APHA holding time)		
	pH	9.4	
			0.1
②NW011	Sulphate		
	Sulphate	39.6	mg/l
			0.02
②NW206	Suspended Solids		
	Suspended Solids	41	mg/l
			3
②NW003	Total Alkalinity		
	Alkalinity total	64	mg CaCO3/l
			1
②NW208	Total Dissolved Solids		
	Total dissolved Solids	143	mg/l
			10
②NW030	Total Hardness		
	Hardness	65	mg CaCO3/l
			1
②NW189	Total Nitrogen		
	Total Nitrogen (N)	0.480	mg/l
			0.002
②NW212	Turbidity		
	Turbidity	35.7	NTU
			0.01

SAMPLE CODE 817-2023-00140038

Client Reference: DC27

Reception Date & Time: 19/12/2023 8:45

Analysis Start Date & Time: 19/12/2023 14:18

Sampling date 2023-12-18

Reception temperature: 14.1 °C

Analysis Ending Date: 30/12/2023

Food & Water Testing

		RESULTS		LOQ
②NW345	Acidity to pH 8.3			
	Acidity	36	mg CaCO ₃ /l	1
②NW179	Ammonia Nitrogen			
	Ammoniacal nitrogen (N)	0.01	mg/l	0.01
②NW075	Calcium - Acid Soluble			
	Calcium (Ca)	0.5	mg/l	0.1
②NW007	Chloride			
	Chloride (Cl)	4.43	mg/l	0.02
②NW023	Conductivity			
	Conductivity	3.3	mS/m	0.1
③NW671	Dissolved (NP) Organic Carbon			
	Carbon	1.8	mg/l	0.1
②NW098	Dissolved Aluminium			
	Aluminium	0.020	mg/l	0.002
②NW583	Dissolved Arsenic			
	Arsenic (As)	0.003	mg/l	0.001
②NW103	Dissolved Boron			
	Boron (B)	<0.03	mg/l	0.03
②NW104	Dissolved Cadmium			
	Cadmium (Cd)	<0.0002	mg/l	0.0002
②NW105	Dissolved Calcium			
	Calcium (Ca)	0.7	mg/l	0.1
②NW106	Dissolved Chromium			
	Chromium (Cr)	0.001	mg/l	0.001
②NW107	Dissolved Cobalt			
	Cobalt (Co)	0.0010	mg/l	0.0005
②NW108	Dissolved Copper			
	Copper (Cu)	0.0009	mg/l	0.0005
②NW109	Dissolved Iron			
	Iron (Fe)	1.68	mg/l	0.01
②NW110	Dissolved Lead			
	Lead (Pb)	0.0013	mg/l	0.0005
②NW112	Dissolved Magnesium			
	Magnesium (Mg)	0.34	mg/l	0.01
②NW113	Dissolved Manganese			
	Manganese (Mn)	0.0339	mg/l	0.0005
②NW114	Dissolved Mercury			
	Mercury (Hg)	<0.0005	mg/l	0.0005
②NW116	Dissolved Nickel			
	Nickel (Ni)	0.0008	mg/l	0.0005
②NW117	Dissolved Potassium			
	Potassium (K)	0.46	mg/l	0.01
②NW472	Dissolved Silica			
	Sand/silica	3.14	mg/l	0.02
②NW120	Dissolved Sodium			
	Sodium (Na)	2.66	mg/l	0.01
②NW584	Dissolved Thallium			

Food & Water Testing

RESULTS			LOQ
②NW584	Dissolved Thallium Thallium (Tl)	<0.0005 mg/l	0.0005
②NW125	Dissolved Zinc Zinc (Zn)	0.027 mg/l	0.002
②NW082	Magnesium - Acid Soluble Magnesium (Mg)	0.29 mg/l	0.01
②NW010	Nitrate-N Nitrate-N	0.03 mg/l	0.01
②NW008	Nitrite-N Nitrite Nitrogen as N	<0.01 mg/l	0.01
②NW195	pH (Tested beyond 15 minute APHA holding time) pH	5.4	0.1
②NW011	Sulphate Sulphate	1.04 mg/l	0.02
②NW206	Suspended Solids Suspended Solids	15 mg/l	3
②NW003	Total Alkalinity Alkalinity total	2 mg CaCO3/l	1
②NW208	Total Dissolved Solids Total dissolved Solids	26 mg/l	10
②NW030	Total Hardness Hardness	3 mg CaCO3/l	1
②NW189	Total Nitrogen Total Nitrogen (N)	0.050 mg/l	0.002
②NW212	Turbidity Turbidity	8.34 NTU	0.01

LIST OF METHODS

NW003	Total Alkalinity: APHA Online Edition 2320 B	NW007	Chloride: APHA Online Edition 4110 B
NW008	Nitrite-N: APHA Online Edition 4110 B	NW010	Nitrate-N: APHA Online Edition 4110 B
NW011	Sulphate: APHA Online Edition 4110 B	NW023	Conductivity: APHA 24th Edition 2510 B
NW030	Total Hardness: APHA Online Edition 2340 B	NW075	Calcium - Acid Soluble: APHA Online Edition 3125 B mod.
NW082	Magnesium - Acid Soluble: APHA Online Edition 3125 B mod.	NW098	Dissolved Aluminium: APHA Online Edition 3125 B mod.
NW103	Dissolved Boron: APHA Online Edition 3125 B mod.	NW104	Dissolved Cadmium: APHA Online Edition 3125 B mod.
NW105	Dissolved Calcium: APHA Online Edition 3125 B mod.	NW106	Dissolved Chromium: APHA Online Edition 3125 B mod.
NW107	Dissolved Cobalt: APHA Online Edition 3125 B mod.	NW108	Dissolved Copper: APHA Online Edition 3125 B mod.
NW109	Dissolved Iron: APHA Online Edition 3125 B mod.	NW110	Dissolved Lead: APHA Online Edition 3125 B mod.
NW112	Dissolved Magnesium: APHA Online Edition 3125 B mod.	NW113	Dissolved Manganese: APHA Online Edition 3125 B mod.
NW114	Dissolved Mercury: APHA Online Edition 3125 B mod.	NW116	Dissolved Nickel: APHA Online Edition 3125 B mod.
NW117	Dissolved Potassium: APHA Online Edition 3125 B mod.	NW120	Dissolved Sodium: APHA Online Edition 3125 B mod.
NW125	Dissolved Zinc: APHA Online Edition 3125 B mod.	NW179	Ammonia Nitrogen: APHA Online Edition 4500-NH3 H
NW189	Total Nitrogen: APHA Online Edition 4500-NO3- I	NW195	pH (Tested beyond 15 minute APHA holding time): APHA 24th Edition 4500-H B
NW206	Suspended Solids: APHA Online Edition 2540 D	NW208	Total Dissolved Solids: APHA Online Edition 2540 C
NW212	Turbidity: APHA 24th Edition 2130 B	NW345	Acidity to pH 8.3: APHA Online Edition 2310 B (Free CO2)

Food & Water Testing

NW472 **Dissolved Silica:** APHA Online Edition 3120 B mod.

NW583 **Dissolved Arsenic:** APHA Online Edition 3125 B mod.

NW584 **Dissolved Thallium:** APHA Online Edition 3125 B mod.

NW671 **Dissolved (NP) Organic Carbon:** APHA Online Edition 5310 B,C

Signature

EXPLANATORY NOTE

- ① Test is not accredited
- ② Test is subcontracted within Eurofins group and is accredited
- ③ Test is subcontracted within Eurofins group and is not accredited
- ④ Test is subcontracted outside Eurofins group and is accredited
- ⑤ Test is subcontracted outside Eurofins group and is not accredited
- ⑥ Test result is provided by the customer and is not accredited
- ⑦ Tested at the sampling point by Eurofins and is not accredited
- ⑧ Tested at the sampling point by Eurofins and is accredited
- ⑨ Test is RLP accredited
- ⑩ Test is subcontracted within Eurofins group and is RLP accredited

N/A means Not Applicable

Not Detected means not detected at or above the Limit of Quantification (LOQ)

LOQ means Limit of Quantification and the unit of LOQ is the same as the result unit

✗ (Unsatisfactory) means does not meet the specification

✓ (Satisfactory) means meets the specification

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Accreditation does not apply to comments or graphical representations.

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END OF REPORT

Food & Water Testing

ANALYTICAL REPORT

REPORT CODEAR-24-NC-006209-01REPORT DATE28/02/2024

AttentionBT Mining Ltd
PO Box 79151
Christchurch
NEW ZEALAND

Phone
Email

Contact for your orders:

SAMPLE CODE817-2024-00018377

Client Reference:DC28

Reception Date & Time:13/02/2024 8:30

Analysis Start Date & Time:13/02/2024 14:51

Product Typeground water

Sampled Date & Time09/02/2024 00:00

Reception temperature:18.3 °C

Analysis Ending Date:28/02/2024

Sampler(s)

RESULTS

LOQ

②NW345	Acidity to pH 8.3	104	mg CaCO3/l	1
	Acidity			
②NW075	Calcium - Acid Soluble	9.2	mg/l	0.1
	Calcium (Ca)			
②NW007	Chloride	5.13	mg/l	0.02
	Chloride (Cl)			
②NW023	Conductivity	10.7	mS/m	0.1
	Conductivity			
③NW671	Dissolved (NP) Organic Carbon	0.5	mg/l	0.1
	Carbon			
②NW098	Dissolved Aluminium	0.004	mg/l	0.002
	Aluminium			
②NW583	Dissolved Arsenic	<0.001	mg/l	0.001
	Arsenic (As)			
②NW103	Dissolved Boron	<0.03	mg/l	0.03
	Boron (B)			
②NW104	Dissolved Cadmium	<0.0002	mg/l	0.0002
	Cadmium (Cd)			
②NW105	Dissolved Calcium	11.4	mg/l	0.1
	Calcium (Ca)			
②NW106	Dissolved Chromium	<0.001	mg/l	0.001
	Chromium (Cr)			
②NW107	Dissolved Cobalt	0.0046	mg/l	0.0005
	Cobalt (Co)			
②NW108	Dissolved Copper	0.0042	mg/l	0.0005
	Copper (Cu)			
②NW109	Dissolved Iron	<0.01	mg/l	0.01
	Iron (Fe)			
②NW110	Dissolved Lead			

Food & Water Testing

		RESULTS		LOQ
②NW110	Dissolved Lead			
	Lead (Pb)	<0.0005	mg/l	0.0005
②NW112	Dissolved Magnesium			
	Magnesium (Mg)	1.03	mg/l	0.01
②NW113	Dissolved Manganese			
	Manganese (Mn)	0.0717	mg/l	0.0005
②NW114	Dissolved Mercury			
	Mercury (Hg)	<0.0005	mg/l	0.0005
②NW116	Dissolved Nickel			
	Nickel (Ni)	0.0088	mg/l	0.0005
②NW117	Dissolved Potassium			
	Potassium (K)	0.38	mg/l	0.01
②NW472	Dissolved Silica			
	Sand/silica	7.06	mg/l	0.02
②NW120	Dissolved Sodium			
	Sodium (Na)	6.58	mg/l	0.01
②NW584	Dissolved Thallium			
	Thallium (Tl)	<0.0005	mg/l	0.0005
②NW125	Dissolved Zinc			
	Zinc (Zn)	0.023	mg/l	0.002
②NW082	Magnesium - Acid Soluble			
	Magnesium (Mg)	0.90	mg/l	0.01
②NW011	Sulphate			
	Sulphate	6.28	mg/l	0.02
②NW206	Suspended Solids			
	Suspended Solids	<6	mg/l	3
②NW003	Total Alkalinity			
	Alkalinity total	22	mg CaCO3/l	1
②NW156	Total Calcium			
	Calcium (Ca)	63.4	mg/l	0.1
②NW208	Total Dissolved Solids			
	Total dissolved Solids	57	mg/l	10
②NW030	Total Hardness			
	Hardness	27	mg CaCO3/l	1
②NW163	Total Magnesium			
	Magnesium (Mg)	7.1	mg/l	0.1
②NW189	Total Nitrogen			
	Total Nitrogen (N)	2.02	mg/l	0.002
②NW212	Turbidity			
	Turbidity	0.27	NTU	0.01

SAMPLE CODE		817-2024-00018378	
Client Reference:	DC33		
Reception Date & Time:	13/02/2024 8:30	Reception temperature:	18.3 °C
Analysis Start Date & Time:	13/02/2024 14:51	Analysis Ending Date:	28/02/2024
Product Type	ground water	Sampler(s)	
Sampled Date & Time	09/02/2024 00:00		

Food & Water Testing

RESULTS		LOQ	
②NW345	Acidity to pH 8.3		
	Acidity	46	mg CaCO ₃ /l
			1
②NW075	Calcium - Acid Soluble		
	Calcium (Ca)	6.7	mg/l
			0.1
②NW007	Chloride		
	Chloride (Cl)	5.25	mg/l
			0.02
②NW023	Conductivity		
	Conductivity	8.6	mS/m
			0.1
③NW671	Dissolved (NP) Organic Carbon		
	Carbon	4.7	mg/l
			0.1
②NW098	Dissolved Aluminium		
	Aluminium	0.018	mg/l
			0.002
②NW583	Dissolved Arsenic		
	Arsenic (As)	<0.001	mg/l
			0.001
②NW103	Dissolved Boron		
	Boron (B)	<0.03	mg/l
			0.03
②NW104	Dissolved Cadmium		
	Cadmium (Cd)	<0.0002	mg/l
			0.0002
②NW105	Dissolved Calcium		
	Calcium (Ca)	7.6	mg/l
			0.1
②NW106	Dissolved Chromium		
	Chromium (Cr)	<0.001	mg/l
			0.001
②NW107	Dissolved Cobalt		
	Cobalt (Co)	0.0207	mg/l
			0.0005
②NW108	Dissolved Copper		
	Copper (Cu)	0.0010	mg/l
			0.0005
②NW109	Dissolved Iron		
	Iron (Fe)	<0.01	mg/l
			0.01
②NW110	Dissolved Lead		
	Lead (Pb)	<0.0005	mg/l
			0.0005
②NW112	Dissolved Magnesium		
	Magnesium (Mg)	1.31	mg/l
			0.01
②NW113	Dissolved Manganese		
	Manganese (Mn)	0.356	mg/l
			0.0005
②NW114	Dissolved Mercury		
	Mercury (Hg)	<0.0005	mg/l
			0.0005
②NW116	Dissolved Nickel		
	Nickel (Ni)	0.0444	mg/l
			0.0005
②NW117	Dissolved Potassium		
	Potassium (K)	1.02	mg/l
			0.01
②NW472	Dissolved Silica		
	Sand/silica	6.87	mg/l
			0.02
②NW120	Dissolved Sodium		
	Sodium (Na)	4.96	mg/l
			0.01
②NW584	Dissolved Thallium		
	Thallium (Tl)	<0.0005	mg/l
			0.0005
②NW125	Dissolved Zinc		

Food & Water Testing

RESULTS			LOQ
②NW125	Dissolved Zinc Zinc (Zn)	0.038 mg/l	0.002
②NW082	Magnesium - Acid Soluble Magnesium (Mg)	1.21 mg/l	0.01
②NW011	Sulphate Sulphate	16.5 mg/l	0.02
②NW206	Suspended Solids Suspended Solids	<6 mg/l	3
②NW003	Total Alkalinity Alkalinity total	9 mg CaCO3/l	1
②NW156	Total Calcium Calcium (Ca)	47.2 mg/l	0.1
②NW208	Total Dissolved Solids Total dissolved Solids	46 mg/l	10
②NW030	Total Hardness Hardness	22 mg CaCO3/l	1
②NW163	Total Magnesium Magnesium (Mg)	9.6 mg/l	0.1
②NW189	Total Nitrogen Total Nitrogen (N)	0.140 mg/l	0.002
②NW212	Turbidity Turbidity	0.18 NTU	0.01

LIST OF METHODS

NW003	Total Alkalinity: APHA Online Edition 2320 B	NW007	Chloride: APHA Online Edition 4110 B
NW011	Sulphate: APHA Online Edition 4110 B	NW023	Conductivity: APHA 24th Edition 2510 B
NW030	Total Hardness: APHA Online Edition 2340 B	NW075	Calcium - Acid Soluble: APHA Online Edition 3125 B mod.
NW082	Magnesium - Acid Soluble: APHA Online Edition 3125 B mod.	NW098	Dissolved Aluminium: APHA Online Edition 3125 B mod.
NW103	Dissolved Boron: APHA Online Edition 3125 B mod.	NW104	Dissolved Cadmium: APHA Online Edition 3125 B mod.
NW105	Dissolved Calcium: APHA Online Edition 3125 B mod.	NW106	Dissolved Chromium: APHA Online Edition 3125 B mod.
NW107	Dissolved Cobalt: APHA Online Edition 3125 B mod.	NW108	Dissolved Copper: APHA Online Edition 3125 B mod.
NW109	Dissolved Iron: APHA Online Edition 3125 B mod.	NW110	Dissolved Lead: APHA Online Edition 3125 B mod.
NW112	Dissolved Magnesium: APHA Online Edition 3125 B mod.	NW113	Dissolved Manganese: APHA Online Edition 3125 B mod.
NW114	Dissolved Mercury: APHA Online Edition 3125 B mod.	NW116	Dissolved Nickel: APHA Online Edition 3125 B mod.
NW117	Dissolved Potassium: APHA Online Edition 3125 B mod.	NW120	Dissolved Sodium: APHA Online Edition 3125 B mod.
NW125	Dissolved Zinc: APHA Online Edition 3125 B mod.	NW156	Total Calcium: APHA Online Edition 3125 B mod.
NW163	Total Magnesium: APHA Online Edition 3125 B mod.	NW189	Total Nitrogen: APHA Online Edition 4500-NO3- I
NW206	Suspended Solids: APHA Online Edition 2540 D	NW208	Total Dissolved Solids: APHA Online Edition 2540 C
NW212	Turbidity: APHA 24th Edition 2130 B	NW345	Acidity to pH 8.3: APHA Online Edition 2310 B (Free CO2)
NW472	Dissolved Silica: APHA Online Edition 3120 B mod.	NW583	Dissolved Arsenic: APHA Online Edition 3125 B mod.
NW584	Dissolved Thallium: APHA Online Edition 3125 B mod.	NW671	Dissolved (NP) Organic Carbon: APHA Online Edition 5310 B,C

Signature

Food & Water Testing

EXPLANATORY NOTE

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- ⑥ Test result is provided by the customer and is not accredited
- ⑦ Tested at the sampling point by Eurofins and is not accredited
- ⑧ Tested at the sampling point by Eurofins and is accredited
- ⑨ Test is RLP accredited
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N/A means Not Applicable

Not Detected means not detected at or above the Limit of Quantification (LOQ)

LOQ means Limit of Quantification and the unit of LOQ is the same as the result unit

✗ (Unsatisfactory) means does not meet the specification

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END OF REPORT

ANALYTICAL REPORT

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Food & Water Testing

		RESULTS		LOQ
②NW109	Dissolved Iron Iron (Fe)	0.07	mg/l	0.01
②NW110	Dissolved Lead Lead (Pb)	<0.0005	mg/l	0.0005
②NW112	Dissolved Magnesium Magnesium (Mg)	0.35	mg/l	0.01
②NW113	Dissolved Manganese Manganese (Mn)	0.0065	mg/l	0.0005
②NW114	Dissolved Mercury Mercury (Hg)	<0.0005	mg/l	0.0005
②NW116	Dissolved Nickel Nickel (Ni)	<0.0005	mg/l	0.0005
②NW117	Dissolved Potassium Potassium (K)	1.16	mg/l	0.01
②NW472	Dissolved Silica Sand/silica	4.98	mg/l	0.02
②NW120	Dissolved Sodium Sodium (Na)	3.50	mg/l	0.01
②NW584	Dissolved Thallium Thallium (Tl)	<0.0005	mg/l	0.0005
②NW125	Dissolved Zinc Zinc (Zn)	0.005	mg/l	0.002
②NW082	Magnesium - Acid Soluble Magnesium (Mg)	0.40	mg/l	0.01
②NW011	Sulphate Sulphate	1.32	mg/l	0.02
②NW206	Suspended Solids Suspended Solids	<5	mg/l	3
②NW003	Total Alkalinity Alkalinity total	5	mg CaCO3/l	1
②NW156	Total Calcium Calcium (Ca)	0.4	mg/l	0.1
②NW208	Total Dissolved Solids Total dissolved Solids	25	mg/l	10
②NW030	Total Hardness Hardness	2	mg CaCO3/l	1
②NW163	Total Magnesium Magnesium (Mg)	0.3	mg/l	0.1
②NW189	Total Nitrogen Total Nitrogen (N)	0.060	mg/l	0.002
②NW212	Turbidity Turbidity	0.29	NTU	0.01

LIST OF METHODS

NW003 **Total Alkalinity:** APHA Online Edition 2320 B

NW011 **Sulphate:** APHA Online Edition 4110 B

NW030 **Total Hardness:** APHA Online Edition 2340 B

NW007 **Chloride:** APHA Online Edition 4110 B

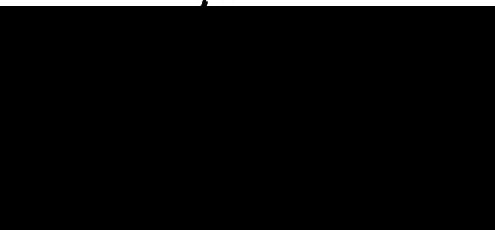
NW023 **Conductivity:** APHA 24th Edition 2510 B

NW075 **Calcium - Acid Soluble:** APHA Online Edition 3125 B mod.

Food & Water Testing

NW082	Magnesium - Acid Soluble: APHA Online Edition 3125 B mod.	NW098	Dissolved Aluminium: APHA Online Edition 3125 B mod.
NW103	Dissolved Boron: APHA Online Edition 3125 B mod.	NW104	Dissolved Cadmium: APHA Online Edition 3125 B mod.
NW105	Dissolved Calcium: APHA Online Edition 3125 B mod.	NW106	Dissolved Chromium: APHA Online Edition 3125 B mod.
NW107	Dissolved Cobalt: APHA Online Edition 3125 B mod.	NW108	Dissolved Copper: APHA Online Edition 3125 B mod.
NW109	Dissolved Iron: APHA Online Edition 3125 B mod.	NW110	Dissolved Lead: APHA Online Edition 3125 B mod.
NW112	Dissolved Magnesium: APHA Online Edition 3125 B mod.	NW113	Dissolved Manganese: APHA Online Edition 3125 B mod.
NW114	Dissolved Mercury: APHA Online Edition 3125 B mod.	NW116	Dissolved Nickel: APHA Online Edition 3125 B mod.
NW117	Dissolved Potassium: APHA Online Edition 3125 B mod.	NW120	Dissolved Sodium: APHA Online Edition 3125 B mod.
NW125	Dissolved Zinc: APHA Online Edition 3125 B mod.	NW156	Total Calcium: APHA Online Edition 3125 B mod.
NW163	Total Magnesium: APHA Online Edition 3125 B mod.	NW179	Ammonia Nitrogen: APHA Online Edition 4500-NH3 H
NW189	Total Nitrogen: APHA Online Edition 4500-NO3- I	NW206	Suspended Solids: APHA Online Edition 2540 D
NW208	Total Dissolved Solids: APHA Online Edition 2540 C	NW212	Turbidity: APHA 24th Edition 2130 B
NW345	Acidity to pH 8.3: APHA Online Edition 2310 B (Free CO2)	NW472	Dissolved Silica: APHA Online Edition 3120 B mod.
NW583	Dissolved Arsenic: APHA Online Edition 3125 B mod.	NW584	Dissolved Thallium: APHA Online Edition 3125 B mod.
NW671	Dissolved (NP) Organic Carbon: APHA Online Edition 5310 B,C		

Signature



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END OF REPORT

Food & Water Testing

ANALYTICAL REPORT

REPORT CODE

AR-24-NC-030135-01

REPORT DATE

03/10/2024

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

undwater

Purchase Order Number:

555467

Monitoring

SAMPLE CODE

817-2024-00110730

Sample Name

DC25

Reception Date & Time:

23/09/2024 9:00

Reception temperature:

11.3 °C

Analysis Started on:

23/09/2024

Analysis Ending Date:

03/10/2024

Product Type

ground water

Sampler(s)

Sampled Date & Time

18/09/2024 00:00

RESULTS

LOQ

②NW345 Acidity to pH 8.3

Acidity

6

mg CaCO3/l

1

⑩NW178 Ammonia Nitrogen

Ammoniacal nitrogen (N)

0.08

mg/l

0.01

②NW007 Chloride

Chloride (Cl)

5.70

mg/l

0.02

②NW023 Conductivity

Conductivity

24.9

mS/m

0.1

②NW098 Dissolved Aluminium

Aluminium

0.046

mg/l

0.002

②NW099 Dissolved Antimony

Antimony (Sb)

<0.001

mg/l

0.001

②NW583 Dissolved Arsenic

Arsenic (As)

0.005

mg/l

0.001

②NW103 Dissolved Boron

Boron (B)

<0.03

mg/l

0.005

②NW104 Dissolved Cadmium

Cadmium (Cd)

<0.0002

mg/l

0.0002

②NW105 Dissolved Calcium

Calcium (Ca)

25.4

mg/l

0.05

②NW106 Dissolved Chromium

Chromium (Cr)

<0.001

mg/l

0.001

②NW107 Dissolved Cobalt

Cobalt (Co)

<0.0005

mg/l

0.0005

②NW108 Dissolved Copper

Copper (Cu)

0.0010

mg/l

0.0005

②NW109 Dissolved Iron

Iron (Fe)

<0.01

mg/l

0.005

Food & Water Testing

		RESULTS		LOQ
②NW110	Dissolved Lead Lead (Pb)	<0.0005	mg/l	0.0005
②NW112	Dissolved Magnesium Magnesium (Mg)	0.57	mg/l	0.01
②NW113	Dissolved Manganese Manganese (Mn)	0.0038	mg/l	0.0005
②NW114	Dissolved Mercury Mercury (Hg)	<0.0005	mg/l	0.0005
②NW116	Dissolved Nickel Nickel (Ni)	<0.0005	mg/l	0.0005
②NW117	Dissolved Potassium Potassium (K)	4.76	mg/l	0.01
②NW118	Dissolved Selenium Selenium (Se)	<0.005	mg/l	0.005
②NW472	Dissolved Silica Sand/silica	9.26	mg/l	0.02
②NW120	Dissolved Sodium Sodium (Na)	21.4	mg/l	0.01
②NW584	Dissolved Thallium Thallium (Tl)	<0.0005	mg/l	0.0005
②NW122	Dissolved Tin Tin (Sn)	<0.0005	mg/l	0.0005
②NW125	Dissolved Zinc Zinc (Zn)	0.005	mg/l	0.002
②NW010	Nitrate-N Nitrate-N	<0.01	mg/l	0.01
②NW008	Nitrite-N Nitrite Nitrogen as N	<0.01	mg/l	0.01
②NW195	pH (Tested beyond 15 minute APHA holding time) pH	7.7		0.1
②NW011	Sulphate Sulphate	20.3	mg/l	0.02
②NW206	Suspended Solids Suspended Solids	<6	mg/l	3
②NW003	Total Alkalinity Alkalinity total	99	mg CaCO3/l	1
②NW208	Total Dissolved Solids Total dissolved Solids	151	mg/l	10
②NW189	Total Nitrogen Total Nitrogen (N)	0.150	mg/l	0.002
②NW212	Turbidity Turbidity	0.30	NTU	0.01

Food & Water Testing

SAMPLE CODE 817-2024-00110731

Sample Name DC27

Reception Date & Time: 23/09/2024 9:00

Analysis Started on: 23/09/2024

Product Type ground water

Sampled Date & Time 18/09/2024 00:00

Reception temperature: 11.3 °C

Analysis Ending Date: 03/10/2024

Sampler(s)

RESULTS

LOQ

②NW345 Acidity to pH 8.3

Acidity	68	mg CaCO3/l	1
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⑩NW178 Ammonia Nitrogen

Ammoniacal nitrogen (N)	<0.01	mg/l	0.01
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②NW007 Chloride

Chloride (Cl)	4.08	mg/l	0.02
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②NW023 Conductivity

Conductivity	3.3	mS/m	0.1
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②NW098 Dissolved Aluminium

Aluminium	0.018	mg/l	0.002
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②NW099 Dissolved Antimony

Antimony (Sb)	<0.001	mg/l	0.001
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②NW583 Dissolved Arsenic

Arsenic (As)	0.002	mg/l	0.001
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②NW103 Dissolved Boron

Boron (B)	<0.03	mg/l	0.005
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②NW104 Dissolved Cadmium

Cadmium (Cd)	<0.0002	mg/l	0.0002
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②NW105 Dissolved Calcium

Calcium (Ca)	0.3	mg/l	0.05
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②NW106 Dissolved Chromium

Chromium (Cr)	<0.001	mg/l	0.001
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②NW107 Dissolved Cobalt

Cobalt (Co)	<0.0005	mg/l	0.0005
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②NW108 Dissolved Copper

Copper (Cu)	<0.0005	mg/l	0.0005
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②NW109 Dissolved Iron

Iron (Fe)	1.09	mg/l	0.005
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②NW110 Dissolved Lead

Lead (Pb)	<0.0005	mg/l	0.0005
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②NW112 Dissolved Magnesium

Magnesium (Mg)	0.32	mg/l	0.01
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②NW113 Dissolved Manganese

Manganese (Mn)	0.0023	mg/l	0.0005
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②NW114 Dissolved Mercury

Mercury (Hg)	<0.0005	mg/l	0.0005
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②NW116 Dissolved Nickel

Nickel (Ni)	0.0007	mg/l	0.0005
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②NW117 Dissolved Potassium

Potassium (K)	0.48	mg/l	0.01
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②NW118 Dissolved Selenium

Selenium (Se)	<0.005	mg/l	0.005
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Food & Water Testing

RESULTS			LOQ
②NW472	Dissolved Silica Sand/silica	2.90 mg/l	0.02
②NW120	Dissolved Sodium Sodium (Na)	2.48 mg/l	0.01
②NW584	Dissolved Thallium Thallium (Tl)	<0.0005 mg/l	0.0005
②NW122	Dissolved Tin Tin (Sn)	<0.0005 mg/l	0.0005
②NW125	Dissolved Zinc Zinc (Zn)	0.005 mg/l	0.002
②NW010	Nitrate-N Nitrate-N	<0.01 mg/l	0.01
②NW008	Nitrite-N Nitrite Nitrogen as N	<0.01 mg/l	0.01
②NW195	pH (Tested beyond 15 minute APHA holding time) pH	5.3	0.1
②NW011	Sulphate Sulphate	0.94 mg/l	0.02
②NW206	Suspended Solids Suspended Solids	<6 mg/l	3
②NW003	Total Alkalinity Alkalinity total	6 mg CaCO3/l	1
②NW208	Total Dissolved Solids Total dissolved Solids	20 mg/l	10
②NW189	Total Nitrogen Total Nitrogen (N)	0.027 mg/l	0.002
②NW212	Turbidity Turbidity	1.15 NTU	0.01

SAMPLE CODE	817-2024-00110732		
Sample Name	DC28		
Sample Reference	Sediment in sample		
Reception Date & Time:	23/09/2024 9:00	Reception temperature:	11.3 °C
Analysis Started on:	23/09/2024	Analysis Ending Date:	03/10/2024
Product Type	ground water	Sampler(s)	
Sampled Date & Time	18/09/2024 00:00		

RESULTS			LOQ
②NW345	Acidity to pH 8.3 Acidity	84 mg CaCO3/l	1
⑩NW178	Ammonia Nitrogen Ammoniacal nitrogen (N)	<0.01 mg/l	0.01
②NW007	Chloride Chloride (Cl)	5.79 mg/l	0.02
②NW023	Conductivity Conductivity	8.6 mS/m	0.1
②NW098	Dissolved Aluminium Aluminium	0.212 mg/l	0.002
②NW099	Dissolved Antimony		

Food & Water Testing

RESULTS			LOQ
②NW099	Dissolved Antimony Antimony (Sb)	<0.001 mg/l	0.001
②NW583	Dissolved Arsenic Arsenic (As)	<0.001 mg/l	0.001
②NW103	Dissolved Boron Boron (B)	<0.03 mg/l	0.005
②NW104	Dissolved Cadmium Cadmium (Cd)	<0.0002 mg/l	0.0002
②NW105	Dissolved Calcium Calcium (Ca)	3.7 mg/l	0.05
②NW106	Dissolved Chromium Chromium (Cr)	<0.001 mg/l	0.001
②NW107	Dissolved Cobalt Cobalt (Co)	0.0149 mg/l	0.0005
②NW108	Dissolved Copper Copper (Cu)	0.0180 mg/l	0.0005
②NW109	Dissolved Iron Iron (Fe)	0.14 mg/l	0.005
②NW110	Dissolved Lead Lead (Pb)	<0.0005 mg/l	0.0005
②NW112	Dissolved Magnesium Magnesium (Mg)	1.30 mg/l	0.01
②NW113	Dissolved Manganese Manganese (Mn)	0.135 mg/l	0.0005
②NW114	Dissolved Mercury Mercury (Hg)	<0.0005 mg/l	0.0005
②NW116	Dissolved Nickel Nickel (Ni)	0.0497 mg/l	0.0005
②NW117	Dissolved Potassium Potassium (K)	1.77 mg/l	0.01
②NW118	Dissolved Selenium Selenium (Se)	<0.005 mg/l	0.005
②NW472	Dissolved Silica Sand/silica	6.12 mg/l	0.02
②NW120	Dissolved Sodium Sodium (Na)	7.36 mg/l	0.01
②NW584	Dissolved Thallium Thallium (Tl)	<0.0005 mg/l	0.0005
②NW122	Dissolved Tin Tin (Sn)	0.0006 mg/l	0.0005
②NW125	Dissolved Zinc Zinc (Zn)	0.178 mg/l	0.002
②NW010	Nitrate-N Nitrate-N	<0.01 mg/l	0.01
②NW008	Nitrite-N Nitrite Nitrogen as N	<0.01 mg/l	0.01
②NW195	pH (Tested beyond 15 minute APHA holding time) pH	5.0	0.1

Food & Water Testing

		RESULTS		LOQ
②NW011	Sulphate			
	Sulphate	22.6	mg/l	0.02
②NW206	Suspended Solids			
	Suspended Solids	178	mg/l	3
②NW003	Total Alkalinity			
	Alkalinity total	4	mg CaCO3/l	1
②NW208	Total Dissolved Solids			
	Total dissolved Solids	33	mg/l	10
②NW189	Total Nitrogen			
	Total Nitrogen (N)	0.056	mg/l	0.002
②NW212	Turbidity			
	Turbidity	83.4	NTU	0.01

SAMPLE CODE 817-2024-00110733

Sample Name DC33

Sample Reference Sediment in sample

Reception Date & Time: 23/09/2024 9:00

Reception temperature: 11.3 °C

Analysis Started on: 23/09/2024

Analysis Ending Date:

Sampled Date & Time 18/09/2024 00:00

		RESULTS		LOQ
②NW345	Acidity to pH 8.3			
	Acidity	100	mg CaCO3/l	1
⑩NW178	Ammonia Nitrogen			
	Ammoniacal nitrogen (N)	<0.01	mg/l	0.01
②NW007	Chloride			
	Chloride (Cl)	5.91	mg/l	0.02
②NW023	Conductivity			
	Conductivity	12.0	mS/m	0.1
②NW098	Dissolved Aluminium			
	Aluminium	0.018	mg/l	0.002
②NW099	Dissolved Antimony			
	Antimony (Sb)	<0.001	mg/l	0.001
②NW583	Dissolved Arsenic			
	Arsenic (As)	<0.001	mg/l	0.001
②NW103	Dissolved Boron			
	Boron (B)	<0.03	mg/l	0.005
②NW104	Dissolved Cadmium			
	Cadmium (Cd)	<0.0002	mg/l	0.0002
②NW105	Dissolved Calcium			
	Calcium (Ca)	0.5	mg/l	0.05
②NW106	Dissolved Chromium			
	Chromium (Cr)	<0.001	mg/l	0.001
②NW107	Dissolved Cobalt			
	Cobalt (Co)	0.0016	mg/l	0.0005
②NW108	Dissolved Copper			
	Copper (Cu)	0.0046	mg/l	0.0005
②NW109	Dissolved Iron			

Food & Water Testing

		RESULTS		LOQ
②NW109	Dissolved Iron Iron (Fe)	<0.01	mg/l	0.005
②NW110	Dissolved Lead Lead (Pb)	<0.0005	mg/l	0.0005
②NW112	Dissolved Magnesium Magnesium (Mg)	0.44	mg/l	0.01
②NW113	Dissolved Manganese Manganese (Mn)	0.0080	mg/l	0.0005
②NW114	Dissolved Mercury Mercury (Hg)	<0.0005	mg/l	0.0005
②NW116	Dissolved Nickel Nickel (Ni)	0.0025	mg/l	0.0005
②NW117	Dissolved Potassium Potassium (K)	0.40	mg/l	0.01
②NW118	Dissolved Selenium Selenium (Se)	<0.005	mg/l	0.005
②NW472	Dissolved Silica Sand/silica	2.70	mg/l	0.02
②NW120	Dissolved Sodium Sodium (Na)	19.4	mg/l	0.01
②NW584	Dissolved Thallium Thallium (Tl)	<0.0005	mg/l	0.0005
②NW122	Dissolved Tin Tin (Sn)	<0.0005	mg/l	0.0005
②NW125	Dissolved Zinc Zinc (Zn)	0.005	mg/l	0.002
②NW010	Nitrate-N Nitrate-N	<0.01	mg/l	0.01
②NW008	Nitrite-N Nitrite Nitrogen as N	<0.01	mg/l	0.01
②NW195	pH (Tested beyond 15 minute APHA holding time) pH	5.8		0.1
②NW011	Sulphate Sulphate	27.0	mg/l	0.02
②NW206	Suspended Solids Suspended Solids	173	mg/l	3
②NW003	Total Alkalinity Alkalinity total	17	mg CaCO3/l	1
②NW208	Total Dissolved Solids Total dissolved Solids	78	mg/l	10
②NW189	Total Nitrogen Total Nitrogen (N)	0.034	mg/l	0.002
②NW212	Turbidity Turbidity	24.9	NTU	0.01

Food & Water Testing

SAMPLE CODE		817-2024-00110734	
Sample Name	DC41		
Reception Date & Time:	23/09/2024 9:00	Reception temperature:	11.3 °C
Analysis Started on:	23/09/2024	Analysis Ending Date:	03/10/2024
Product Type	ground water	Sampler(s)	
Sampled Date & Time	18/09/2024 00:00		

		RESULTS		LOQ
②NW345	Acidity to pH 8.3			
	Acidity	38	mg CaCO ₃ /l	1
⑩NW178	Ammonia Nitrogen			
	Ammoniacal nitrogen (N)	0.15	mg/l	0.01
②NW007	Chloride			
	Chloride (Cl)	5.06	mg/l	0.02
②NW023	Conductivity			
	Conductivity	2.8	mS/m	0.1
②NW098	Dissolved Aluminium			
	Aluminium	0.040	mg/l	0.002
②NW099	Dissolved Antimony			
	Antimony (Sb)	<0.001	mg/l	0.001
②NW583	Dissolved Arsenic			
	Arsenic (As)	<0.001	mg/l	0.001
②NW103	Dissolved Boron			
	Boron (B)	<0.03	mg/l	0.005
②NW104	Dissolved Cadmium			
	Cadmium (Cd)	<0.0002	mg/l	0.0002
②NW105	Dissolved Calcium			
	Calcium (Ca)	0.2	mg/l	0.05
②NW106	Dissolved Chromium			
	Chromium (Cr)	<0.001	mg/l	0.001
②NW107	Dissolved Cobalt			
	Cobalt (Co)	<0.0005	mg/l	0.0005
②NW108	Dissolved Copper			
	Copper (Cu)	<0.0005	mg/l	0.0005
②NW109	Dissolved Iron			
	Iron (Fe)	<0.01	mg/l	0.005
②NW110	Dissolved Lead			
	Lead (Pb)	<0.0005	mg/l	0.0005
②NW112	Dissolved Magnesium			
	Magnesium (Mg)	0.34	mg/l	0.01
②NW113	Dissolved Manganese			
	Manganese (Mn)	0.0021	mg/l	0.0005
②NW114	Dissolved Mercury			
	Mercury (Hg)	<0.0005	mg/l	0.0005
②NW116	Dissolved Nickel			
	Nickel (Ni)	<0.0005	mg/l	0.0005
②NW117	Dissolved Potassium			
	Potassium (K)	1.05	mg/l	0.01
②NW118	Dissolved Selenium			
	Selenium (Se)	<0.005	mg/l	0.005

Food & Water Testing

RESULTS			LOQ
②NW472	Dissolved Silica Sand/silica	4.71 mg/l	0.02
②NW120	Dissolved Sodium Sodium (Na)	2.70 mg/l	0.01
②NW584	Dissolved Thallium Thallium (Tl)	<0.0005 mg/l	0.0005
②NW122	Dissolved Tin Tin (Sn)	<0.0005 mg/l	0.0005
②NW125	Dissolved Zinc Zinc (Zn)	0.003 mg/l	0.002
②NW010	Nitrate-N Nitrate-N	0.26 mg/l	0.01
②NW008	Nitrite-N Nitrite Nitrogen as N	<0.01 mg/l	0.01
②NW195	pH (Tested beyond 15 minute APHA holding time) pH	5.1	0.1
②NW011	Sulphate Sulphate	1.48 mg/l	0.02
②NW206	Suspended Solids Suspended Solids	50 mg/l	3
②NW003	Total Alkalinity Alkalinity total	5 mg CaCO ₃ /l	1
②NW208	Total Dissolved Solids Total dissolved Solids	20 mg/l	10
②NW189	Total Nitrogen Total Nitrogen (N)	0.090 mg/l	0.002
②NW212	Turbidity Turbidity	30.5 NTU	0.01

LIST OF METHODS

NW003	Total Alkalinity: APHA Online Edition 2320 B	NW007	Chloride: APHA Online Edition 4110 B
NW008	Nitrite-N: APHA Online Edition 4110 B	NW010	Nitrate-N: APHA Online Edition 4110 B
NW011	Sulphate: APHA Online Edition 4110 B	NW023	Conductivity: APHA 24th Edition 2510 B
NW098	Dissolved Aluminium: APHA Online Edition 3125 B mod.	NW099	Dissolved Antimony: APHA Online Edition 3125 B mod.
NW103	Dissolved Boron: APHA Online Edition 3125 B mod.	NW104	Dissolved Cadmium: APHA Online Edition 3125 B mod.
NW105	Dissolved Calcium: APHA Online Edition 3125 B mod.	NW106	Dissolved Chromium: APHA Online Edition 3125 B mod.
NW107	Dissolved Cobalt: APHA Online Edition 3125 B mod.	NW108	Dissolved Copper: APHA Online Edition 3125 B mod.
NW109	Dissolved Iron: APHA Online Edition 3125 B mod.	NW110	Dissolved Lead: APHA Online Edition 3125 B mod.
NW112	Dissolved Magnesium: APHA Online Edition 3125 B mod.	NW113	Dissolved Manganese: APHA Online Edition 3125 B mod.
NW114	Dissolved Mercury: APHA Online Edition 3125 B mod.	NW116	Dissolved Nickel: APHA Online Edition 3125 B mod.
NW117	Dissolved Potassium: APHA Online Edition 3125 B mod.	NW118	Dissolved Selenium: APHA Online Edition 3125 B mod.
NW120	Dissolved Sodium: APHA Online Edition 3125 B mod.	NW122	Dissolved Tin: APHA Online Edition 3125 B mod.
NW125	Dissolved Zinc: APHA Online Edition 3125 B mod.	NW178	Ammonia Nitrogen: APHA Online Edition 4500-NH ₃ H
NW189	Total Nitrogen: APHA Online Edition 4500-NO ₃ - I	NW195	pH (Tested beyond 15 minute APHA holding time): APHA 24th Edition 4500-H B
NW206	Suspended Solids: APHA Online Edition 2540 D	NW208	Total Dissolved Solids: APHA Online Edition 2540 C

Food & Water Testing

NW212 **Turbidity:** APHA 24th Edition 2130 B

NW345 **Acidity to pH 8.3:** APHA Online Edition 2310 B (Free CO2)

NW472 **Dissolved Silica:** APHA Online Edition 3120 B mod.

NW583 **Dissolved Arsenic:** APHA Online Edition 3125 B mod.

NW584 **Dissolved Thallium:** APHA Online Edition 3125 B mod.

Signature

EXPLANATORY NOTE

- ① Test is not accredited
- ② Test is subcontracted within Eurofins group and is accredited
- ③ Test is subcontracted within Eurofins group and is not accredited
- ④ Test is subcontracted outside Eurofins group and is accredited
- ⑤ Test is subcontracted outside Eurofins group and is not accredited
- ⑥ Test result is provided by the customer and is not accredited
- ⑦ Tested at the sampling point by Eurofins and is not accredited
- ⑧ Tested at the sampling point by Eurofins and is accredited
- ⑨ Test is RLP accredited
- ⑩ Test is subcontracted within Eurofins group and is RLP accredited

N/A means Not Applicable

Not Detected means not detected at or above the Limit of Quantification (LOQ)

LOQ means Limit of Quantification and the unit of LOQ is the same as the result unit

✗ (Unsatisfactory) means does not meet the specification

✓ (Satisfactory) means meets the specification

The Customer acknowledges and accepts that: (a) where Eurofins is not responsible for sampling, the test result(s) in this report apply only to the sample as received. Customer is solely responsible for the sampling process and warrants that the sample provided to Eurofins is representative of the lot / batch from which the samples were drawn; and (b) Eurofins expresses no opinion and accepts no liability in respect of the Customer's production process or homogeneity of the product.

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The tests are identified by a five-digit code, their description is available on request.

Accreditation does not apply to comments or graphical representations.

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END OF REPORT

Food & Water Testing

ANALYTICAL REPORT

REPORT CODE **AR-25-NC-007160-01** REPORT DATE **13/03/2025**

Client Name: [REDACTED]
Address: [REDACTED]
City: [REDACTED]
Region: [REDACTED]
Country: [REDACTED]
Phone: [REDACTED]
Email: [REDACTED]

Contact for your orders: [REDACTED] **Order code:** EUNZCH-00209434
Submission Reference: MFS groundwater WQ Feb '25 **Purchase Order Number:** 567411

SAMPLE CODE **817-2025-00021500**

Sample Name: DC25
Reception Date & Time: 01/03/2025 8:45 **Reception temperature:** 19.4 °C
Analysis Started on: 03/03/2025 **Analysis Ending Date:** 13/03/2025
Product Type: ground water **Sampled Date & Time:** 27/02/2025 10:50

RESULTS

LOQ

②NW345 Acidity to pH 8.3			
Acidity	24	mg CaCO3/l	1
②NW007 Chloride			
Chloride (Cl)	5.12	mg/l	0.02
②NW023 Conductivity			
Conductivity	21.8	mS/m	0.1
②NW098 Dissolved Aluminium			
Aluminium	0.010	mg/l	0.002
②NW099 Dissolved Antimony			
Antimony (Sb)	<0.001	mg/l	0.001
②NW583 Dissolved Arsenic			
Arsenic (As)	0.002	mg/l	0.001
②NW103 Dissolved Boron			
Boron (B)	<0.005	mg/l	0.005
②NW104 Dissolved Cadmium			
Cadmium (Cd)	<0.0002	mg/l	0.0002
②NW105 Dissolved Calcium			
Calcium (Ca)	20.1	mg/l	0.05
②NW106 Dissolved Chromium			
Chromium (Cr)	<0.001	mg/l	0.001
②NW107 Dissolved Cobalt			
Cobalt (Co)	0.0016	mg/l	0.0005
②NW108 Dissolved Copper			
Copper (Cu)	<0.0005	mg/l	0.0005
②NW109 Dissolved Iron			
Iron (Fe)	0.009	mg/l	0.005
②NW110 Dissolved Lead			
Lead (Pb)	<0.0005	mg/l	0.0005
②NW112 Dissolved Magnesium			
Magnesium (Mg)	0.94	mg/l	0.01

Food & Water Testing

RESULTS			LOQ
②NW113	Dissolved Manganese		
	Manganese (Mn)	0.152	mg/l
			0.0005
②NW114	Dissolved Mercury		
	Mercury (Hg)	<0.0005	mg/l
			0.0005
②NW116	Dissolved Nickel		
	Nickel (Ni)	0.0006	mg/l
			0.0005
②NW117	Dissolved Potassium		
	Potassium (K)	3.58	mg/l
			0.01
②NW118	Dissolved Selenium		
	Selenium (Se)	<0.005	mg/l
			0.005
②NW472	Dissolved Silica		
	Sand/silica	14.8	mg/l
			0.02
②NW120	Dissolved Sodium		
	Sodium (Na)	16.3	mg/l
			0.01
②NW584	Dissolved Thallium		
	Thallium (Tl)	<0.0005	mg/l
			0.0005
②NW122	Dissolved Tin		
	Tin (Sn)	<0.0005	mg/l
			0.0005
②NW125	Dissolved Zinc		
	Zinc (Zn)	0.004	mg/l
			0.002
②NW010	Nitrate-N		
	Nitrate-N	<0.01	mg/l
			0.01
②NW008	Nitrite-N		
	Nitrite Nitrogen as N	<0.01	mg/l
			0.01
②NW195	pH (Tested beyond 15 minute APHA holding time)		
	pH	7.5	
			0.1
②NW011	Sulphate		
	Sulphate	10.2	mg/l
			0.02
②NW206	Suspended Solids		
	Suspended Solids	8	mg/l
			3
②NW003	Total Alkalinity		
	Alkalinity total	87	mg CaCO3/l
			1
②NW208	Total Dissolved Solids		
	Total dissolved Solids	87	mg/l
			10
②NW189	Total Nitrogen		
	Total Nitrogen (N)	0.055	mg/l
			0.002
②NW212	Turbidity		
	Turbidity	1.00	NTU
			0.01

SAMPLE CODE	817-2025-00021501		
Sample Name	DC27		
Reception Date & Time:	01/03/2025	8:45	Reception temperature: 19.4 °C
Analysis Started on:	03/03/2025		Analysis Ending Date: 13/03/2025
Product Type	ground water		Sampled Date & Time 27/02/2025 10:15

RESULTS			LOQ
②NW345	Acidity to pH 8.3		
	Acidity	54	mg CaCO3/l
			1

Food & Water Testing

		RESULTS		LOQ
②NW007	Chloride			
	Chloride (Cl)	4.27	mg/l	0.02
②NW023	Conductivity			
	Conductivity	2.7	mS/m	0.1
②NW098	Dissolved Aluminium			
	Aluminium	0.012	mg/l	0.002
②NW099	Dissolved Antimony			
	Antimony (Sb)	<0.001	mg/l	0.001
②NW583	Dissolved Arsenic			
	Arsenic (As)	0.002	mg/l	0.001
②NW103	Dissolved Boron			
	Boron (B)	0.005	mg/l	0.005
②NW104	Dissolved Cadmium			
	Cadmium (Cd)	<0.0002	mg/l	0.0002
②NW105	Dissolved Calcium			
	Calcium (Ca)	0.43	mg/l	0.05
②NW106	Dissolved Chromium			
	Chromium (Cr)	<0.001	mg/l	0.001
②NW107	Dissolved Cobalt			
	Cobalt (Co)	<0.0005	mg/l	0.0005
②NW108	Dissolved Copper			
	Copper (Cu)	0.0016	mg/l	0.0005
②NW109	Dissolved Iron			
	Iron (Fe)	1.07	mg/l	0.005
②NW110	Dissolved Lead			
	Lead (Pb)	<0.0005	mg/l	0.0005
②NW112	Dissolved Magnesium			
	Magnesium (Mg)	0.27	mg/l	0.01
②NW113	Dissolved Manganese			
	Manganese (Mn)	0.0035	mg/l	0.0005
②NW114	Dissolved Mercury			
	Mercury (Hg)	<0.0005	mg/l	0.0005
②NW116	Dissolved Nickel			
	Nickel (Ni)	0.0005	mg/l	0.0005
②NW117	Dissolved Potassium			
	Potassium (K)	0.50	mg/l	0.01
②NW118	Dissolved Selenium			
	Selenium (Se)	<0.005	mg/l	0.005
②NW472	Dissolved Silica			
	Sand/silica	3.43	mg/l	0.02
②NW120	Dissolved Sodium			
	Sodium (Na)	2.02	mg/l	0.01
②NW584	Dissolved Thallium			
	Thallium (Tl)	<0.0005	mg/l	0.0005
②NW122	Dissolved Tin			
	Tin (Sn)	<0.0005	mg/l	0.0005
②NW125	Dissolved Zinc			
	Zinc (Zn)	0.009	mg/l	0.002

Food & Water Testing

RESULTS			LOQ
②NW010	Nitrate-N		
	Nitrate-N	<0.01	mg/l
			0.01
②NW008	Nitrite-N		
	Nitrite Nitrogen as N	<0.01	mg/l
			0.01
②NW195	pH (Tested beyond 15 minute APHA holding time)		
	pH	5.3	
			0.1
②NW011	Sulphate		
	Sulphate	0.47	mg/l
			0.02
②NW206	Suspended Solids		
	Suspended Solids	<5	mg/l
			3
②NW003	Total Alkalinity		
	Alkalinity total	3	mg CaCO3/l
			1
②NW208	Total Dissolved Solids		
	Total dissolved Solids	19	mg/l
			10
②NW189	Total Nitrogen		
	Total Nitrogen (N)	0.047	mg/l
			0.002
②NW212	Turbidity		
	Turbidity	2.15	NTU
			0.01

SAMPLE CODE	817-2025-00021502		
Sample Name	DC28		
Reception Date & Time:	01/03/2025	8:45	Reception temperature: 19.4 °C
Analysis Started on:	03/03/2025		Analysis Ending Date: 13/03/2025
Product Type	ground water		Sampled Date & Time 27/02/2025 09:00

RESULTS			LOQ
②NW345	Acidity to pH 8.3		
	Acidity	82	mg CaCO3/l
			1
②NW007	Chloride		
	Chloride (Cl)	4.69	mg/l
			0.02
②NW023	Conductivity		
	Conductivity	6.5	mS/m
			0.1
②NW098	Dissolved Aluminium		
	Aluminium	0.300	mg/l
			0.002
②NW099	Dissolved Antimony		
	Antimony (Sb)	<0.001	mg/l
			0.001
②NW583	Dissolved Arsenic		
	Arsenic (As)	<0.001	mg/l
			0.001
②NW103	Dissolved Boron		
	Boron (B)	<0.005	mg/l
			0.005
②NW104	Dissolved Cadmium		
	Cadmium (Cd)	<0.0002	mg/l
			0.0002
②NW105	Dissolved Calcium		
	Calcium (Ca)	1.81	mg/l
			0.05
②NW106	Dissolved Chromium		
	Chromium (Cr)	<0.001	mg/l
			0.001
②NW107	Dissolved Cobalt		
	Cobalt (Co)	0.0088	mg/l
			0.0005

Food & Water Testing

RESULTS			LOQ
②NW108	Dissolved Copper Copper (Cu)	0.0075 mg/l	0.0005
②NW109	Dissolved Iron Iron (Fe)	0.085 mg/l	0.005
②NW110	Dissolved Lead Lead (Pb)	<0.0005 mg/l	0.0005
②NW112	Dissolved Magnesium Magnesium (Mg)	0.76 mg/l	0.01
②NW113	Dissolved Manganese Manganese (Mn)	0.0530 mg/l	0.0005
②NW114	Dissolved Mercury Mercury (Hg)	<0.0005 mg/l	0.0005
②NW116	Dissolved Nickel Nickel (Ni)	0.0263 mg/l	0.0005
②NW117	Dissolved Potassium Potassium (K)	0.60 mg/l	0.01
②NW118	Dissolved Selenium Selenium (Se)	<0.005 mg/l	0.005
②NW472	Dissolved Silica Sand/silica	6.52 mg/l	0.02
②NW120	Dissolved Sodium Sodium (Na)	4.60 mg/l	0.01
②NW584	Dissolved Thallium Thallium (Tl)	<0.0005 mg/l	0.0005
②NW122	Dissolved Tin Tin (Sn)	<0.0005 mg/l	0.0005
②NW125	Dissolved Zinc Zinc (Zn)	0.105 mg/l	0.002
②NW010	Nitrate-N Nitrate-N	<0.01 mg/l	0.01
②NW008	Nitrite-N Nitrite Nitrogen as N	<0.01 mg/l	0.01
②NW195	pH (Tested beyond 15 minute APHA holding time) pH	5.6	0.1
②NW011	Sulphate Sulphate	16.2 mg/l	0.02
②NW206	Suspended Solids Suspended Solids	105 mg/l	3
②NW003	Total Alkalinity Alkalinity total	<1 mg CaCO3/l	1
②NW208	Total Dissolved Solids Total dissolved Solids	40 mg/l	10
②NW189	Total Nitrogen Total Nitrogen (N)	0.040 mg/l	0.002
②NW212	Turbidity Turbidity	69.5 NTU	0.01

Food & Water Testing

SAMPLE CODE		817-2025-00021503	
Sample Name	DC33		
Reception Date & Time:	01/03/2025 8:45	Reception temperature:	19.4 °C
Analysis Started on:	03/03/2025	Analysis Ending Date:	13/03/2025
Product Type	ground water	Sampled Date & Time	27/02/2025 12:00

RESULTS		LOQ	
②NW345	Acidity to pH 8.3		
	Acidity	72	mg CaCO3/l
			1
②NW007	Chloride		
	Chloride (Cl)	5.34	mg/l
			0.02
②NW023	Conductivity		
	Conductivity	29.2	mS/m
			0.1
②NW098	Dissolved Aluminium		
	Aluminium	0.023	mg/l
			0.002
②NW099	Dissolved Antimony		
	Antimony (Sb)	<0.001	mg/l
			0.001
②NW583	Dissolved Arsenic		
	Arsenic (As)	<0.001	mg/l
			0.001
②NW103	Dissolved Boron		
	Boron (B)	<0.005	mg/l
			0.005
②NW104	Dissolved Cadmium		
	Cadmium (Cd)	<0.0002	mg/l
			0.0002
②NW105	Dissolved Calcium		
	Calcium (Ca)	1.46	mg/l
			0.05
②NW106	Dissolved Chromium		
	Chromium (Cr)	<0.001	mg/l
			0.001
②NW107	Dissolved Cobalt		
	Cobalt (Co)	0.0018	mg/l
			0.0005
②NW108	Dissolved Copper		
	Copper (Cu)	0.0021	mg/l
			0.0005
②NW109	Dissolved Iron		
	Iron (Fe)	<0.005	mg/l
			0.005
②NW110	Dissolved Lead		
	Lead (Pb)	<0.0005	mg/l
			0.0005
②NW112	Dissolved Magnesium		
	Magnesium (Mg)	0.60	mg/l
			0.01
②NW113	Dissolved Manganese		
	Manganese (Mn)	0.0135	mg/l
			0.0005
②NW114	Dissolved Mercury		
	Mercury (Hg)	<0.0005	mg/l
			0.0005
②NW116	Dissolved Nickel		
	Nickel (Ni)	0.0024	mg/l
			0.0005
②NW117	Dissolved Potassium		
	Potassium (K)	0.65	mg/l
			0.01
②NW118	Dissolved Selenium		
	Selenium (Se)	<0.005	mg/l
			0.005
②NW472	Dissolved Silica		
	Sand/silica	8.11	mg/l
			0.02

Food & Water Testing

		RESULTS		LOQ
②NW120	Dissolved Sodium			
	Sodium (Na)	46.4	mg/l	0.01
②NW584	Dissolved Thallium			
	Thallium (Tl)	<0.0005	mg/l	0.0005
②NW122	Dissolved Tin			
	Tin (Sn)	<0.0005	mg/l	0.0005
②NW125	Dissolved Zinc			
	Zinc (Zn)	0.007	mg/l	0.002
②NW010	Nitrate-N			
	Nitrate-N	<0.01	mg/l	0.01
②NW008	Nitrite-N			
	Nitrite Nitrogen as N	<0.01	mg/l	0.01
②NW195	pH (Tested beyond 15 minute APHA holding time)			
	pH	6.6		0.1
②NW011	Sulphate			
	Sulphate	75.4	mg/l	0.02
②NW206	Suspended Solids			
	Suspended Solids	258	mg/l	3
②NW003	Total Alkalinity			
	Alkalinity total	44	mg CaCO3/l	1
②NW208	Total Dissolved Solids			
	Total dissolved Solids	139	mg/l	10
②NW189	Total Nitrogen			
	Total Nitrogen (N)	0.083	mg/l	0.002
②NW212	Turbidity			
	Turbidity	124	NTU	0.01

SAMPLE CODE 817-2025-00021504

Sample Name DC41

Reception Date & Time: 01/03/2025 8:45

Analysis Started on: 03/03/2025

Product Type ground water

Reception temperature: 19.4 °C

Analysis Ending Date: 13/03/2025

Sampled Date & Time 27/02/2025 14:30

		RESULTS		LOQ
②NW345	Acidity to pH 8.3			
	Acidity	39	mg CaCO3/l	1
②NW007	Chloride			
	Chloride (Cl)	4.72	mg/l	0.02
②NW023	Conductivity			
	Conductivity	2.8	mS/m	0.1
②NW098	Dissolved Aluminium			
	Aluminium	0.037	mg/l	0.002
②NW099	Dissolved Antimony			
	Antimony (Sb)	<0.001	mg/l	0.001
②NW583	Dissolved Arsenic			
	Arsenic (As)	<0.001	mg/l	0.001
②NW103	Dissolved Boron			
	Boron (B)	<0.005	mg/l	0.005

Food & Water Testing

RESULTS			LOQ
②NW104	Dissolved Cadmium		
	Cadmium (Cd)	<0.0002	mg/l
			0.0002
②NW105	Dissolved Calcium		
	Calcium (Ca)	0.30	mg/l
			0.05
②NW106	Dissolved Chromium		
	Chromium (Cr)	<0.001	mg/l
			0.001
②NW107	Dissolved Cobalt		
	Cobalt (Co)	<0.0005	mg/l
			0.0005
②NW108	Dissolved Copper		
	Copper (Cu)	<0.0005	mg/l
			0.0005
②NW109	Dissolved Iron		
	Iron (Fe)	<0.005	mg/l
			0.005
②NW110	Dissolved Lead		
	Lead (Pb)	<0.0005	mg/l
			0.0005
②NW112	Dissolved Magnesium		
	Magnesium (Mg)	0.30	mg/l
			0.01
②NW113	Dissolved Manganese		
	Manganese (Mn)	0.0019	mg/l
			0.0005
②NW114	Dissolved Mercury		
	Mercury (Hg)	<0.0005	mg/l
			0.0005
②NW116	Dissolved Nickel		
	Nickel (Ni)	<0.0005	mg/l
			0.0005
②NW117	Dissolved Potassium		
	Potassium (K)	1.05	mg/l
			0.01
②NW118	Dissolved Selenium		
	Selenium (Se)	<0.005	mg/l
			0.005
②NW472	Dissolved Silica		
	Sand/silica	4.76	mg/l
			0.02
②NW120	Dissolved Sodium		
	Sodium (Na)	2.24	mg/l
			0.01
②NW584	Dissolved Thallium		
	Thallium (Tl)	<0.0005	mg/l
			0.0005
②NW122	Dissolved Tin		
	Tin (Sn)	<0.0005	mg/l
			0.0005
②NW125	Dissolved Zinc		
	Zinc (Zn)	0.007	mg/l
			0.002
②NW010	Nitrate-N		
	Nitrate-N	0.03	mg/l
			0.01
②NW008	Nitrite-N		
	Nitrite Nitrogen as N	<0.01	mg/l
			0.01
②NW195	pH (Tested beyond 15 minute APHA holding time)		
	pH	5.1	
			0.1
②NW011	Sulphate		
	Sulphate	1.42	mg/l
			0.02
②NW206	Suspended Solids		
	Suspended Solids	6	mg/l
			3
②NW003	Total Alkalinity		
	Alkalinity total	<1	mg CaCO3/l
			1

Food & Water Testing

	RESULTS		LOQ
②NW208 Total Dissolved Solids			
Total dissolved Solids	10	mg/l	10
②NW189 Total Nitrogen			
Total Nitrogen (N)	0.084	mg/l	0.002
②NW212 Turbidity			
Turbidity	1.21	NTU	0.01

LIST OF METHODS

NW003 Total Alkalinity: APHA Online Edition 2320 B	NW007 Chloride: APHA Online Edition 4110 B
NW008 Nitrite-N: APHA Online Edition 4110 B	NW010 Nitrate-N: APHA Online Edition 4110 B
NW011 Sulphate: APHA Online Edition 4110 B	NW023 Conductivity: APHA 24th Edition 2510 B
NW098 Dissolved Aluminium: APHA Online Edition 3125 B mod.	NW099 Dissolved Antimony: APHA Online Edition 3125 B mod.
NW103 Dissolved Boron: APHA Online Edition 3125 B mod.	NW104 Dissolved Cadmium: APHA Online Edition 3125 B mod.
NW105 Dissolved Calcium: APHA Online Edition 3125 B mod.	NW106 Dissolved Chromium: APHA Online Edition 3125 B mod.
NW107 Dissolved Cobalt: APHA Online Edition 3125 B mod.	NW108 Dissolved Copper: APHA Online Edition 3125 B mod.
NW109 Dissolved Iron: APHA Online Edition 3125 B mod.	NW110 Dissolved Lead: APHA Online Edition 3125 B mod.
NW112 Dissolved Magnesium: APHA Online Edition 3125 B mod.	NW113 Dissolved Manganese: APHA Online Edition 3125 B mod.
NW114 Dissolved Mercury: APHA Online Edition 3125 B mod.	NW116 Dissolved Nickel: APHA Online Edition 3125 B mod.
NW117 Dissolved Potassium: APHA Online Edition 3125 B mod.	NW118 Dissolved Selenium: APHA Online Edition 3125 B mod.
NW120 Dissolved Sodium: APHA Online Edition 3125 B mod.	NW122 Dissolved Tin: APHA Online Edition 3125 B mod.
NW125 Dissolved Zinc: APHA Online Edition 3125 B mod.	NW189 Total Nitrogen: APHA Online Edition 4500-NO3- I
NW195 pH (Tested beyond 15 minute APHA holding time): APHA 24th Edition 4500-H B	NW206 Suspended Solids: APHA Online Edition 2540 D
NW208 Total Dissolved Solids: APHA Online Edition 2540 C	NW212 Turbidity: APHA 24th Edition 2130 B
NW345 Acidity to pH 8.3: APHA Online Edition 2310 B (Free CO2)	NW472 Dissolved Silica: APHA Online Edition 3120 B mod.
NW583 Dissolved Arsenic: APHA Online Edition 3125 B mod.	NW584 Dissolved Thallium: APHA Online Edition 3125 B mod.

Signature

EXPLANATORY NOTE

- ① Test is not accredited
- ② Test is subcontracted within Eurofins group and is accredited
- ③ Test is subcontracted within Eurofins group and is not accredited
- ④ Test is subcontracted outside Eurofins group and is accredited
- ⑤ Test is subcontracted outside Eurofins group and is not accredited
- ⑥ Test result is provided by the customer and is not accredited
- ⑦ Tested at the sampling point by Eurofins and is not accredited
- ⑧ Tested at the sampling point by Eurofins and is accredited
- ⑨ Test is RLP accredited
- ⑩ Test is subcontracted within Eurofins group and is RLP accredited

N/A means Not Applicable

Not Detected means not detected at or above the Limit of Quantification (LOQ)

LOQ means Limit of Quantification and the unit of LOQ is the same as the result unit

✗ (Unsatisfactory) means does not meet the specification

✓ (Satisfactory) means meets the specification

MAV means Maximum Allowable Value

Food & Water Testing

The Customer acknowledges and accepts that: (a) where Eurofins is not responsible for sampling, the test result(s) in this report apply only to the sample as received. Customer is solely responsible for the sampling process and warrants that the sample provided to Eurofins is representative of the lot / batch from which the samples were drawn; and (b) Eurofins expresses no opinion and accepts no liability in respect of the Customer's production process or homogeneity of the product. This document can only be reproduced in full.

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Accreditation does not apply to comments or graphical representations.

Unless otherwise stated, all tests in this analytical report (except for subcontracted tests) are performed at 43 Detroit Drive, Rolleston, Christchurch, NEW ZEALAND.

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If the Customer pays for storage of the samples Eurofins will take commercially reasonable steps to store the samples for the agreed period in terms of industry practice.

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END OF REPORT

APPENDIX C PROPOSED GROUNDWATER MONITORING

Table A.1: Proposed groundwater monitoring details.

DETAILS	DESCRIPTION
Monitoring purpose	The purpose of the groundwater monitoring activities will be to: • Monitor for potential seepage migration along groundwater flow pathways. • Understand groundwater levels and confirm groundwater flow directions.
Number of monitoring wells	The proposed number of monitoring wells proposed for each area (see Figure 19 for location), are provided below: • Area A: 2 • Area B: 3 • Area C: 2 • Area D: 2 • Area E: 1 • Area F: 1 Location and number of wells will be refined as mining studies advance.
Screen targets	Screens will target intercepted structures (e.g., fracture zones) and/or bedding contacts (e.g., BCM and Basement contact).
Sampling frequency	Sampling frequency will be quarterly.
Sampling methodology	• Manual and automated (with pressure transducers) groundwater level measurement. • Low flow sampling methodology is the preferred method to obtain a representative sample where possible.
Sampling parameters	Field: • Groundwater level (manual and from pressure transducers). • pH, temperature, electrical conductivity, oxidation reduction potential, dissolved oxygen. Laboratory: • pH • Electrical Conductivity • Alkalinity • Acidity (to pH 8.3) • Sulfate • Dissolved Aluminium • Dissolved Zinc • Dissolved Iron • Dissolved Nickel • Dissolved Copper • Dissolved Cadmium • Dissolved Manganese • Dissolved Calcium • Dissolved Magnesium • Dissolved Organic Carbon • Total Suspended Solids • Turbidity
Quality Control sampling	• One trip blank per sampling event. • One duplicate sample per every 10-20 primary samples. • One field blank per sampling event
Reporting requirements	Groundwater monitoring data collected will be reported in an annual water report alongside surface water monitoring.

APPENDIX D LIMITATIONS

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