

Appendix N - Post-Mining Water Quality Model



RUSTLERS ROOST & Q29

Pit Lake Water Quality Predictions

CDM Smith

29 July 2022



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EXECUTIVE SUMMARY

Land & Water Consulting (LWC) was engaged by CDM Smith to undertake predictive calculations of potential water quality of two pit lake systems (Rustlers Roost (RR) and Quest 29 (Q29)) post mining.

The following is understood:

- Rustlers Roost (RR) and Quest 29 (Q29) are brownfield sites on Mineral Leases (ML) located in the Mount Bunday locality, approximately 85 km south-east of Darwin in the Northern Territory (NT). These sites will be redeveloped for open-cut mining involving connection of the non-contiguous areas by a haul road and construction of an accommodation camp (the Project). The sites have a history of gold mining activity with first gold being discovered in the 1940s and activities occurring over intermittent periods during the past 70 years.
- The mine sites are located approximately 11 km apart and are connected by an existing unsealed access track, which will be upgraded to accommodate haulage of ore from the Quest 29 satellite pits to a proposed processing facility at Rustlers Roost. Ore mined at both sites will be processed at a new purpose-built processing facility located at the Rustlers Roost site to produce gold bullion which will be trucked offsite for sale.
- The rate of production will be up to 5 million tonnes per annum (Mtpa) over an approximately 10-year life of mine (LOM). Following completion of mining activities, the Project area will be closed and rehabilitated in accordance with an approved Mine Closure Plan (MCP).
- The main Project areas of RR and Q 29 are located between 5 km and 12 km directly south-west of the Arnhem Highway on Old Mount Bunday Station, Perpetual Pastoral Lease (PPL) 1163 and McKinlay River Pastoral Station (PPL 1184) (Figure 1-1, Appendix A).
- The Project includes the expansion of existing pits, waste rock landforms, water storage dams and internal roads. Two new pits will be constructed at RR and new infrastructure includes an onsite processing plant, a tailings storage facility (TSF), a landfill, laydown area, magazine, administration office, accommodation camp and groundwater bores for water supply. The Project includes an entire development envelope of 790 ha which is taken to be the maximum extent within which disturbance may occur. However, a large portion of the additional Project footprint is within historically disturbed areas.

The objective of this assessment is to provide potential water quality composition of key elements in pit lake water during and following recovery of the water table in each of the RR and Q29 pits.

Key conclusions are as follows:

1. There are variations of in pit submerged storage options:
 - o Option 1a - Simple Underwater Disposal
 - o Option 1b - Underwater Disposal with a Surface Barrier
 - o Option 1c - Underwater Disposal with Groundwater Barriers
 - o Option 1d - Underwater Disposal with Surface and Groundwater Barriers.

It is understood that Option 1a is proposed.



2. With respect to RR Pit Lake, the scaled up leach (accounting for 1.6 Mt of rock in RR) adjusted for a literature based cumulative scaling factor (CSF) with mean groundwater composition predicts:
 - a. Lake water in RR pit is predicted to have high concentrations of contaminants of potential environmental concern (CPEC, relative to screening criteria) for Years 1 – 5 after mining has ceased. This is largely driven by the surface water run-off contacting the PAF rock in pit walls (refer Section 5.2 for discussion on the likely overestimation of this term).
 - b. In year 10 copper is predicted to be elevated above the ANZECC & ARMCANZ 2000 Long-Term Irrigation Water and also the Mount Bundy trigger value (TV), ANZG default guideline value (DGV) and ambient groundwater.
 - c. At this point the calculations assume pit wall run-off is contributing to <20% inflow. This decreases further at year 20 and copper continues to exceed ANZECC & ARMCANZ 2000 Long-Term Irrigation Water due to the strong pit wall run-off signature (refer Section 5.2).
 - d. By Year 30, most CPEC are at ambient groundwater concentrations except cobalt and copper which exceed the average ambient ground water concentration (and Bundy TV).
3. With respect to Q29 Pit Lake, the scaled up leach (accounting for 0.35 Mt rock in Q29) adjusted for a literature based CSF with mean groundwater composition predicts:
 - a. When adopting the CSF and mean groundwater concentrations, lake water in Q29 pits is predicted to have high concentrations of CPEC (relative to screening criteria) for Years 1 – 5 after mining has ceased. This is largely driven by the surface water run-off contacting the PAF rock in pit walls (refer Section 5.2 for discussion on the likely overestimation of this term).
 - b. In year 10, cobalt, copper, nickel, and zinc are predicted to be elevated above the ANZECC & ARMCANZ 2000 Long-Term Irrigation Water and also the Mount Bundy TV, ANZG DGV and ambient groundwater. At this point the calculations assume pit wall run-off is contributing to 20% inflow. This decreases at year 20 and only copper continues to exceed ANZECC & ARMCANZ 2000 Long-Term Irrigation Water due to the strong pit wall run-off signature (refer Section 5.2). By Year 30, most CPEC are at ambient groundwater concentrations except cobalt, copper, and nickel, which exceed the average ambient ground water concentration (and maximum concentration, nickel excepted).
4. The calculations of course over simplify the development of the lakes. The calculations make several necessary simplifications and assumptions, most key being:
 - a. the in pit PAF continues to leach CPEC and act as a source term over the 30 year period despite being covered by lake water;
 - b. the assumption that release rates used represent all PAF rock in the pit and in the pit walls. A Monte Carlo type distribution of release rates married to a block model of lithology and S ratios with subsequent scaling concentrations would provide a fairer representation of CPEC release rate distribution over pit wall surfaces and in pit (or external to pit) waste rock storage/ placement.



5. Eight linkages were identified in the conceptual site model, concerning potential impacts to migratory avian species (and bats), human receptors (abstraction for drinking water external to the Site), stock watering and supply of water for groundwater dependant ecosystems.
 - a. Given the presumed nature of lakes recovery, the elevated concentrations predicted occur in the early recovery period where net flow outwards is minimal during recovery.
 - b. When the lakes recover the flow may become through flow and at this point the predicted concentrations are either below groundwater concentrations, laboratory limits of reporting (LOR) or in the case of cobalt, copper and nickel are still elevated above ecological criteria (i.e. ANZG DGV). The risk then may be mitigated by reactive retardation as the groundwater flows outwards from the pits, with respect to down hydraulic gradient receptors (groundwater dependant ecosystems).
 - c. Note that concentrations are not predicted to exceed stock watering criteria by year 10 post mining i.e. during the net inflow period. Tier 2 review of avian toxicity data does not indicate an unacceptable risk profile to migratory birds using the lakes during the recovery period or post steady state.
6. In reality, if the PAF rock is stored / managed appropriately to mitigate oxidation of sulfidic material, then release rates could be much lower, and subsequent leach concentrations would be lower.
7. Further, when the in pit material is covered and oxidation of sulfidic material lessens, the ongoing flux of CPEC to the water column would also diminish.
8. The current assumptions and simplifications also use no CSF or generic CSF, which also will likely overestimate CPEC concentrations.
9. It is possible that the CPEC may bind with available ferric oxyhydroxides (FeOH) or organic matter in terms of stratification and therefore have colloidal behaviour. Stratification due to salinity or temperature may develop and this may affect the distribution of elements in the lake water column.
10. When the pit is allowed to flood and contacts the in pit and wall PAF rock, this may cause a 'super' flush of acidity and metals/ metalloids to groundwater (potential risk where lake water flows outwards from the pit).
11. Interim management measures that mitigate oxidation and generation of acidity (and metal/ metalloids release) from stored PAF rock should be considered. It is understood that an acid mine drainage plan has been prepared.
12. Pit wall rock may represent a notable source of CPEC containing leach depending on rainfall events / volume and drainage from run-off will need to be managed accordingly to mitigate risk to external receptors.

We provide the following recommendations:

1. Consider oxygen consumption tests on PAF and PAF-LC rock to assess:
 - a. Annual rate of acidity generation (per kg, per m² and wt% FeS₂ – depending on material)
 - b. The reactive lifetime of the material



- c. Timing and magnitude of peak acidity
- d. Rate of ANC consumption
- e. 'Lag time' or onset to acid conditions

Oxygen consumption tests can be used to directly measure the sulfide oxidation rate of a material, supplementing yet overcoming the limitations of column leach and humidity cell tests (note that these tests have not been approved for use by any regulator):

- a. OxCon Rapid Oxygen Consumption Cell Test:
 - i. Determination of intrinsic sulfide oxidation rate, reactive lifetime of materials and the rate of ANC consumption under simulated site conditions.
 - b. OxCon Wallrock Oxygen Consumption:
 - ii. Determination of intrinsic sulfide oxidation rate, reactive lifetime of materials and the rate of ANC consumption.
 - iii. Sulfide oxidation rate as a function of surface area (m^2) under simulated site conditions.
2. Create a block model of the geology/ lithology to better understand the distribution of PAF rock and magnitude of release rates per area of pit wall – this should then allow refinement of the pit wall source and possibly an adjustment to the in pit release rate profile too.
 3. Consider reactive transport modelling for cobalt, copper and nickel at year 30 post closure to provide additional level of redundancy in terms of understanding fate and transport of these CPEC to down hydraulic gradient receptors assuming predications are not as conservative as believed to be.
 4. Review the predictions and discussions made within this report against the current acid mine/ rock drainage management plan to ensure consistency in proposed management measures with respect to the linkages identified and requirements for drainage management.

Please note the statement of limitations as Appendix H.



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1 INTRODUCTION

1.1 OVERVIEW

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The following is understood:

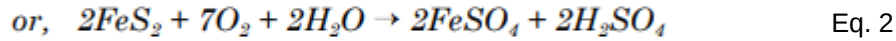
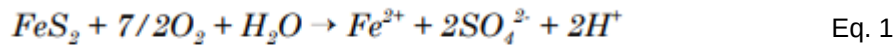
- Rustlers Roost (RR) and Quest 29 (Q29) are brownfield sites on Mineral Leases (ML) located in the Mount Bunday locality, approximately 85 km south-east of Darwin in the Northern Territory (NT). These sites will be redeveloped for open-cut mining involving connection of the non-contiguous areas by a haul road and construction of an accommodation camp (the Project). The sites have a history of gold mining activity with first gold being discovered in the 1940s and activities occurring over intermittent periods during the past 70 years.
- The mine sites are located approximately 11 km apart and are connected by an existing unsealed access track, which will be upgraded to accommodate haulage of ore from the Quest 29 satellite pits to a proposed processing facility at Rustlers Roost. Ore mined at both sites will be processed at a new purpose-built processing facility located at the Rustlers Roost site to produce gold bullion which will be trucked offsite for sale.
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- The Project includes the expansion of existing pits, waste rock landforms, water storage dams and internal roads. Two new pits will be constructed at RR and new infrastructure includes an onsite processing plant, a tailings storage facility (TSF), a landfill, laydown area, magazine, administration office, accommodation camp and groundwater bores for water supply. The Project includes an entire development envelope of 790 ha which is taken to be the maximum extent within which disturbance may occur. However, a large portion of the additional Project footprint is within historically disturbed areas.

1.2 CONTEXT

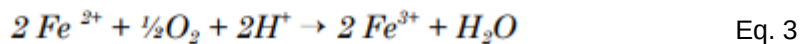
Acid mine drainage (AMD) (or Acid Rock Drainage, ARD) is the result of the combined chemical and biological oxidation of sulfide minerals and the concomitant release of associated metals, such as iron, aluminium, manganese, uranium, and other toxic heavy metals/ metalloids. The oxidation of pyrite, the predominant sulfide mineral, can be expressed by the following stoichiometric equations:



Pyrite Oxidation:



Ferrous iron (Fe^{2+}) is oxidized to its ferric state as follows.



Thus, the exclusion of oxygen mitigates the initiation of sulfide oxidation and the concomitant release of associated metals/ metalloids. Noting that once oxidation is initiated it is a self perpetuating reaction. The lack of oxygen only slows the rate of the reactions it cannot stop them.

The reaction given by Equation 3 is dependent upon the pH of the solution and presence of catalysts such as *Thiobacillus ferrooxidans* and other acidophilic bacteria. Under acidic conditions (pH 2 to 3), the biological oxidation rate is approximately 16 to 35 fold greater than the chemical rate.

Ferric iron does not remain in solution much above pH 2 to 3 where it is hydrolysed to $Fe(OH)_3$. Under more alkaline conditions $Fe(OH)_3$ is formed.

The placement of reactive waste under water cover has proven to be a highly effective method for AMD/ ARD control. Water cover is an effective barrier to the gaseous diffusion of oxygen.

The prime mechanism for oxygen entry into saturated reactive waste is by convective transport of dissolved oxygen in groundwater or infiltrating water. At the typical flows of water entering the submerged waste, oxidation rates are normally very low and of minor consequence. However, the flow of waters through the submerged wastes will slowly dissolve precipitates, buffering minerals and secondary minerals which will gradually release contaminants over time.

Open pit mines that have ceased production are increasingly being considered for the permanent and environmentally acceptable disposal of mine waste rock and tailings that are, or have the demonstrated potential to become, sources of acidic drainage.

There are four basic concepts for the placement of wastes in pits (refer MEND, 1995 for more detailed information):

1. Option 1 – Underwater disposal
2. Option 2 – Elevated water tables
3. Option 3 – Dry disposal
4. Option 4 – Perched water table within a cover system (to exclude oxygen)

Not all pits are suitable for the in-pit disposal of wastes. The success would depend on many technical factors, including:



- the acid generation potential of the wastes and pit walls;
- the degree of oxidation of the wastes (fresh or already oxidised)
- the geotechnical characteristics and properties of the wastes and the pit walls;
- predicted pore water, pit water, and groundwater quality;
- hydrogeology of the open pit; and
- the hydrology of the open pit.

Mine related constraints must also be taken into consideration. These include:

- sterilising remaining mineralisation below the pit;
- wall stability and related safety concerns;
- available access; and
- the proximity of underground workings to the open pit.

Consideration must be given to both the short term and long term implications of the in-pit disposal concept; these include ecological and human health protection and closure planning perspectives.

1.3 OBJECTIVE

The objective of this assessment is to provide potential water quality composition of key elements in pit lake water during and following recovery of the water table in each of the RR and Q29 pits.

1.4 SCOPE

The following tasks were formed the scope:

1. Undertake geochemical calculations/ modelling to predict the pit lake water quality where pit lakes are proposed post-mining, with respect to Rustlers Roost and Quest 29.



2 CONCEPTUAL SITE MODEL

2.1 GENERAL

The generation, release, mobility, and attenuation of mine drainage are complex processes governed by a combination of physical, chemical and biological factors (GARDGuide, 2015). The extent to which mine drainage enters and affects the environment depends largely on the characteristics of the sources, pathways and receptors which vary by commodity, climate, mine facility, and phase.

A conceptual site model (CSM) has been developed to identify potential source(s), pathway(s) and receptor(s) associated with the geochemistry of storing PAF rock within the Pit.

The CSM contributes to an understanding of possible effects posed to environmental values associated in pit storage of acid generating waste materials.

The following sections establish each of the source-pathway-receptor assessment components as well as the potential linkages formed where these three components are present.

2.2 MINE FEATURES

2.2.1 Rustlers Roost

According to CDM Smith (2021), the RR portion of the Project area is located on ML 1083 which covers approximately 756 ha. The current infrastructure and landforms at the Rustlers Roost mine area comprise the following (Figure 1-2, Appendix A):

- Associated open pits that have flooded and have become a single pit (approximate dimensions 50 m depth, 1,000 m length and 300 m width). The pit lake currently holds approximately 3.16 Gigalitres (GL) of water based on post mining pit shell bathymetry and current water level of 56.90 mAHD (surveyed on 3 November 2020).
- Remnants of old processing plant and ROM. In 1997 most of the plant, buildings and other mining infrastructure were removed, apart from three large tanks and some concrete footings.
- Annie Dam covering approximately 11.4 ha and with an estimated capacity of 200,000 kilolitres (kL).
- Existing waste rock dump (WRD), with approximate dimensions of 30 m high, 1,000 m long and 400 m wide.
- Two heap leach pads (total approximate dimensions 20 m in height, 600 m in length and 450 m width) and heap leach ponds.

The proposed development at RR includes the following key components:

- Processing plant and Run of Mine (ROM) - The processing facility will be constructed in the northern portion of Rustlers Roost, immediately north of the WRD and will be contained in an area approximately 1000 m long and 400 m wide.



- Expanded existing main pit and two minor pits - The RR main pit is proposed to be expanded by approximately 57% to the east and west and increased in depth from 50 m to 265 m. Dewatering of the pits will be undertaken with diesel powered in-pit sumps. Dewatering will occur as required as a result of direct precipitation from rain events and groundwater in-flow. To access ore that has been recently identified through drilling and to prevent future sterilisation through placement of the TSF over and immediately adjacent these areas, PGO is proposing to mine two small additional pits (Annie's Okaley and Annie's Dam Pits).
- Tailings storage facility - The TSF will be located in the southern section of ML 1083 and will occupy 243.0 ha of land. The TSF size is based on a nominal tailings disposal volume of 4 Mtpa for a total of 40 Mt capacity (i.e. 10 years production). The TSF will be raised in height progressively over a 10-year period to reach storage capacity for the LOM.
- Waste rock dumps – The area including and to the north of the existing U-shaped WRD will be the designated location for the disposal of waste rock from Rustlers Roost pit. Waste rock will be placed in two separate WRDs termed the northern WRD and the southern WRD. A total of 19.6 Mt of waste material will be produced from the main Rustlers Roost pit. Approximately 18 Mt will be placed within the surface WRDs and 1.6 Mt of fresh waste backfilled into the pits.
- Mine laydown area – A compacted earth mine laydown area covering approximately 6.0 ha will be constructed in the RR portion of the Project area.
- Administration facility – An administration facility covering approximately 0.42 ha will be constructed in proximity of the laydown area and processing facility in the north of RR.
- Landfill – A landfill is proposed to be constructed at RR encompassing largely disturbed land to the west of the main pit and east of the TSF. The landfill will be constructed over 4.0 ha to a depth of 5 m and be utilised for the 10-year Project period.
- The final post-mining landform is anticipated to predominantly contain the mined main pit shells, with the Annie's Okaley pit backfilled and Annie's Dam pit consumed within the TSF. The elevated WRD, landfill and TSF will be surrounded by water diversion berms and capped. It is anticipated refilling of the main pit shell will result in one remaining pit lake (i.e. RR).

2.2.2 Quest 29

- Q29 is located 10 km south-east of RR; and is located across five MLs (i.e. ML 29781, ML 29782, ML29783, ML 29785 and ML 29786), which collectively cover approximately 658 ha. There are currently no proposed activities, other than exploration, on Q29 ML 29781, ML 29785 or ML 29786. Therefore, the Q29 portion of the Project area only includes mining lease ML 29783.
- The current infrastructure and landforms at the Q29 mine area comprise the following (Figure 1-3, Appendix A):
- Five open-cut pits, being the BHS Pit, North Koolpin Pit, West Koolpin Pit (South Koolpin Pit), Zamu Pit and Taipan Pit (based on information in EIS appendix H)
- with dimensions of the largest of the pits approximately 25 m depth, 280 m length and 50 m width);
- Five WRDs (largest of the WRDs approximately 10 m height, 280 m length and 80 m width);



- One heap leach pad (approximate dimensions 20 m in height, 200 m length and 200 m width);
- Heap leach pond; and
- Remaining infrastructure of the Carbon in Leach (CIL) tanks.

The proposed development at Q29 included the following:

- Expanded existing pits – The five existing pits at Q29 are proposed to be expanded and mined to a depth of 75 m from the current depth of 25 m. On completion of mining Zamu pit, the pit will be backfilled with waste material from mining of the remaining Quest 29 pits;
- Waste rock dump - The proposed surface WRD at Q29 will be developed in the area north of Zamu Pit. This was selected to minimise haulage distances for the initial stage of mining Zamu pit. During construction the WRD face angle will be 37°, with a berm width of 19.5 m and 4 x 10 m lifts. The WRD construction will commence with the placement of non-acid forming (NAF) material for the base and outer annulus. Potential acid forming (PAF) material encountered will be placed onto of the NAF base and encapsulated within the centre of the WRD. No PAF material will be placed on outer perimeter, slopes, toe, surface or base of the dump; and
- The final post-mining landform is anticipated to contain the mined pit shells, with Zamu pit predominately backfilled using waste rock material, surrounded by water diversion berms and the capped WRD. It is anticipated refilling of the pit shells will result in five remaining pit lakes.

2.3 PAF STORAGE/ MANAGEMENT CONCEPT

The current proposed PAF management strategy is to store a portion of waste PAF rock within the pits:

- 1.6 Mt to RR; and
- 0.35 Mt to Q29 pits
- With balance of rock to surface WRDs

A key benefit of sub-aqueous disposal is the exclusion of oxygen in order to prevent oxidation (or minimise ongoing oxidation) of sulfide in the rock.

2.4 GROUNDWATER AFFECTING ACTIVITIES

Mining related (ground)water affecting activities (WAA's), are those development activities that have the potential to interact with groundwater and alter groundwater conditions from the baseline, and hence are relevant as potential origins for environmental hazard(s).

An important component of this study is understanding its direct effect on the baseline groundwater regime and the effects this may cause to Environmental Values (EVs). There are three categories of direct groundwater effects potentially relevant to this study that may be realised as a result of PAF rock in pit potential WAAs:

- **Altered groundwater quantity**
Seepage to the water table from the exposed rock face opened up by the in pit storage of waste rock (both NAF and PAF).



- **Altered groundwater quality**

Seepage to the water table from the in pit waste rock (both NAF and PAF) – a function of the geochemistry of the waste materials. Solutes then have the capacity to be transported away from beneath these facilities towards EVs under newly established hydraulic gradients.

- **Physical disruption of aquifers**

The development of pit voids below the water table will interfere with the baseline groundwater flow regime (drawing groundwater towards them during mining as well as after closure where a void will remain), this has the potential to mitigate transport of seepage impacted groundwater away from the mine site during mining and post-closure.

These potential direct effects and other mechanisms which may occur over the life of the mine and post closure have been linked to the hydrogeochemical processes occurring at the site to develop a (hydro)geochemical (CSM) (Table 2-2).

This hydrogeochemical CSM presented here is a representation of the physical and chemical processes that determine the way in which waste rock related elements may move from source areas containing the identified source materials through the environmental media (including soil, water, and air, all of which have the capacity to transport contaminants) to affect potential receptors.



Table 2-1 Water Affecting Activity for the Pits

Water affecting activity		Potential direct effects			Potential water quality at closure
		Quantity	Quality	Aquifer disruption	
Mine pit at closure	Open pit	Groundwater will flow to the Pit void under gradients established by evaporative discharge from the void and any temporary water body formed within	Water collecting within open void may have increased concentrations of metals, metalloids and acidity	Open pit will interrupt groundwater flow regimes within the different Hydro stratigraphic units (HSUs) that are intersected	- Exposure to PAF materials will increase the solute load to groundwater - Evapo-concentration of incidental water within the open Pit will increase the concentration of all solutes accumulated on the walls/ base of the Pit and within any temporarily present water. - Note there is a maximum value for total dissolved solutes at which evapo-concentration stops (around 400,000 mg/L), thus evapo-concentration is a finite process. - Water quality within the Pit at any point in time will be a function of the mass balance of water and solute; mass in (water and mass of solute) and mass out (dispersion and rate of evaporation)



2.5 SOURCES

The geology of the project site provides the sources of the chemical substances of potential environment concern (CPEC). These chemicals are naturally present in the environment. Based on the data provided in the geochemical report generated for the site natural enrichments of metals and metalloids are present in these geological materials.

Table 2-2 Identified Sources

Geochemical Source (S)	Description	Discussion	Considered herein
S1	PAF rock disposed to Pit	It is understood that PAF rock will be placed in the Annie Oakley Pit (RR) and Zamu Pit (Q29): RR in pit PAF = 1.6 Mt Q29 in pit PAF = 0.35 Mt	☒
S2	PAF rock in Pit Walls	Exposed PAF rock in pit walls. Area of PAF rock in pit walls estimated by Hanking to be: RR = 436,200 m ² Q29 = 63,992 m ² total (adopt BHS area = 19,300 m ² noting backfilling of Zamu.	☒

The source term can be defined as the suite of elements with a propensity to leach from the source material. The source term is further refined by screening the concentrations measured in any leachate generated against generic water quality guideline concentrations. This process provides an assessment of the risk these concentrations may pose to EV's. The screening process is summarised in the process flow diagram in Figure 3-1 in Section 3.

2.6 PATHWAYS

A pathway is the route along which a solute might move through the environment from its source to an EV. Potential pathways considered for the site are presented in Table 2-3.



Table 2-3 Identified pathways

Pathways (P)	Description	Relevant to this study?
P1	Groundwater inflow to the Pit and contact of water with exposed oxidised rock / materials	☒
P2	Direct biota uptake / contact of Pit water	☒
P3	Vertical or lateral migration of solutes from the Pit to the external groundwater	☒
P4	Abstraction and use (environmental values) of groundwater external to the Pit following P3 (now / future)	☒
Key: ☐ Not identified or not relevant, not considered further in this assessment ☒ Potentially relevant, considered in this assessment		

In summary, four pathways are considered relevant with respect to connection of the source (exposed waste rock and wall rock in the Pit) to receptors (ecology and identified environmental values of groundwater).

2.7 RECEPTORS

2.7.1 Beneficial use of groundwater

Three historical monitoring bores exist within the Project area, with one at RR and two at Q29. Bore MB01 at RR is to the south of the heap leach pad, between the pad and the leach ponds. The Q29 bores are located in the northern section of the Project area between the DHS pit and the leach pad and leach ponds (Q29MB01 and Q29MB02). Due to the lack of historic groundwater monitoring bores in the Project area, knowledge of historic groundwater quality is deficient. Existing water quality results indicate that groundwater may have been locally impacted by historical mining activities (i.e. Q29MB01 and Q29MB02).

Background groundwater quality at RR from historical bore reports with available water quality data (five bores drilled in 1994 and one bore drilled in 1985), indicate freshwater quality with an average pH of 6.8 and EC of 114 $\mu\text{S}/\text{cm}$. Water quality from two sampling occasions indicate pH values are slightly acidic, ranging between 5.9 to 6.2, EC is low (110 to 140 $\mu\text{S}/\text{cm}$) and exceedance of the aquatic ecosystem protection guidelines values (GVs) for Zn and Ni.

Background groundwater quality at Q29 from historical bore reports with available water quality data (one bore drilled in 1999 and two bores drilled in 1976), indicates that groundwater is fresh and good quality, with an average pH of 7.06 and an EC of 262 $\mu\text{S}/\text{cm}$.

Recent monitoring of Q29MB01 shows elevated EC and dissolved metals in comparison to other sites. pH values range between 6.09 to 7.33, and elevated EC, well above the aquatic ecosystem protection GV of 250 $\mu\text{S}/\text{cm}$ (ranging from 210 to 1,213 $\mu\text{S}/\text{cm}$) and exceedance of the ecosystem protection GV for Al, As, Cd, Cr, Cu and Zn.



Q29MB02 located west of the heap leach ponds and pad at Quest 29, has had elevated EC and occasional exceedances of the aquatic ecosystem protection GVs for As, Cd, Cr, Cu, Pb and Zn. pH values range from slightly acidic (6.49) to slightly alkaline (7.6), and elevated EC, above the aquatic ecosystem protection GVs of 250 $\mu\text{S/cm}$ (ranging from 210 to 336 $\mu\text{S/cm}$).

Additional monitoring bores were constructed in 2020 in the RR and Q29 portions of the Project area to improve understanding of groundwater quality.

Based on the beneficial use declaration (BUD) for areas downstream of the Project, beneficial uses for the receiving environment include:

- Agricultural and stock water supply;
- Environmental and riparian; and
- Cultural.

2.7.1.1 Agricultural and Stock Water Supply

The aim of the BUD is to maintain the productivity of the land and the water resource to ensure agricultural and stock water supply in accordance with the principle of ecologically and economically sustainable development.

Historically the RR and Q29 Project area has been concurrently used for pastoral activities like grazing of native vegetation by cattle as the mining leases are located on Old Mount Bunday Station and McKinlay River Pastoral Station.

It is understood that an access agreement exists with the existing leaseholder of Old Mount Bunday Station.

A separate agreement with the leaseholder of McKinlay River Station will be finalised prior to Project construction and is expected to align with the existing agreement. The agreements require that the mine owner / operator, consistent with operational requirements and approval conditions, take reasonable measures to limit interference with surface and groundwater resources, to maintain water quality suitability for stock water supply in accordance with ANZECC (2000) stock drinking water guidelines.

The predominant agricultural land use in the region includes pastoral stations and orchards, with the most extensive land use in the vicinity of the Project area being pastoral, involving low intensity grazing of beef cattle over the woodland terrain.

Grazing is also widespread in neighbouring areas including Adelaide River, Jabiru, Pine Creek and further afield in the greater Darwin and Katherine regions. Smaller agricultural activities like orchards and aquaculture have been identified within the BUD areas.

2.7.1.2 Environmental and Riparian

Identified environmental values such as the wetland and permanent water bodies in the Mary Floodplain for surface water BUD and riparian vegetation associated with groundwater dependent ecosystems for groundwater are dependent on good water quality and reliable stream flows. The surface water in the lower Mount Bunday creek as a tributary to the larger Mary River Floodplain system is connected to the Project area and is of significance for the health of the aquatic ecosystems downstream of the Project area.



2.7.1.3 Cultural

The BUD also recognises that water resources have important cultural and spiritual values, particularly for indigenous peoples. While there were no recorded or registered sacred sites identified during an AAPA Certificates search, culturally significant areas relevant to the BUD and downstream of the Project area have been identified in the environmental impact statement (EIS).

Other cultural use may include recreational activities. For example, the Mary River floodplain is a major tourist and recreational fishing attraction for the region. Recreational fishing locations downstream within the Mary River system includes Hardies Creek (approximately 10 km downstream from the Arnhem Highway crossing), Corroboree Billabong (approximately 20 km downstream) and Shady Camp (approximately 60 km downstream). In addition, the Adelaide River floodplain is also a major tourist attraction for recreational fishing in the region.

While there is no specific guidance for protection of these values in the ANZG (2018) guidelines, consideration must be given to cultural issues in the planning and management of water resources. For example, to maintain water quality that supports cultural values the specific water quality objectives for the relevant environmental values are applied (e.g. ANZG (2018) 95% species protection) in the Project water management plan (WMP).

In accordance with the surface water and groundwater beneficial use declarations, water quality objectives and indicators need to be considered within the Project area to protect the following beneficial uses/environmental values:

- Water use for agricultural purposes – irrigation water for primary production;
- Water use for farming purposes – livestock water supply;
- Health of aquatic ecosystems; and
- Cultural and spiritual environmental values.

2.7.1.4 Applicable Water Quality Criteria

Based on the identified beneficial uses, the following default guideline values have been adopted:

- The toxicant Default Guideline Values (DGVs) for the protection of freshwater ecosystems protection, as per the 2018 *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG, 2018). DGVs have been developed for three categories of current or desired ecosystem conditions, i.e:
 - o High conservation or ecological value systems. Where local biological or chemical data have not yet been gathered, the 99% species protection default guideline values (DGVs) apply, if they exist.
 - o slightly to moderately disturbed systems. For toxicants in water, apply 95% species protection DGVs, or 99% species protection for highly bioaccumulating toxicants, if local biological-effects data are unavailable.
 - o highly disturbed systems. For toxicants in water, the 90% or 80% species protection DGVs are considered acceptable.

The Mount Bunday catchment is classified as “tropical lowland rivers and streams” and is considered a highly disturbed ecosystem.



- The livestock (beef cattle) drinking water trigger values, as per the ANZECC 2000 Water Quality Guidelines (ANZECC/ARMCANZ, 2000); and
- The short- and long-term trigger values in irrigation water, as per the ANZECC 2000 Water Quality Guidelines (ANZECC/ARMCANZ, 2000).

As per the ANZG 2018 Water Quality Guidelines, ideally site-specific guideline values that are relevant to local conditions or situations should be used instead of default guideline values. Site-specific guideline values have not yet been developed for the Project area. However, in 2015 site-specific trigger levels (SSTVs) were developed for discharge of treated water into the Mount Bundy Creek from the Toms Gully Project Area, which is located about 10kms to the north of the Project area. In 2018, the CSIRO undertook a review of these SSTVs (Stauber & Batley, 2018) and proposed revised wet-season SSTV for the discharge point or compliance site at Toms Gully Mine (SWTG2) after dilution.

Figure 2-1 Project water quality criteria

Parameter	Units	SSTV ^(A)	Tropical Australia Lowland Rivers ^(B)	Freshwater Aquatic Ecosystem 95% Protection Level	Livestock Watering (Beef cattle)	Irrigation	
						Long Term	Short Term
Physico-chemical							
pH	-	5.8 – 8.0	6.0 – 8.0	-	-	-	-
Electrical Conductivity	µS/cm	41	20 – 250	-	-	-	-
Dissolved Oxygen	% sat	-	85 – 120	-	-	-	-
Total Dissolved Solids	mg/L	-	-	-	4,000	-	-
Total Suspended Solids	mg/L	54	-	-	-	-	-
Turbidity	NTU	87	2 – 15	-	-	-	-
Metals/metalloids							
Aluminium (pH <5.5)	mg/L	-	-	-	5	5	20
Aluminium (pH >5.5)	mg/L	0.295	-	0.035	5	5	20
Arsenic (As III)	mg/L	0.042	-	0.024	0.5	0.1	2.0
Arsenic (As VI)	mg/L	-	-	0.013	0.5	0.1	2.0
Cadmium	mg/L	0.0004	-	0.0002	0.01	0.01	0.05
Chromium (Cr III)	mg/L	0.006	-	-	1	0.1	1
Chromium (Cr VI)	mg/L	-	-	0.001	1	0.1	1
Cobalt	mg/L	-	-	-	1	0.05	0.1
Copper	mg/L	0.0018	-	0.0014	2	0.2	5
Iron	mg/L	2.7	-	-	-	0.2	10
Lead	mg/L	0.0036	-	0.0034	0.1	2	5
Manganese	mg/L	2.5	-	1.9	-	0.2	10
Nickel	mg/L	0.013	-	0.011	1	0.2	2
Selenium (total)	mg/L	-	-	0.011	0.02	0.02	0.05
Uranium	mg/L	-	-	-	0.2	0.01	0.1
Zinc	mg/L	0.015	-	0.008	20	2	5
Major Ions							
Calcium	mg/L	-	-	-	1,000	-	-
Magnesium	mg/L	-	-	-	2,000	-	-
Sulfate as SO ₄	mg/L	210	-	-	1,000	-	-
Nutrients							
Ammonia	mg/L	1.4	0.01	0.9	-	-	-
Nitrate	mg/L	-	-	-	400	-	-
Nitrite	mg/L	-	-	-	30	-	-
Nitrite + Nitrate as N	mg/L	-	0.01	-	-	-	-
Total Nitrogen as N	mg/L	-	0.2 – 0.3	-	-	5	25 – 125
Total Phosphorus as P	mg/L	-	0.01	-	-	0.05	0.8 – 12

^(A): Toms Gully Project SSTVs (Stauber & Batley, 2018)

^(B): As per Table 3.3.4 and Table 3.3.5 in ANZECC & ARMCANZ 2000 Water Quality Guidelines for lowland rivers.

2.7.2 Summary of relevant receptors

For the source pathway receptor assessment, the receptor (R) represents the component, or receiving environment of an EV. These are summarised in Table 2-4.

Table 2-4 Identified Project area EVs

Environmental value ¹		Details
Ecosystem health	RAMSAR listed wetlands	☒ None identified
	Conservation category or Resource enhancement wetlands	☒ None identified
	Directory of Important Wetlands in Australia wetlands	☒ None identified
	Environmental Protection Policies wetlands	☒ None identified
	Wild rivers	☒ None identified
	Poorly represented wetlands in Conservation reserves system	☒ None identified
	Groundwater Dependant Ecosystems supporting significant flora, vegetation and fauna	There are no mapped Type 1 Groundwater dependant ecosystems (GDEs) within either the Project area (including the general region) or downstream (the Northern Territory has not been mapped for type 1). In addition, there are no type 2 GDEs mapped within the Project area; however, the lower reaches of Mount Bunday Creek, the McKinley River and lower reaches of Marrakai Creek are mapped as having a high potential for aquatic GDEs.

Environmental value ¹		Details
		The GDE Atlas maps Type 2 GDEs (i.e. surface expressions) as potentially occurring consistently along the entire length of the downstream receiving watercourses including the Adelaide River and Mary River (Figure 4-6). Similarly, Type 3 terrestrial GDEs are mapped as potentially occurring along large portions of the downstream area, but at a much broader scale (i.e. greater width along the riparian corridor). However, type 3 GDE mapping extends further upstream in both Marrakai Creek and Mount Bunday Creek, in proximity to the haul road. Potential GDE mapping covers areas mapped as potential habitat for threatened species. It is likely that swathes of the mapped downstream habitat access water through either surface expression of groundwater (Type 2) or subsurface groundwater (Type 3). Aquatic habitat values that provide for aquatic plants in the Project area are limited by the ephemeral nature of flows in the higher order watercourses that drain the sites and the lack of natural permanent water bodies. No submerged aquatic plants were identified during the surveys. This underpins the highly ephemeral nature of the creeks and drainage lines (AES 2019). However, images from site inspections indicate the presence of aquatic vegetation at numerous locations related with previous mining and pastoral activities within the Project area (Annie's Dam, RR and Q29 pit lakes and leach ponds). These waterbodies, however, will be predominantly consumed by new and extended mining infrastructure. Migratory species may use accessible water bodies for bathing/ drinking (i.e. bird and bat species).
	Ecosystems supporting significant amenity, recreation and cultural ^[4] values	☒ See Table 2-5
	Saline lakes, estuaries and near shore ecosystems	☐ None identified
	Downstream marine ecosystems	☐ None identified
Beneficial use	Drinking water supplies	☐ None identified
	Water supplies supporting significant commercial activities, e.g. mining and pastoral	☒ Livestock watering - See Table 2-5
	Inland waters with high levels of active and passive recreation including multiple use wetlands	☒ See Table 2-5
	Inland waters with significant cultural ^[4] or aesthetic values	☒ See Table 2-5

Key: ☐ Not identified or not relevant, not considered further in this assessment
☒ Relevant, considered in this assessment



These EVs can be summarised into a short list of potential receptors that can be easily linked to generic guideline concentrations for any identified COPC (Table 2-5).

Table 2-5 Potentially relevant receptors

Receptor (R)	Description
R1	Migratory Birds (or other Fauna such as Bats) accessing Pit Lakes Pit lake water has been known to impair the reproduction and survival of aquatic birds due to the high potential for dietary toxicity through food chain bioaccumulation (Ramirez and Rogers, 2000 - it is noted that the method of transfer was that lake water was used for irrigation onto grassland and the selenium was taken up via soil / flora accumulation rather than direct consumption (ingestion) of water). Acidic water can cause severe trauma to bird gastrointestinal tracts and eventual death. The acidic water also removes natural oils from the birds' feathers causing them to die by drowning or hypothermia. This has caused large scale bird deaths at the Berkeley Pit in Montana, United States in 1995 and 2016 (Guarino, 2016).
R2	Future Human Use Cultural use may include recreational activities. For example, the Mary River floodplain is a major tourist and recreational fishing attraction for the region. Recreational fishing locations downstream within the Mary River system includes Hardies Creek (approximately 10 km downstream from the Arnhem Highway crossing), Corroboree Billabong (approximately 20 km downstream) and Shady Camp (approximately 60 km downstream). In addition, the Adelaide River floodplain is also a major tourist attraction for recreational fishing in the region. While there is no specific guidance for protection of these values in the ANZG (2018) guidelines, consideration must be given to cultural issues in the planning and management of water resources. For example, to maintain water quality that supports cultural values the specific water quality objectives for the relevant environmental values are applied (e.g. ANZG (2018) 95% species protection) in the Project WMP. In accordance with the surface water and groundwater beneficial use declarations, water quality objectives and indicators need to be considered within the Project area to protect the following beneficial uses/environmental values: ☐ Water use for agricultural purposes – irrigation water for primary production; ☐ Water use for farming purposes – livestock water supply; ☐ Health of aquatic ecosystems; and ☐ Cultural and spiritual environmental values.
R3	Stock Watering The predominant agricultural land use in the region includes pastoral stations and orchards, with the most extensive land use in the vicinity of the Project area being pastoral, involving low intensity grazing of beef cattle over the woodland terrain. Grazing is also widespread in neighbouring areas including Adelaide River, Jabiru, Pine Creek and further afield in the greater Darwin and Katherine regions. Smaller agricultural activities like orchards and aquaculture have been identified within the BUD areas.



Receptor (R)	Description
R4	Groundwater dependant ecosystems (GDE) Identified environmental values such as the wetland and permanent water bodies in the Mary Floodplain for surface water BUD and riparian vegetation associated with groundwater dependent ecosystems for groundwater are dependent on good water quality and reliable stream flows. The surface water in the lower Mount Bundey creek as a tributary to the larger Mary River Floodplain system is connected to the Project area and is of significance for the health of the aquatic ecosystems downstream of the Project area.

2.8 POTENTIAL IMPACT LINKAGES

The fundamental concept of the assessment is that first there should be an exposure pathway (which incorporates an exposure route) linking a source with a receptor. Where a linkage exists, an assessment of the nature and significance of the exposure pathway is required to determine the level of threat posed.

Assessment of proposed mine features and related hydrogeochemical processes and source terms (CPEC exceeding tier 1 criteria) indicates that there are relevant sources (S1 and S2). There are identified receptors. There are also potential pathways linking these sources and receptors. These three components (source-pathway-receptor) are assembled into individual linkages that require further (tier 2) assessment.

A total of 8 linkages are identified as being potentially relevant / significant (Table 2-6).



Table 2-6 Potential impact linkages

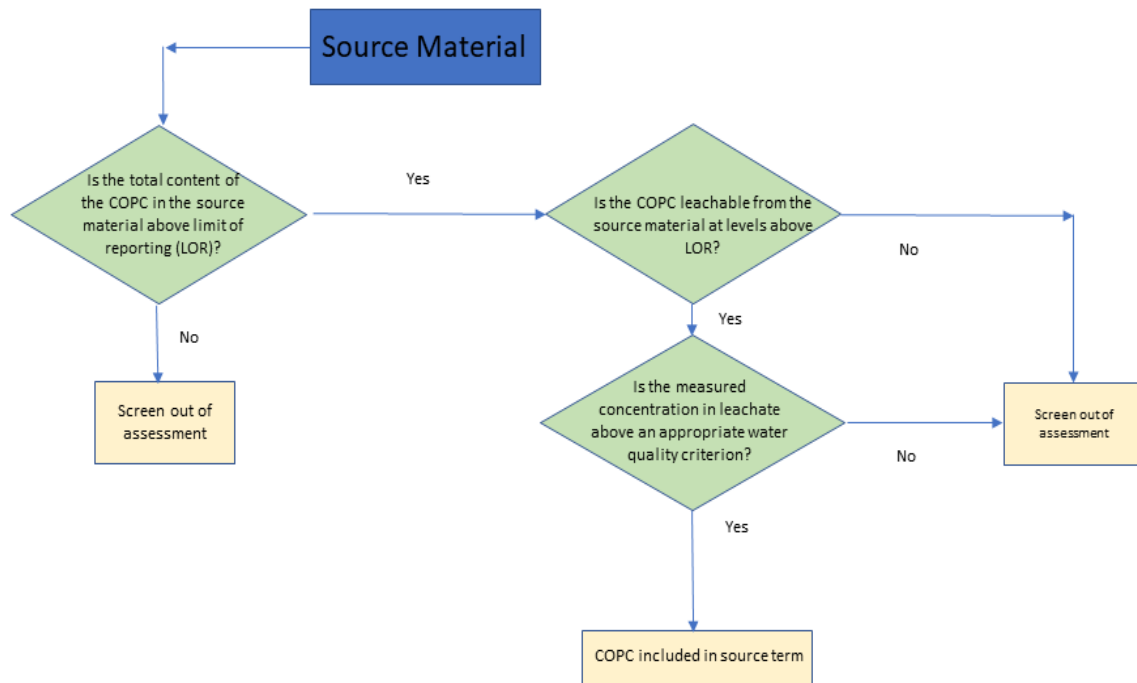
Source (S)	Primary Pathway (P) ^[2]	Secondary Pathway (P)	Tertiary Pathway (P)	Receptor (R)	Linkage # (L)
S1 – PAF rock in the pit	P1 - Groundwater inflow and contact with exposed oxidised rock / materials	P2 - direct uptake / contact	-	R1 Migratory Birds/ Bats or other fauna accessing the Pit (contact)	L1
	P1 - Groundwater inflow (and/ or rainfall) and contact with exposed oxidised rock / materials	P3 - Lateral migration of solutes away from the Pit	P4 - Abstraction	R2 Future Human Use	L2
			P4 - Abstraction	R3 Stock watering	L3
			P2 - direct uptake / contact	R4 GDE	L4
S2 Pit wall rock	P1 - Groundwater inflow and contact with exposed oxidised rock / materials	P2 - direct uptake / contact P3 - Lateral migration of solutes away from the Pit	-	R1 Migratory Birds (contact)	L5
			P4 - Abstraction	R2 Future Human Use	L6
			P4 - Abstraction	R3 Stock watering	L7
			P2 - direct uptake / contact	R4 GDE	L8

3 SOURCE TERM

3.1 CONTEXT

The source term represents the composition of chemical leachate / seepage arising from the waste rock. The source term is derived from geochemical (kinetic) testing and the derivation process is summarised in the process flow diagram in Figure 3-1.

Figure 3-1 Source term screening process



Where COPC = contaminant of potential concern = CPEC

The source term will be contributed to by inputs of water, in this case groundwater as the pits recover post mining, plus also rainfall and surface water run-off.

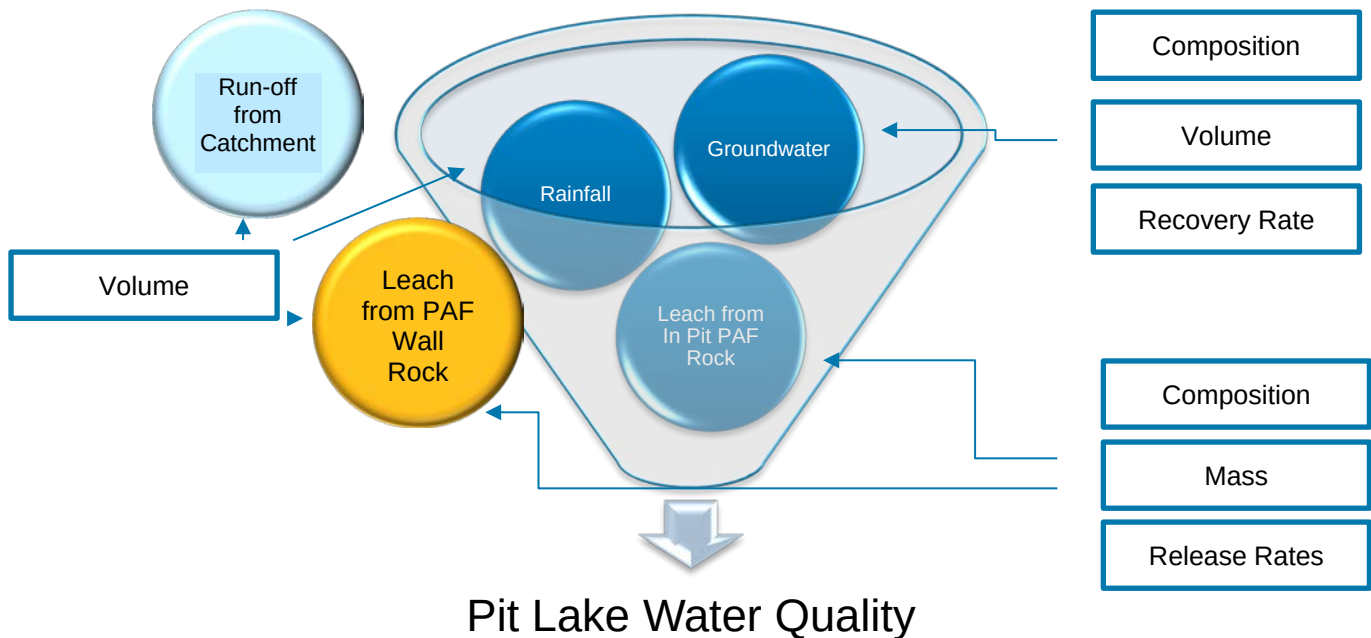
It is therefore important to consider ambient / background groundwater quality to assess:

1. elements that may already be above SSTV or applicable water quality criteria; and
2. understand groundwater composition with view to 'mixing' of source term leach (this obviously also includes dilution).

For the purposes of assessment and source term derivation, rainfall and surface run-off are taken to not have significant ionic or elemental composition prior to contact with waste rock, i.e. they act in a dilutary sense only.



Figure 3-2 Simplistic conceptualisation to pit lake water quality predictions



There are many other inputs and outputs that shape pit lake development and quality.

3.2 COLUMN LEACH TESTING

Continuous column leach tests are typically conducted by filling a length of pipe or funnel with a solid sample and continuously passing water (or another leachant) or adding the water at specific frequencies through the sample for a specified period. Leachate samples can be collected at any desired frequency and analysed for any constituent of interest. There are many variables in column leach test design, including:

- Column length and diameter
- Flow type (forced flow from bottom or gravity flow from top)
- Flow rate/residence time
- Sample pre-treatment (particle size reduction, oxidation, bacterial inoculation)
- Leaching composition (water or another reagent, sparged to remove O₂, etc.)

Column tests are well-suited to determining the concentrations of constituents that can be released over a relatively small number of pore volumes, which corresponds to shorter time periods. Noting that



there is no one standard method for how these data are used to predict drainage quality. The methods are site specific.

The column method adopted for the RR and Q29 project was the AMIRA 2002 Kinetic column test method where funnels are packed with approximately 1-2kg of material and flushed with water. Water is applied at a rate of 100mls/kg per week (weeks 1 and 2) and then at 400ml/kg weeks 3 and 4. The columns are subjected to heat for 12 hours of each day, and the leachate is collected every 4 weeks.

3.3 PROJECT WATER QUALITY

3.3.1 Rustlers Roost

Piper diagram of various waters associated with the project is presented as Figure 3-3. Based on the field water quality parameters, it can be concluded that the groundwater at RR:

- Is acidic to slightly acidic, with pH levels varying from 3.77 to 6.78, with an average of 5.7. To a minor degree, pH levels vary with rainfall. pH levels in monitoring well RRMB07 are more acidic (i.e. between 3.8 and 4.4) than in the other monitoring wells (i.e. between 5.1 and 6.8). RRMB07 is located north of the open pit;
- Is fresh, with electrical conductivity (EC) varying from 36 $\mu\text{S}/\text{cm}$ to 305 $\mu\text{S}/\text{cm}$, with an average of 155 $\mu\text{S}/\text{cm}$, and total dissolved solids (TDS) varying from 23 mg/L to 196 mg/L, with an average of 105 mg/L;
- Has low dissolved oxygen levels, ranging from 1% to 40% saturation, with an average of 13%; and
- Has bicarbonate alkalinity (as CaCO_3) ranging from 2 mg/L to 195 mg/L, with an average of 68 mg/L.

Piper diagrams of groundwater (historical and current data) and open pit water are presented Figure 3-3. Based on the ionic composition:

- The groundwater at wells RRMB02, RRMB03, RRMB04, RRMB05, RRMB06, RRMB07 and RRMB08 can be classified as a “calcium-magnesium-bicarbonate” water type;
- The groundwater at well RRMB01 can be classified as a “mixed sodium-bicarbonate-chloride” water type.
- Monitoring well RRMB01 is located adjacent to the former heap leach pad. Groundwater quality in well RRMB01 shows evidence of influence from potential waste rock leachate; and
- The water in the open pit can be classified as a “calcium-magnesium-bicarbonate” water type.

Detailed groundwater, open pit and surface water analysis results, with comparison against the adopted water quality guidelines/ trigger values are presented in Appendix B.

With respect to the groundwater exceedances of the adopted water quality guidelines/ trigger values:

- Exceedances of the adopted trigger values for aquatic ecosystems are summarised in Table 3-1. It must be noted that, given the absence of GDEs in the Project area and the absence of groundwater discharge into local creeks and drainages, these trigger values are only relevant in case of abstraction of groundwater and discharge to surface water (e.g. for pit dewatering);



- There were no exceedances of the water quality guidelines for livestock watering; and
- Exceedances of the long-term irrigation guideline values were observed for iron, manganese, and total phosphorus in some of the wells.

Figure 3-3 Piper diagram of project area water types (CDM Smith 2021) groundwater at left, Rustlers Roost pit at right)

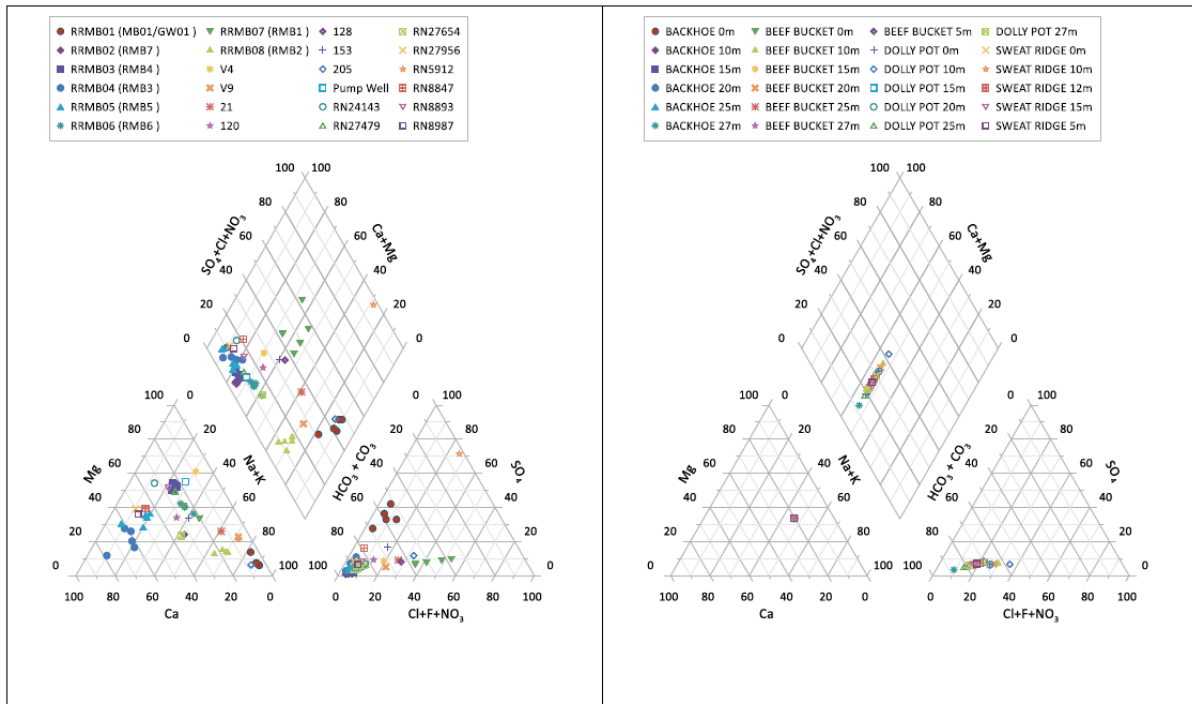


Table 3-1 Rustlers Roost Summary of Groundwater Exceedances of Aquatic Ecosystem Trigger Values (Table 4-17 From CDM Smith, 2021)

Analyte	RRMB01	RRMB02	RRMB03	RRMB04	RRMB05	RRMB06	RRMB07	RRMB08
Field Readings								
Electrical Conductivity	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes
pH	Yes	-	Yes	-	-	Yes	Yes	Yes
Turbidity	-	-	-	-	-	-	-	-
Metals (dissolved)								
Arsenic	-	-	-	-	Yes	Yes	-	-
Chromium	-	-	-	Yes	-	-	-	-
Copper	Yes	Yes	Yes	-	-	Yes	Yes	Yes
Lead	-	-	Yes	-	-	-	Yes	-
Zinc	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes
Nutrients								
Ammonia	Yes	-	-	-	-	-	-	-
Physico-chemical								
pH (lab)	Yes	-	-	-	-	-	-	-
Total Suspended Solids	Yes	-	-	-	-	-	-	-
Turbidity	Yes	-	-	-	-	-	-	-

Notes:

Light green highlight: only exceeds the Toms Gully SSTV

Light blue highlight: only exceeds the ANZG 2018 trigger value

Overall, the groundwater quality monitoring has shown groundwater is typically fresh, acidic to near neutral and has exceedances of aquatic ecosystems guideline values (GVs) for some metals and nutrients at some sampling occasions and locations. The elevated phosphorus and metal concentrations may be associated with underlying mineralogical deposits with more readily leachable weathered zones.

The groundwater monitoring bores show limited impacts from previous mining activities. Only RRMB01, which is located next to the heap leach pad, shows signals of influence from potential waste rock leachate.

3.3.2 Quest 29

Based on the field water quality parameters, it can be concluded that the groundwater at Q29:

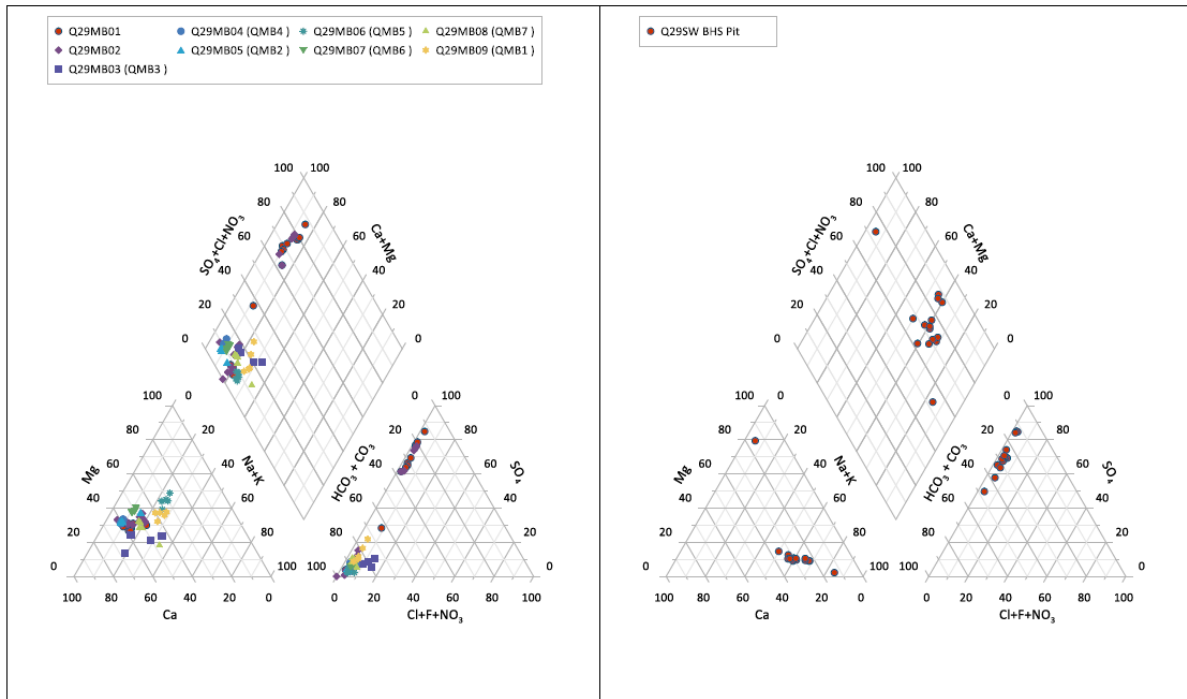
- Is acidic to neutral, with pH levels varying from 4.47 to 7.6, with an average of 6.38. To a minor degree, pH levels vary with rainfall. pH levels in monitoring well Q29MB03 are more acidic (i.e. between 4.47 and 5.86) than in the other monitoring wells (i.e. between 4.73 and 7.33);
- Is fresh, with electrical conductivity (EC) varying from 4.3 $\mu\text{S}/\text{cm}$ to 1,213 $\mu\text{S}/\text{cm}$, with an average of 473 $\mu\text{S}/\text{cm}$, and total dissolved solids (TDS) varying from 25 mg/L to 676 mg/L, with an average of 247 mg/L;
- Has low dissolved oxygen levels, ranging from 1% to 60% saturation, with an average of 9%;
- Has bicarbonate alkalinity (as CaCO_3) ranging from 12 mg/L to 255 mg/L, with an average of 136 mg/L.

Piper diagrams of groundwater and open pit water are presented on Figure 3-4. Based on the ionic composition:



- The groundwater at wells Q29MB03, Q29MB04, Q29MB05, Q29MB06, Q29MB07, Q29MB08 and Q29MB09 can be classified as a “calcium-magnesium-bicarbonate” water type;
- The groundwater at wells Q29MB01 and Q29MB02 can be classified as a “calcium-magnesium-sulphate” water type. These wells are located near the BHS heap leach pad and groundwater may have been impacted by leachate from the heap leach pad; and
- The water in the open pit can be classified as a “sodium-chloride” water type.

Figure 3-4 Piper Plots of Groundwater (left) and Open Pit Water (Right) at Q29 (Figure 4-20 of CDM Smith, 2021)



Detailed groundwater, open pit, and surface water analysis results, with comparison against the adopted water quality guidelines/trigger values are presented in Appendix B.

With respect to the groundwater exceedances of the adopted water quality guidelines/trigger values:

- Exceedances of the adopted trigger values for aquatic ecosystems are summarised in Table 3-2. It must be noted that, given the absence of GDEs in the Project area and the absence of groundwater discharge into local creeks and drainages, these trigger values are only relevant in case of abstraction of groundwater and discharge to surface water (e.g. for pit dewatering);
- There were no exceedances of the water quality guidelines for livestock watering; and
- Exceedances of the long-term irrigation guideline values were in water sampled from most wells observed for:
 - o arsenic
 - o iron
 - o manganese; and
 - o total phosphorus.



Table 3-2 Quest 29 Summary of Groundwater Exceedances of Aquatic Ecosystem Trigger Values

Analyte	Q29 MB01	Q29 MB02	Q29 MB03	Q29 MB04	Q29 MB05	Q29 MB06	Q29 MB07	Q29 MB08	Q29 MB09
Field Readings									
Electrical Conductivity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
pH	-	Yes	Yes	-	-	Yes	-	-	Yes
Turbidity	Yes	Yes	-	-	-	-	-	-	-
Major Ions									
Sulphate	Yes	Yes	-	-	-	-	-	-	-
Metals (dissolved)									
Aluminium	Yes	-	-	-	-	-	-	-	-
Arsenic	Yes	Yes	-	Yes	Yes	-	Yes	-	-
Cadmium	Yes	-	-	-	-	-	-	-	-
Chromium	Yes	Yes	-	-	-	-	-	-	-
Copper	Yes	-	Yes	-	-	-	-	-	Yes
Iron	Yes	Yes	-	-	-	-	Yes	-	-
Lead	-	Yes	-	-	-	-	-	-	-
Nickel	-	-	Yes	Yes	-	-	-	-	-
Zinc	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physico-chemical									
Total Suspended Solids	Yes	Yes	-	-	-	-	-	-	-

Notes:

Light green highlight: only exceeds the Toms Gully SSTV

Light blue highlight: only exceeds the ANZG 2018 trigger value

Overall, the groundwater at Q29 is acidic to neutral and fresh. Exceedances of the adopted aquatic freshwater trigger values were observed for several analytes in all monitoring wells. All monitoring bores, except for Q29MB01 and Q29MB02, showed similar water chemistry with small variations indicating limited impacts from previous mining activities.

Existing water quality results indicate that groundwater may have been locally impacted by historical mining activities (i.e. at Q29MB01 and Q29MB02), as evidenced by the elevated sulphate levels observed in these bores. Bores Q29MB01 and Q29MB02 are located in proximity to the BHS leach pad and appear to be impacted by ae rock solutes with elevated sulphate levels.

Recent monitoring of Q29MB01 shows elevated EC and dissolved metals in comparison to other sites. pH values range between 6.09 to 7.33, and elevated EC, well above the aquatic ecosystem protection GVs of 250 $\mu\text{S}/\text{cm}$ (ranging from 210 to 1,213 $\mu\text{S}/\text{cm}$) and exceedance of the ecosystem protection G Vs of Al, As, Cd, Cr, Cu and Zn.

Q29MB02 located west of the heap leach ponds and pad has had elevated EC and occasional exceedances of the aquatic ecosystem protection GVs of As, Cd, Cr, Cu, Pb and Zn. pH values range from slightly acidic (6.49) to slightly alkaline (7.6), and elevated EC, above the aquatic ecosystem protection GVs of 250 $\mu\text{S}/\text{cm}$ (ranging from 210 to 336 $\mu\text{S}/\text{cm}$).



3.4 DERIVATION OF SOURCE TERM

Following the process in Figure 3-1, the source term for RR is presented as Appendix C-1 and for Q29, Appendix C-2.



4 PIT LAKE WATER QUALITY PREDICTIONS

4.1 SOURCE S1 – PAF ROCK IN PIT

4.1.1 BULK SCALE DRAINAGE

The source term is derived from the kinetic testing results as per Section 3. A key challenge associated with the application of kinetic test results is the extrapolation of leachate chemistry to predict full-scale mine-site drainage chemistry even when waste rock compositions, tonnages and site water balance are constrained.

A common approach is to convert laboratory kinetic test leachate concentrations into a geochemical loading rate (e.g., mg/kg_{rock}/week) which is then upscaled to the tonnage of the waste dump to predict drainage quality as mg/L (Kirchner and Mattson, 2015):

$$\text{Predicted Concentration} = \frac{\text{HC Load} \times \text{Time} \times \text{Mass of Rock in Dump}}{\text{Volume of Infiltrating Water}}$$

Eq. 4

The release rates (HC Load; mg/kg_{rock}/week) are calculated from the kinetic testing for key chemicals in the source term and are summarised in Table 4-2 based on the concentrations in Appendix C-1 for RR and Appendix C-2 for Q29. The calculated release rates are presented in Appendix D.

The assumptions used to calculate the total scaled up *predicted concentrations* are presented in Table 4-1.



Table 4-1 Average Release Rates

	RR		Q29	
Element / parameter	Average 52 week leach concentration (mg/L)	Average 52 week release mg/kg _{rock} week ⁻¹	Average 52 week leach concentration (mg/L)	Average 52 week release mg/kg _{rock} week ⁻¹
aluminium	466	314	363	9.2
arsenic	0.13	0.0032	0.05	0.00072
cobalt	2.5	0.038	2.46	0.04
copper	19.8	0.289	33.5	0.66
cadmium	0.04	0.0007	0.07	0.0012
chromium	0.23	0.0044	0.11	0.002
manganese	17.7	0.38	9.4	0.17
nickel	2.27	0.052	9.5	0.21
lead	0.02	0.0003	0.02	0.00036
selenium	0.08	0.0014	0.15	0.0029
uranium	0.12	0.002	0.22	0.0045
zinc	3.44	0.060	11.6	0.21



Table 4-2 Scale up parameters

Parameter	RR	Q29	Source/ Rationale	Reference/
Time (weeks)	44 weeks	44 weeks	Current duration of kinetic column testing	
Mass of Waste PAF Rock (Mt) in the Pit	1.6	0.35	As advised by Hanking	
Bulk density (t/m ³)	2.6	2.6	As advised by Hanking	
Volume of infiltrating water - groundwater	Around 4,200 ML per year to planned Lake volume of 38,000 ML.	Between 36.6 and 803 ML per year (several pits).	Appendix H of the EIS (Groundwater modelling report) and as discussed with CDM Smith.	
Volume of infiltrating water – run-off	Around 570 ML per year total (assumed to RR).	570 year total across five pits – proportional to Table 6-6 of Appendix H of the EIS.	Table 6-6 of Appendix H of the EIS (Groundwater modelling report).	
HC Load	Leach concentrations from column testing of psh tr	Leach concentrations from column testing of S bs Fr	Refer Appendix C-1 and C-2 for source term and release rates for RR. Refer Appendix C-3 and C-4 for source term and release rates for Q29.	

4.1.2 PREDICTING IN PIT PAF LEACH CONCENTRATIONS (OPERATIONAL)

The average release rates (Table 4-1) are used to estimate concentrations of the source term elements in leach where PAF is placed in the base of the Pits and subject to rainfall/ run-off prior to pit lake recovery, using Equation 4.

The following assumptions are made for RR:

1. The PAF pile has a mass of 1.6 million tonne and a bulk density of 2.6 tonne per m³ (rock).
2. The PAF rock is placed across the footprint of the Pit (footprint of 25,000 m²)
3. Precipitation is 1430 mm annual which translates to 1430 L per m².



4. Another way of considering this is using proportional precipitation adopted in the groundwater modelling exercise for the area of the RR Pit, i.e. as per Table 4-5 and Table 4-6.
5. For an area of 25,000 m² the direct precipitation falling on the pile in any given week would then be 6×10^{-5} L.
6. Not all rock in the pile would be saturated, according to Hajizadeh Namaghi, et al., (2015). a saturation of 0.2 of the rock pile would be a reasonable estimation. Thus 20% of 1.6 Mt would be 320,000 tonne (3.2×10^8 kg of rock) may be saturated by infiltration and generate leach.
7. Release rate is weekly based as using an annual cumulative value + precipitation would represent a single significant flush event once a year, which is illogical. Using weekly release coupled to an average weekly precipitation gives a prediction of leach concentration during a week of solid uninterrupted rain.

Such assumptions of scale provide predicted concentrations of source term elements shown in Table 4-3 and Table 4-4. Refer calculations in Appendix C-1 (RR) and Appendix C-2 (Q29).

Similar assumptions were applied to Q29 in pit PAF:

1. The PAF pile has a mass of 0.35 million tonne and a bulk density of 2.6 tonne per m³ (rock).
2. The PAF rock is placed across the footprint of a Pit (footprint of 25,000 m²)
3. Precipitation is 1430 mm annual which translates to 1430 L per m².
4. Proportional precipitation adopted in the groundwater modelling exercise for the area of the RR Pit, i.e. as per Table 4-5 and Table 4-6.
5. Saturation of 0.2 of the rock pile would be contact rock of 0.07 Mt or 70,000 kg of rock may be saturated by infiltration and generate leach.
6. Release rate is weekly based as using an annual cumulative value + precipitation would represent a single significant flush event once a year, which is illogical. Using weekly release coupled to an average weekly precipitation gives a prediction of leach concentration during a week of solid uninterrupted rain.



Table 4-4 Source S1 Leach prediction (PAF Pile in base of pit) – Q29

													Annual
	A Release	tonne	Kg rock	mg	Bulk Density t/m3	m3	Possible Footprint (m2)	Rainfall (mm)	L per m2	Litres per footprint	Weekly	Per event	mg/L
Arsenic	0.001	3.50E+05	7.00E+07	5.07E+04	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06		0.000
Cobalt	0.046	3.50E+05	7.00E+07	3.22E+06	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06		0.025
Copper	0.66	3.50E+05	7.00E+07	4.65E+07	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06		0.355
Cadmium	0.00	3.50E+05	7.00E+07	8.71E+04	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06		0.001
Chromium	0.00	3.50E+05	7.00E+07	1.60E+05	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06		0.001
nickel	0.21	3.50E+05	7.00E+07	1.48E+07	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06		0.113
lead	0.00	3.50E+05	7.00E+07	2.59E+04	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06		0.000
selenium	0.00	3.50E+05	7.00E+07	2.04E+05	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06		0.002
uranium	0.005	3.50E+05	7.00E+07	3.21E+05	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06		0.002
zinc	0.21	3.50E+05	7.00E+07	1.47E+07	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06		0.113

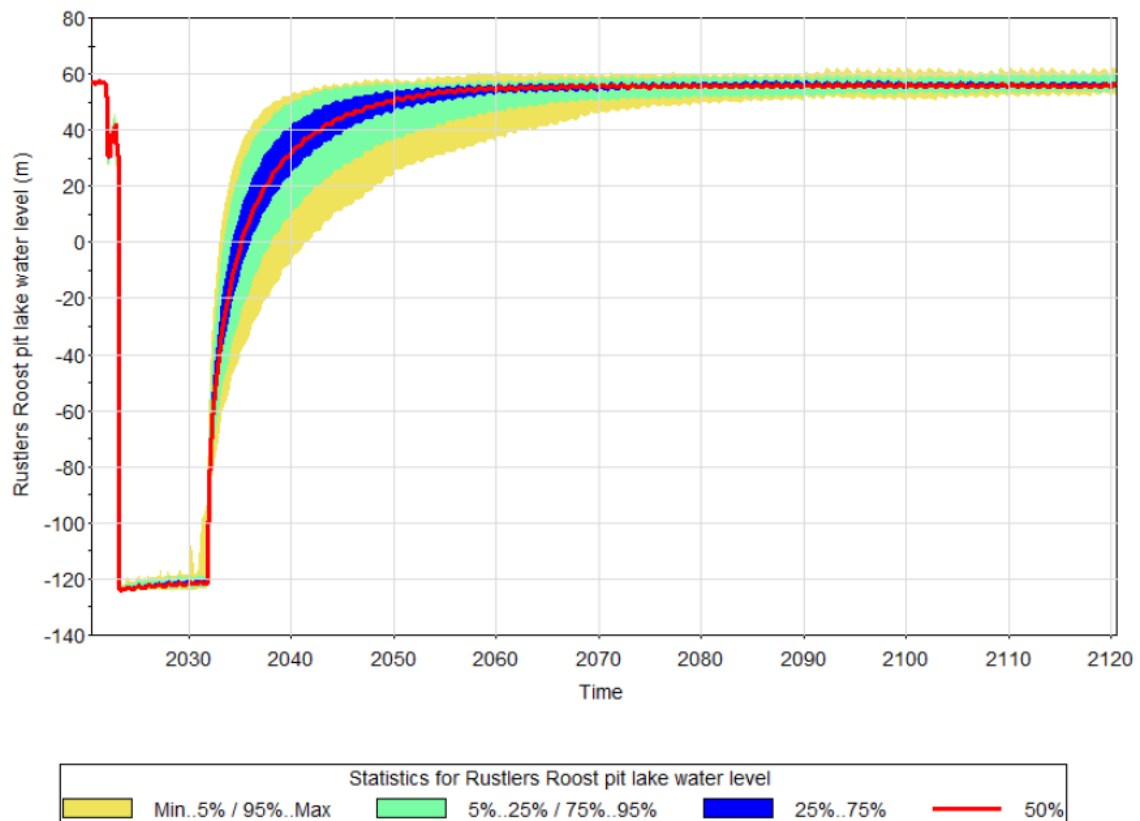


4.1.3 PAF IN PIT LONG TERM (SOURCE S1 MIXING)

4.1.4 Rustlers Roost

It is understood that the Rustlers Roost Lake will progressively fill to around 38,000 ML volume, with full recovery taking around 30 years (Figure 6-14 of CDM Smith, 2021 – reproduced as Figure 4-1).

Figure 4-1 Modelled Pit Lake water level during recovery (Figure 4-10 of CDM Smith 2022)



The RR pit lake water level (re-bound) is predicted to reach ~0 m AHD around 5 years post closure. The predicted water level is considered in terms of elevations of PAF (Table 4-7).

Thus, the Pit is predicted to fill quite rapidly for the first 10 years post closure.

It is estimated in CDM Smith (2021) that approximately 570 ML of run-off will be recovered by the Pits (RR and Q29) per annum. Proportional run-off is calculated given the planned pit footprints provide in Table 6-6 of Appendix H of the EIS (Table 4-5).

Rainfall is estimated at ~240 ML per annum total – proportional volumes are given in Table 4-6. Precipitation is given as 1,430 mm. This equates to 1,430 L per m² per annum.



Table 4-5 Proportional run-off – all Pits

Pit	Site	Planned Footprint (m ²)	Proportion of 570 ML run-off (%)	~Run-off (ML)
Rustlers Roost	RR	598,000	66	376
Annie Okaley	RR	62,000	6.8	39
Annie's Dam	RR	42,000	4.6	26
Zamu	Q29	91,600	10.1	58
South Koolpin	Q29	32,200	3.6	21
North Koolpin	Q29	32,600	3.6	21
Taipan	Q29	31,200	3.6	21
BHS	Q29	13,700	1.5	9
TOTAL	-	903,300	-	570

Table 4-6 Proportional rainfall – all Pits

Pit	Site	Planned Footprint (m ²)	Proportion of 240 ML rainfall (%)	~Rainfall (ML)
Rustlers Roost	RR	598,000	66	158
Annie Okaley	RR	62,000	6.8	16
Annie's Dam	RR	42,000	4.6	11
Zamu	Q29	91,600	10.1	24
South Koolpin	Q29	32,200	3.6	9
North Koolpin	Q29	32,600	3.6	9
Taipan	Q29	31,200	3.6	9
BHS	Q29	13,700	1.5	3.6
TOTAL	-	903,300	-	240



Scale up parameters for RR lake filling via groundwater, rainfall and run-off are given in Table 4-8 - as the Lake level re-bounds, PAF rock in the Pit (Source S1) will progressively be covered (with respect to mitigation of oxidation). As the water level rises over this period, it is reasonable to assume that the unsubmerged area of PAF in the wall rock will decrease incrementally – in this predictive assessment we assumed the reductions listed in per time increment until the steady state volume of ~38,000 ML is reached.

The predicted RR lake water elemental concentrations for source term CPEC are given in Table 4-9.

Table 4-7 Scale up parameters for Pit inflow and volume – Rustlers Roost

			Year 1	Year 5	Year 10	Year 20	Year 30
Parameter	Value	Source/ Reference/ Rationale					
Time (weeks) for In pit	52 – refer value for 52 weeks in Appendix C-1, which mimics 1 year of oxidation.	Arbitrary extrapolation – can be extended to any week value.	52	52	52	52	52
Mass of Waste PAF Rock (kg)	1.6×10^6	Hanking	1.6E+6	1.6E+6	1.6E+6	1.6E+6	1.6E+6
Rainfall (L)	1.6×10^8	Table 4-5	1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08
Run-off Volume (L)	3.8×10^8	Table 4-4	3.76E+08	3.76E+08	3.76E+08	3.76E+08	3.76E+08
Groundwater Influx (L)	Variable per stage of recovery	CDM Smith (2021)	1.27E+09	6.33E+09	1.27E+10	2.53E+10	3.80E+10
Cumulative (L)	Calculated		1.80E+09	6.86E+09	1.32E+10	2.59E+10	3.85E+10
Ratio Run- off:Groundwater	Calculated		2.09E-01	5.48E-02	2.85E-02	1.45E-02	9.76E-03
Run-off Contribution	Fraction	Estimated from water level prediction covering elevation	0.8	0.6	0.1	0.05	0



Table 4-8 elevations of transition and fresh rock (m AHD)

	RR	Q29				
		BHS	Koolpin Nth	Koolpin W	Taipan	Zamu
Top of transition Zone	30	25	12	-6	-30	-10
Top of fresh zone	5	9	-1	-20	-50	-20

Table 4-9 Predicted leach concentrations in lake water over time from in pit PAF

Parameter	Unit	Year 1	Year 5	Year 10	Year 20	Year 30
arsenic	mg/L	6.26E-05	1.64E-05	8.54E-06	4.36E-06	2.93E-06
cobalt	mg/L	1.88E-03	4.93E-04	2.57E-04	1.31E-04	8.79E-05
copper	mg/L	1.54E-02	4.03E-03	2.10E-03	1.07E-03	7.19E-04
cadmium	mg/L	3.97E-05	1.04E-05	5.41E-06	2.76E-06	1.85E-06
chromium	mg/L	1.70E-04	4.46E-05	2.32E-05	1.18E-05	7.95E-06
nickel	mg/L	2.59E-03	6.78E-04	3.53E-04	1.80E-04	1.21E-04
lead	mg/L	1.75E-05	4.59E-06	2.39E-06	1.22E-06	8.19E-07
selenium	mg/L	6.85E-05	1.80E-05	9.34E-06	4.77E-06	3.20E-06
uranium	mg/L	1.06E-04	2.77E-05	1.44E-05	7.35E-06	4.93E-06
zinc	mg/L	2.77E-03	7.27E-04	3.78E-04	1.93E-04	1.30E-04

4.1.5 Quest 29

Estimations represent one of Koolpin West (South) or Taipian given similarity in size, rainfall, and runoff for these pits. Zamu is understood to be selected for backfilling and Koolpin North does not report PAF rock. Pit lake level recovery for Koolpin South (also termed West?) is given in Figure 4-2 – note recovery to above identified PAF elevation occurs quite quickly over a period of ~5 years with average final volume of 600 ML. Thus, we have assumed that 80% of pit wall PAF rock is covered by Year 5 (Table 4-10) at a volume of 475 ML. The resulting lake water concentrations from in pit Q29 disposal (~0.35 Mt) for source term are given in Table 4-11.



Figure 4-2 Predicted South Koolpin pit lake level over time (after Figure 6-19 from CDM Smith)



Table 4-10 Scale up parameters for Pit inflow and volume – Quest 29

Parameter	Value	Source/ Reference/ Rationale	Year 1	Year 5	Year 10	Year 20	Year 30
Time (weeks) for In pit	52 – refer value for 52 weeks in Appendix A, which mimics 1 year of oxidation.	Arbitrary extrapolation – can be extended forward to any week value.	52	52	52	52	52
Mass of Waste PAF Rock (kg)	1.6×10^6	Hanking	3.50E+05	3.50E+05	3.50E+05	3.50E+05	3.50E+05
Rainfall (L)	1.6×10^8	Table 4-5	9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06
Run-off Volume (L)	3.8×10^8	Table 4-4	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07
Groundwater Influx (L)	Variable per stage of recovery	CDM Smith (2021)	9.50E+07	4.75E+08	6.00E+08	6.00E+08	6.00E+08
Cumulative (L)	Calculated		1.30E+09	1.25E+08	5.05E+08	6.30E+08	6.30E+08
Ratio Run-off:Groundwater	Calculated		1.62E-02	1.68E-01	4.16E-02	3.33E-02	3.33E-02
Run-off Contribution	Fraction	Estimated	0.8	0.2	0.1	0.05	0

Table 4-11 Predicted leach concentrations in Quest29 lake water over time from in pit PAF (no CSF)

		Year 1	Year 5	Year 10	Year 20	Year 30
Parameter	Unit					
arsenic	mg/L	1.06E-04	2.61E-05	2.09E-05	2.09E-05	2.09E-05
cobalt	mg/L	6.70E-03	1.66E-03	1.33E-03	1.33E-03	1.33E-03
copper	mg/L	9.67E-02	2.39E-02	1.92E-02	1.92E-02	1.92E-02
cadmium	mg/L	1.81E-04	4.49E-05	3.60E-05	3.60E-05	3.60E-05
chromium	mg/L	3.32E-04	8.22E-05	6.59E-05	6.59E-05	6.59E-05
nickel	mg/L	3.09E-02	7.64E-03	6.12E-03	6.12E-03	6.12E-03
lead	mg/L	5.38E-05	1.33E-05	1.07E-05	1.07E-05	1.07E-05
selenium	mg/L	4.25E-04	1.05E-04	8.44E-05	8.44E-05	8.44E-05
uranium	mg/L	6.67E-04	1.65E-04	1.32E-04	1.32E-04	1.32E-04
zinc	mg/L	3.07E-02	7.59E-03	6.08E-03	6.08E-03	6.08E-03

4.2 SOURCE S2 - PIT WALL

PAF rock will be exposed on the pit wall. A source term is required for the rinsing of sub-aerial pit wall by precipitation and inundation of exposed pit wall by the pit lake.

Both acidic and pH-neutral source terms were developed for pit wall runoff. The proportion of acidic to pH-neutral loading from wall can be identified/ revised based on the lag time calculated for the complete depletion of ANC from these units.

The surface area / particle size of rock used in column leach testing is not known and so a direct correlation between column leach rock mass and pit wall area is not achievable.

The degree of geochemical loading from the pit wall is likely to be greatly influenced by the fracture intensity of the walls induced by blasting:

- The blast effects in the pit wall can be subdivided into two zones; a blast influenced zone and a blast damaged zone.
- The blast damaged zone consists of highly fractured pit wall rock exposed on the pit wall face or ravel collected on benches.
- The blast influenced zone consists of more widely spaced fractures into the pit wall behind the blast damaged zone that will become progressively more fractured over time.
- The method for estimating the depth of blast damage in the transition zones was sourced from Hustrulid (1999). Each zone was calculated based on controlled blasting patterns and practices for medium strength rock and ammonium nitrate and fuel oil (ANFO) used as the blasting agent. Under these assumptions, blast fractured zone depth would be expected to range from a minimum of 0.85 m to maximum depth of 1.05 m. Blast influenced zone depth would typically range from 2.65 m to 3.15 m. Given these ranges, the blast damaged zone is estimated to extend 1.0 m into the final pit wall, and the blast influenced zone is estimated to extend another 2.9 m into the pit wall.
- The effective volume of material in a planar unit area of 1 m² (1 m³) is increased by a factor of 1.41 to account for an assumed average pit wall slope of 45 degrees, i.e. 1.41 m³. Finally, the



mass of rock is determined by multiplying the effective volume by average waste density of 2.7 t/m³ which gives 3.81 tonne (or 3,807 kg) for the blast fractured zone.

- Of note, the blast influenced zone would have a mass of 11,040 kg using the same logic but with a depth of 2.9 m.
- Accounting for both blast fractured and influenced zones, total mass of rock would be 15.2 tonne (15,200 kg).

This represents:

1. Ongoing loading from exposed rock now, during mining or post mining; and
2. Single load transfer available once the pit wall is submerged; and

The proportion of exposed rock throughout the life of mine and post closure will be governed by the elevation of the water table. The full parameters and values are presented in Appendix D-1 for RR and Appendix D-2 for Q29.

For simplicity, the calculations in D-1 and D-2 assumes that all PAF wall rock is exposed. When the water table rebounds the loading will decrease due to less exposed surface area. This is managed by the run-off contribution fraction shown in Table 4-7 and Table 4-10.

Cumulative scaling factor (CSF) can be applied in these types of assessment to account for mass loading correction factors between laboratory and field scale calculations (e.g. grains size, seasonality, temperature, water contact etc.). None of the calculations presented here have a CSF applied (conservative) (refer section 5.1).

Note that acidities but not alkalinities are associated with the sub-aqueous load - Pit wall acidity is predominantly stored in sulfide mineralisation, which is released during oxidation. Acidity can then be stored on mineral surfaces in acidic oxide minerals (i.e. jarosite and alunite). This acidity stored in oxide minerals will be released upon pit wall submergence. Once the pit wall becomes submerged, oxidation and associated acidity release from primary sulphide minerals will largely be inhibited.



Table 4-12 Annual Rustlers Roost pit wall contribution predictions based on average 44 week kinetic testing (mg/l) – refer Appendix E-1

Chemical/ Parameter	Predicted annual pit wall run-off concentrations scaled for entire pit area and rainfall/ run-off (pre lake entry) – no CSF
arsenic	0.87
cobalt	26
copper	215
cadmium	0.22
chromium	0.95
nickel	14.47
lead	0.098
selenium	0.38
uranium	0.59
zinc	15.52



Table 4-13 Annual Quest 29 pit wall contribution predictions based on average 44 week kinetic testing (mg/l) – refer Appendix E-2

Chemical/ Parameter	Predicted annual pit wall run-off concentrations scaled for entire pit area and rainfall/ run-off (pre lake entry) – no CSF
arsenic	0.65
cobalt	41.56
copper	599
cadmium	0.44
chromium	0.87
nickel	81
lead	0.14
selenium	1.1
uranium	1.76
zinc	81



4.3 COMBINED S1 + S2 (LAKE WATER)

As per Figure 3-2, combining the two sources S1 and S2 gives predicted lake water concentrations at each increment as per Table 4-14 (for RR) and Table 4-15 (Q29) also incorporating both mean and maximum groundwater concentrations noting the lakes are predominantly groundwater fed. Flow through is not considered so some dilution likely to occur.

Table 4-14 Predicted concentrations in Rustlers Roost lake water years 1 – 30 (includes S1 and S2) using mean release values from Table 4-1, mean and maximum groundwater and source terms S1 and S2 (refer Appendix F-1) – no CSF, highest criterion exceedance listed – assumes no AMD management

			Year 1	Year 5	Year 10	Year 20	Year 30
aluminium	mg/L	Mean - groundwater	33941	6676	579	148	0.20
aluminium	mg/L	Maximum - groundwater	33942	6677	580	149	1.29
arsenic	mg/L	Mean - groundwater	0.36	0.08	0.02	0.01	0.01
arsenic	mg/L	Maximum - groundwater	0.42	0.14	0.08	0.07	0.07
cobalt	mg/L	Mean - groundwater	4.4	0.91	0.12	0.06	0.044
cobalt	mg/L	Maximum - groundwater	4.5	0.92	0.13	0.07	0.053
copper	mg/L	Mean - groundwater	36	7	0.62	0.17	0.01
copper	mg/L	Maximum - groundwater	36	7	0.65	0.19	0.03
cadmium	mg/L	Mean - groundwater	0.04	0.008	0.00	0.00	0.00
cadmium	mg/L	Maximum - groundwater	0.04	0.008	0.00	0.00	0.00
chromium	mg/L	Mean - groundwater	0.19	0.04	0.00	0.00	0.00
chromium	mg/L	Maximum - groundwater	0.19	0.04	0.01	0.00	0.00
manganese	mg/L	Mean - groundwater	41	8.249	0.87	0.35	0.17
manganese	mg/L	Maximum - groundwater	42	8.689	1.31	0.79	0.61
nickel	mg/L	Mean - groundwater	2	0.48	0.044	0.01	0.00
nickel	mg/L	Maximum - groundwater	2	0.48	0.048	0.017	0.01
lead	mg/L	Mean - groundwater	0.021	0.008	0.00	0.00	0.00
lead	mg/L	Maximum - groundwater	0.022	0.009	0.01	0.01	0.01
selenium	mg/L	Mean - groundwater	0.07	0.01	0.00	0.00	0.00
selenium	mg/L	Maximum - groundwater	0.07	0.01	0.00	0.00	0.00
uranium	mg/L	Mean - groundwater	0.10	0.02	0.00	0.00	0.00
uranium	mg/L	Maximum - groundwater	0.10	0.02	0.00	0.00	0.00
zinc	mg/L	Mean - groundwater	2.62	0.53	0.07	0.03	0.02
zinc	mg/L	Maximum - groundwater	2.67	0.59	0.12	0.09	0.08
>Groundwater							
>ANZG Default GV 95%							
>Bundy Creek TV's							
>Stock Watering (Beef)							
>ANZECC & ARMCANZ 2000 Short-Term Irrigation Water							
>ANZECC & ARMCANZ 2000 Long-Term Irrigation Water							

Table 4-15 Predicted concentrations in Quest29 lake water years 1 – 30 (includes S1 and S2) using mean release values from Table 4-1, mean and maximum groundwater and source terms S1 and S2 (refer Appendix F-2) – no CSF, highest criterion exceedance listed – assumes no AMD management

			Year 1	Year 5	Year 10	Year 20	Year 30
aluminium	mg/L	Mean	1117	69	28	14	0.28
aluminium	mg/L	Maximum	1117	69	28	14	0.28
arsenic	mg/L	Mean	0.13	0.045	0.042	0.041	0.040
arsenic	mg/L	Maximum	0.29	0.205	0.202	0.201	0.200
cobalt	mg/L	Mean	5.63	0.39	0.18	0.11	0.042
cobalt	mg/L	Maximum	5.63	0.39	0.18	0.11	0.045
copper	mg/L	Mean	81	5.012	2.020	1.02	0.022
copper	mg/L	Maximum	81	5.018	2.026	1.03	0.028
cadmium	mg/L	Mean	0.06	0.004	0.002	LOR	LOR
cadmium	mg/L	Maximum	0.06	0.005	0.003	0.002	0.001
chromium	mg/L	Mean	0.12	0.01	0.01	0.01	0.004
chromium	mg/L	Maximum	0.13	0.02	0.01	0.01	0.011
manganese	mg/L	Mean	0.61	0.50	0.49	0.49	0.49
manganese	mg/L	Maximum	1.62	1.51	1.50	1.50	1.50
nickel	mg/L	Mean	11.00	0.69	0.28	0.147	0.011
nickel	mg/L	Maximum	11.01	0.71	0.30	0.162	0.026
lead	mg/L	Mean	0.021	0.003	0.002	0.002	0.001
lead	mg/L	Maximum	0.024	0.006	0.005	0.005	0.005
selenium	mg/L	Mean	0.15	0.010	0.005	0.003	0.001
selenium	mg/L	Maximum	0.15	0.010	0.005	0.003	0.001
uranium	mg/L	Mean	0.24	0.02	0.007	0.004	0.001
uranium	mg/L	Maximum	0.24	0.02	0.007	0.004	0.001
zinc	mg/L	Mean	10.94	0.703	0.297	0.162	0.027
zinc	mg/L	Maximum	11.01	0.766	0.361	0.226	0.091
Groundwater							
ANZG Default GV 95%							
Bundy Creek TV's							
Stock Watering (Beef)							
ANZECC & ARMCANZ 2000 Short-Term Irrigation Water							
ANZECC & ARMCANZ 2000 Long-Term Irrigation Water							



4.4 SUMMARY

Plots for each CPEC relative to applicable screening criteria in lake water in each of the two pits (RR and Q29) are presented as Appendix G-1 (RR) and Appendix G-2 (Q29).



5 DISCUSSION

5.1 SCALING FACTORS

5.1.1 CONTEXT

Discrepancies in geochemical and physical conditions between laboratory kinetic reactors and full-scale waste dumps exist, the discrepancies include, but are not limited to:

- water-rock interaction (contact);
- gas transport and oxygen content;
- reactive grain size distribution (and associated occlusion of reactive minerals);
- temperature (both sulfide and carbonate dissolution reactions are temperature-dependent).

Kirchner and Mattson (2015) report that direct scaling of geochemical loads measured by laboratory kinetic tests, such as humidity cells, relative to the mass of a full-scale mine waste facility will lead to concentration predictions for mine drainage that are unrealistically high for many dissolved constituents.

As a result, “scaling factors” are applied to account for discrepancies in parameters such as grain size, temperature and water/ rock ratio between the laboratory experiments and the field scale waste rock facilities.

Lapakko and Olsen (2015) consider that there is little agreement on scaling factors to be used for extrapolating laboratory dissolution test results for predicting solute release rates from proposed waste rock piles in the field.

The scaling factor for a given solute is the ratio of its release rate in the field to that observed in the laboratory, and its magnitude is dependent on both the solute and site-specific variables. Such research concluded that modelling should use cumulative probability distribution as recommended by the National Academy of Sciences (National Research Council, 2007) as opposed to a single value. Lapakko and Olsen (2015) concluded that they are deemed more appropriate for assessment of risk by regulatory agencies, an assessment that is essential to environmental review of proposed mining operations.

The Lapakko and Olsen (2015) laboratory rates were calculated based on sulfate release during weeks 6 to 71 observed for 17 blast hole samples with sulfur contents of 0.18 to 1.64 percent. The samples were collected from the mine site from which comparative field data were generated. Annual field rates were determined over a period of 3 to 13 years for five waste rock piles, ranging in mass from 2,000,000 to 15,000,000 tons, with estimated sulfur contents of 0.24 to 0.97 percent. Laboratory and field rates were expressed per unit mass sulfur. Comparison of 17 laboratory rates and 42 annual field rates yielded in 714 distinct calculated scaling factors. These values were fit to a beta distribution for which the mean and standard deviation were 0.127 (~13%) and 0.083, respectively, with cumulative probability 1 being a CSF of 0.4 (40%).

It should be noted that the results were generated based on dissolution of a specific rock type in the laboratory and under specific conditions of climate and waste rock stockpile design in the field. Consequently, care must be taken when applying these results to other conditions.



Kirchner and Mattson (2015) observed that geochemical loads for major ions from two test sites are commonly more than two orders of magnitude lower than those predicted by direct scaling of laboratory kinetic test loads, yielding bulk scaling factors of <1%. In these models, many dissolved trace ions that may be of concern in mine drainage (e.g., As, Cu, Cd, Se, etc.) may still be significantly overpredicted if the model is calibrated to major ions, likely as a result of solubility limits and other attenuation mechanisms. Unlike loading rates, concentrations in field bin and waste dump drainage were commonly found to be on the same order of magnitude for both neutral and acidic sites suggesting that geochemical equilibrium may be attained at relatively small scales in waste piles.

In an attempt to account for the variable geochemical regimes, many authors have begun introducing scaling factors based on theoretical assumptions and field observations (Malmström et al., 2000; Neuner et al., 2009; Kempton, 2012). In theory, a scaling factor (generally <100%) is assigned to each of the lab-to-field discrepancies identified and multiplied by the upscaled load.

Understandably, depending on the type of waste material and the climatic conditions at a mine site, the sometimes inter-related individual scaling factors vary widely in practice (Kempton, 2012). A so-called cumulative scaling factor (CSF), defined as the product of all individual scaling factors can be calculated empirically where laboratory kinetic and waste drainage chemistry data are available, however a comprehensive database for different deposit types and climate conditions currently does not exist.

Nevertheless, several studies have addressed this topic and CSF on the order of 5 to 60% have been reported (e.g., Andrina et al., 2012; Hanna & Lapakko, 2012; Morin & Hutt, 1994).

Kirchner and Mattso (2015) reported a range of 0.01% to 4% and concluded that many species appear to be solubility-limited at a scale of field bin experiments (150-200 kg), which is a factor that should be accounted for in water quality prediction modelling.

Of note when considering scaling factors, a detailed examination of kinetic testing by Maest and Nordstrom (2017), including speciation and inverse modelling, of humidity cell tests (HCTs) from three projects with different geology and mineralisation showed that rapid sulfide oxidation dominates over a limited period of time that starts between 40 and 200 weeks of testing.

Factors that complicate the use of HCTs include: sample representation, time for microbial oxidisers to grow, sample storage before testing, geochemical reactions that add or remove constituents, and the HCT results chosen for use in modelling the environmental performance at mine sites.

5.1.2 CUMULATIVE SCALING FACTOR PREDICTION OUTCOMES

If considering a cumulative scaling factor for this data, this must be sourced from the literature and this is not ideal, noting CSF is related to the many variables set out above.

We present the predictions from Section 4.3 using the cumulative probability CSF of 0.4 from Lapakko and Olsen (2015), noting the mean of such study was 0.127 and the upper value sits comfortably within the 5 to 60% range commonly observed in the literature, noting the far lower CSF reported by Kirchner and Mattso (2015). Obviously this CSF is an illustrative guesstimate but is considered reasonably conservative.

The CSF adjusted predictions for RR are shown in Table 5-1 and the CSF adjusted predictions for Q29 are in Table 5-2.



Table 5-1 Predicted concentrations in Rustlers Roost lake water during recovery (source S1 and S2 combined with Cumulative Scaling Factor and showing contribution of mean and maximum groundwater) – assumes no drainage management (Appendix F-3)

	Units	Groundwater	Year 1	Year 5	Year 10	Year 20	Year 30
aluminium	mg/L	Mean	13557	2667	232	60	0.5
aluminium	mg/L	Maximum	13559	2668	233	61	1.6
arsenic	mg/L	Mean	0.15	0.04	0.01	0.01	0.01
arsenic	mg/L	Maximum	0.21	0.10	0.07	0.07	0.07
cobalt	mg/L	Mean	1.78	0.37	0.05	0.03	0.021
cobalt	mg/L	Maximum	1.79	0.38	0.060	0.04	0.030
copper	mg/L	Mean	14.38	2.84	0.26	0.07	0.01
copper	mg/L	Maximum	14.40	2.86	0.28	0.10	0.03
cadmium	mg/L	Mean	0.04	0.01	0.002	LOR	LOR
cadmium	mg/L	Maximum	0.04	0.01	0.002	LOR	LOR
chromium	mg/L	Mean	0.20	0.04	0.00	0.002	0.002
chromium	mg/L	Maximum	0.20	0.04	0.01	0.00	0.002
manganese	mg/L	Mean	16.57	3.40	0.45	0.24	0.17
manganese	mg/L	Maximum	17.01	3.84	0.89	0.68	0.61
nickel	mg/L	Mean	2.57	0.51	0.05	0.01	0.002
nickel	mg/L	Maximum	2.58	0.51	0.05	0.02	0.006
lead	mg/L	Mean	0.02	0.008	0.005	0.005	0.005
lead	mg/L	Maximum	0.02	0.009	0.006	0.006	0.006
selenium	mg/L	Mean	0.07	0.01	0.002	LOR	LOR
selenium	mg/L	Maximum	0.07	0.01	0.002	LOR	LOR
uranium	mg/L	Mean	0.11	0.022	0.003	LOR	LOR
uranium	mg/L	Maximum	0.11	0.022	0.003	LOR	LOR
zinc	mg/L	Mean	2.61	0.53	0.067	0.03	0.02
zinc	mg/L	Maximum	2.67	0.59	0.122	0.089	0.078
Key							
>Groundwater							
>ANZG Default GV 95%							
>Bundy Creek TV's							
>Stock Watering (Beef)							
>ANZECC & ARMCANZ							
2000 Short-Term Irrigation Water							
>ANZECC & ARMCANZ 2000 Long-Term Irrigation Water							

When adopting the CSF and mean groundwater concentrations, lake water in RR pit is predicted to have high concentrations of CPEC (relative to screening criteria) for Years 1 – 5 after mining has ceased. This is largely driven by the surface water run-off contacting the PAF rock in pit walls (refer Section 5.2 for discussion on the likely overestimation of this term).

Aluminium is high due to the calculated release rate originating from acidic column. The calculation does not account for alkalinity / pH of water (buffering). Given the specific geochemical nature of aluminium, i.e. only in solution when $\sim\text{pH} < 4.5$ then it is not expected to be present in solution in circumneutral lake water (likely to be colloidal).

In year 10 copper and manganese is predicted to be elevated above the ANZECC & ARMCANZ 2000 Long-Term Irrigation Water and also the Bundy TV, ANZG DGV and ambient groundwater.

At this point the calculations assume pit wall run-off is contributing to $<20\%$ inflow. This decreases further at year 20 and copper continues to exceed ANZECC & ARMCANZ 2000 Long-Term Irrigation Water due to the strong pit wall run-off signature (refer Section 5.2).

By Year 30, most CPEC are at ambient groundwater concentrations except cobalt and copper which exceed the average ambient ground water concentration (and Bundy TV). Section 5.2 discusses the realism, simplifications and assumptions associated with these predictions.

When adopting the CSF and mean groundwater concentrations, lake water in Q29 pits is predicted to have high concentrations of CPEC (relative to screening criteria) for Years 1 – 5 after mining has ceased. This is largely driven by the surface water run-off contacting the PAF rock in pit walls (refer Section 5.2 for discussion on the likely overestimation of this term).

In year 10, cobalt, copper, nickel, and zinc are predicted to be elevated above the ANZECC & ARMCANZ 2000 Long-Term Irrigation Water and also the Mount Bundy TV, ANZG DGV and ambient groundwater. At this point the calculations assume pit wall run-off is contributing to 20% inflow. This decreases at year 20 and only copper continues to exceed ANZECC & ARMCANZ 2000 Long-Term Irrigation Water due to the strong pit wall run-off signature (refer Section 5.2). By Year 30, most CPEC are at ambient groundwater concentrations except cobalt, copper, and nickel, which exceed the average ambient ground water concentration (and maximum concentration, nickel excepted).

Section 5.2 discusses the simplifications and assumptions associated with these predictions.



Table 5-2 Predicted concentrations in Quest 29 lake water during recovery (source S1 and S2 combined with Cumulative Scaling Factor and showing contribution of mean and maximum groundwater) – assumes no drainage management (Appendix F-4)

			Year 1	Year 5	Year 10	Year 20	Year 30
aluminium	mg/L	Mean	447.7	28.0	11.3	5.8	0.28
aluminium	mg/L	Maximum	447.7	28.0	11.3	5.8	0.28
arsenic	mg/L	Mean	0.08	0.042	0.041	0.0	0.040
arsenic	mg/L	Maximum	0.24	0.202	0.201	0.2	0.200
cobalt	mg/L	Mean	2.28	0.18	0.10	0.07	0.042
cobalt	mg/L	Maximum	2.28	0.18	0.10	0.07	0.045
copper	mg/L	Mean	32.32	2.02	0.821	0.422	0.022
copper	mg/L	Maximum	32.33	2.03	0.827	0.428	0.028
cadmium	mg/L	Mean	0.06	0.004	0.002	LOR	LOR
cadmium	mg/L	Maximum	0.06	0.005	0.003	0.002	0.001
chromium	mg/L	Mean	0.12	0.01	0.01	0.01	0.004
chromium	mg/L	Maximum	0.12	0.02	0.01	0.01	0.011
manganese	mg/L	Mean	0.60	0.50	0.49	0.49	0.49
manganese	mg/L	Maximum	1.61	1.51	1.50	1.50	1.50
nickel	mg/L	Mean	8.28	0.52	0.22	0.113	0.011
nickel	mg/L	Maximum	8.30	0.54	0.23	0.128	0.026
lead	mg/L	Mean	0.019	0.003	0.002	0.002	0.001
lead	mg/L	Maximum	0.023	0.006	0.005	0.005	0.005
selenium	mg/L	Mean	0.14	0.010	0.005	0.003	0.001
selenium	mg/L	Maximum	0.14	0.010	0.005	0.003	0.001
uranium	mg/L	Mean	0.22	0.01	0.007	0.004	0.001
uranium	mg/L	Maximum	0.22	0.01	0.007	0.004	0.001
zinc	mg/L	Mean	10.27	0.661	0.281	0.154	0.027
zinc	mg/L	Maximum	10.33	0.725	0.344	0.217	0.091
>Groundwater							
>ANZG Default GV 95%							
>Bundy Creek TV's							
>Stock Watering (Beef)							
>ANZECC & ARMCANZ 2000 Short-Term Irrigation Water							
>ANZECC & ARMCANZ 2000 Long-Term Irrigation Water							



5.2 PIT LAKE DEVELOPMENT & PREDICTED CONCENTRATIONS

The calculations of course over simplify the development of the lakes. The calculations make several necessary simplifications and assumptions, most key being:

1. the in pit PAF continues to leach CPEC and act as a source term over the 30 year period despite being covered by lake water;
2. the assumption that release rates represent all PAF rock in the pit and in the pit walls. A Monte Carlo type distribution of release rates married to a block model of lithology and S ratios with subsequent scaling concentrations would provide a fairer representation of CPEC release rate distribution over pit wall surfaces and in pit (or external to pit) waste rock storage/ placement.

In reality, if the PAF rock is stored / managed appropriately to mitigate oxidation of sulfidic material, then release rates could be much lower, and subsequent leach concentrations would be lower.

Further, when the in pit material is covered and oxidation of sulfidic material lessens, the ongoing flux of CPEC to the water column would also diminish.

The current assumptions and simplifications also use no CSF or a generic CSF, which also will likely overestimate CPEC concentrations.

It is possible that the CPEC may bind with available ferric oxyhydroxides (FeOH) or organic matter in terms of stratification and therefore have colloidal behaviour. Stratification due to salinity or temperature coupled to evaporative effects may develop and this may affect the distribution of elements in the lake water column.

5.3 PIT LAKE CONSIDERATIONS

Not all pits are suited for waste disposal and especially disposal of reactive waste. MEND (1995) lists some of the key considerations regarding suitability include:

1. mining constraints - future access to remaining ore reserves; other nearby mining activities; - stability; - safety of workers during placement of wastes;
2. mineralisation of exposed pit walls; and
3. hydrogeology/hydrology.

Other factors that also need to be considered include morphology, depth of overburden and potential benefits (e.g. future lake uses i.e. recreation etc.).

Mining Related Constraints

Few pits are ever "mined-out". Residual mineralisation often remains and may prove to be economically recoverable at a future date. In addition, concern is often raised regarding creation of flooded pits above existing or potential future mine workings. Other factors which may impact on the use of the pit include interconnection with other nearby mine workings, and concerns regarding the stability of underground workings located under the pit.



Mine owners/operators have generally opposed backfilling of pits for one or more of the above reasons; however, it has recently been clearly demonstrated that there can be a net positive benefit to using an open pit for mine waste disposal.

There is also concern over the safety aspects of working in old pits. Pit walls may be unstable or degraded to the point where the risk of entry into the pit may preclude its use. For example, at several sites, it was indicated that helicopters had to be used for safe access to pit waters for sampling water quality. On the other hand, backfilling may well be a cost effective technique for stabilising pit walls.

Pit Walls

Acid production from exposed mineralisation on the pit walls may be a factor. Leachates draining into the pit from joints, fractures, faults and exposed walls may be acidic and could seriously impact on the utility of using pits for waste deposition. In these cases, concepts can generally be adapted to address this concern (e.g. grouting); however, cost effective solutions may not always be available.

Hydrogeology

MEND (1995) observes that the hydrogeology of the pit is by far the most critical factor in assessing the applicability of any pit for waste disposal.

The hydrogeology of the site will often dictate what engineered controls are necessary to develop an acceptable disposal option. Key factors regarding the pit include:

1. presence of faults and major flow pathways;
2. bulk permeability of the surrounding rock around the pit;
3. hydraulic connections to other mining areas;
4. groundwater flow path and potential downstream receptors (e.g. potable groundwater supplies, surface water streams);
5. location and gradient of the groundwater table; and
6. stratigraphy/permeability of overburden and bedrock.

According to MEND (1995), the ideal pit for reactive wastes producing contaminated leachate would have the following characteristics:

1. minimal to no groundwater gradient across the pit to ensure that no release of contaminants occurs as a result of groundwater transport;
2. low permeability bedrock with few faults such that the pit effectively acts as a bathtub with no drain (i.e., a terminal lake). All flows to the pit enter and discharge at the top resulting in no infiltration or groundwater discharge.

The hydrology of the surface region surrounding the pit may be a very important factor, as the surface flow conditions will affect:

1. the flooding of the pit;
2. the final water table elevation;
3. the concentrations of contaminants leached from the wastes;



4. the dilution provided for contaminated seepage/ drainages from the pit which reach receiving water bodies; and
5. the possible connection of a flooded pit with other surface water bodies.

For reactive waste disposal, assurance that the water cover will be maintained is critical for most applications. Predicted water table elevations at this pit are predicted to cover the PAF waste rock when POD 3 is utilised.

5.4 PROPOSED DISPOSAL

There are four basic concepts for placement of wastes in pits:

1. Option 1 – Underwater disposal
2. Option 2 – Elevated water tables
3. Option 3 – Dry disposal
4. Option 4 – Perched water tables

The proposed approach of full submergence fits the Standard Option 1.

Where PAF rock would be left 'stored' in the pit during operations, some generation of acidity and concomitant metal solubilisation may occur in the interim period. This is in addition to any contribution from pit wall rock. Interim storage of PAF rock should be managed appropriately to mitigate generation of acidity and concomitant metals (particularly the pH sensitive metals copper and cobalt). Arsenic solubility does not appear to be particularly pH sensitive so drainage may need to be managed and treated in the interim period.

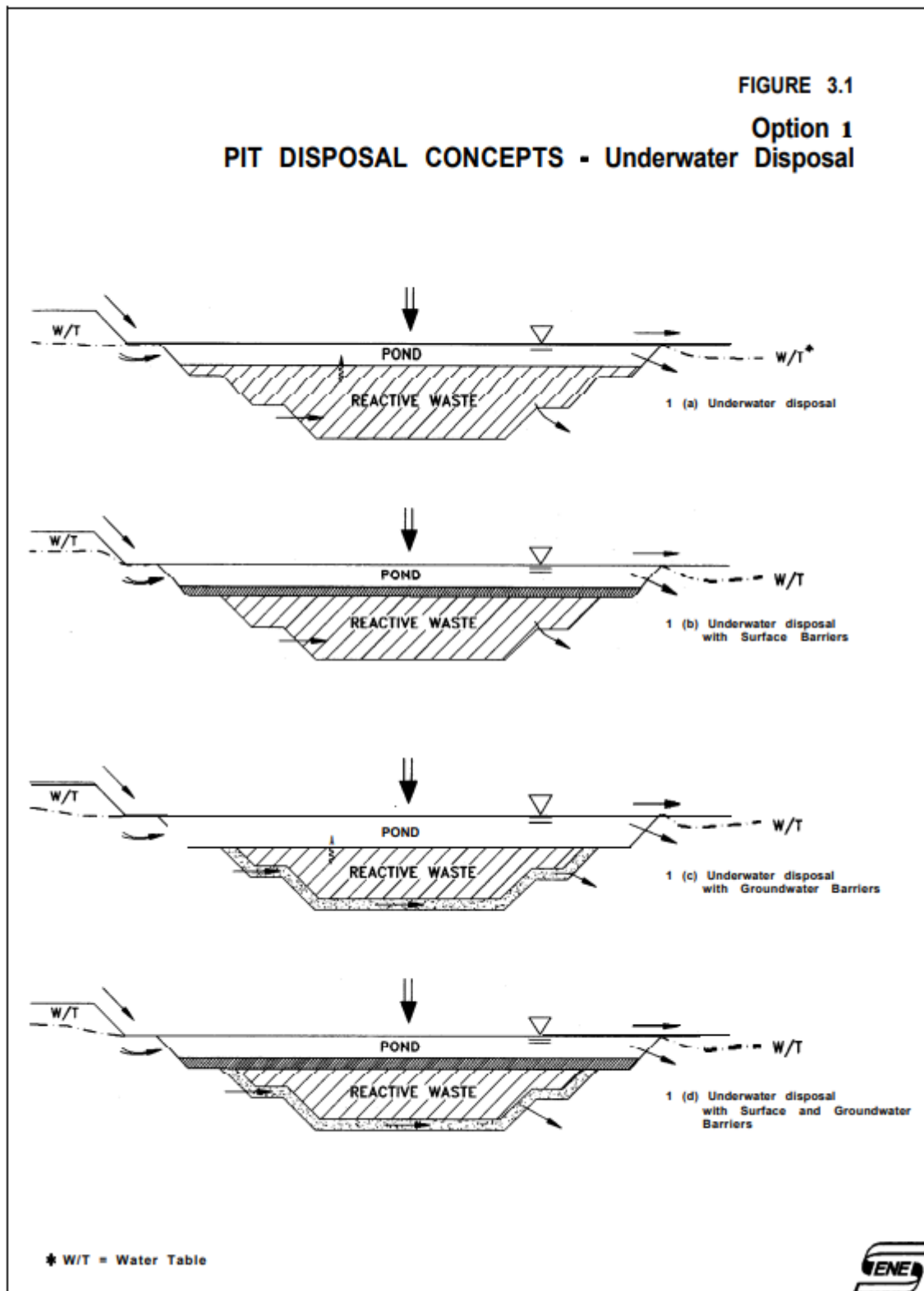
There are variations of in pit submerged storage options:

- Option 1a - Simple Underwater Disposal
- Option 1b - Underwater Disposal with a Surface Barrier
- Option 1c - Underwater Disposal with Groundwater Barriers
- Option 1d - Underwater Disposal with Surface and Groundwater Barriers.

These are shown in Figure 5-4. Option 1a is understood to be relevant.



Figure 5-1 Underwater disposal of PAF in pit (MEND, 1995)



5.5 WATER QUALITY PREDICTIONS AND CONCEPTUAL SITE MODEL

The CSM set out in Section 2 is revisited with the outcomes of the predictive calculations and should be viewed in terms of the assumptions and simplifications adopted with respect to predictive concentrations modelling as per Section 5.1 and 5.2.

Eight linkages were identified, and these are considered below in Table 5-3 noting predicted estimated concentrations of CPEC as per Table 5-1 and Table 5-2.

With respect to cobalt and copper being above ecological criterion (ANZG 2018 DGV) at year 30 in both pits, heavy metals in excess could cause several diseases in migratory shorebirds. High concentration of lead deposits in the tissues of bird feathers could destroy their thermoregulation, the growth of nestlings and affect the recognition of their siblings. Chromium is known to impact embryo development and hatching success of eggs in mallard ducks, while nickel affects pigment colours of feathers during moulting.

Zinc is high in Year 1 – 5 - zinc in higher concentration can affect reproduction and increase kidney toxicity. Scientists have earlier found that half of cockatiel populations could die if exposed to about 16 mg of zinc orally for a couple of weeks. The metal, in high levels, is also a known lethal poison for ducks and Nicobar pigeon. Cobalt in excess can negatively affect metabolism in avian populations and a high concentration of copper can damage birds' kidneys and impair reproduction.

With respect to cobalt, ducklings fed cobalt (200 or 500 mg/kg as chloride) developed necrosis of skeletal muscle and smooth muscle of the gizzard and intestine, similar to that induced by vitamin E-selenium deficiency. No lesions were seen in cardiac muscle (Van Vleet et al, 1981). Considering these values as mg/L then similar toxicity response may be gained. These concentrations quoted by Van Vleet et al are and ~90 times larger than predicted year 1 concentration and 8,500 times larger than the predicted year 30 concentration, such that notable toxic effects from cobalt on avian migratory populations are not readily significant.

With respect to copper, we note that the current ANZG 2018 criterion is based on:

- Fish: 10 species, 2.6 µg/L (*Ptylocheilus oregonensis*, from 7-day LC50) to 131 µg/L (*Pimephales promelas*, 7-day LC50); seven species had geometric means <25 µg/L
- Crustaceans: five species, 1.7 µg/L (*D. pulex* and *G. pulex*, NOEC, reproduction & mortality) to 12.1 µg/L (*Hyalella azteca*, from 10 to 14-day LC50)
- Insects: three species, 2.2 µg/L (*Tanytarsus dissimilis*, from 10-day LC50) to 11 µg/L (*Chironomus tentans*, 10 to 20-day LC50)
- Molluscs: three species, 1.64 µg/L (*Flumicola virens*, from 14-day LC50) to 56.2 (*Corbicula manilensis*, from 7 to 42-day LC50). The latter figure was not included in calculations as it was outside the pH range.



Fish, insects, crustaceans and molluscs may colonise the lakes – the predicted concentrations at year 30 would not exceed the upper values quoted as LC50s.

The key receptor species is considered to be migratory birds.

There are few reports of copper toxicosis in wild birds. One study (Henderson, Winterfield, 1975) reports lesions in Canada geese after having ingested copper sulfate at about 600 mg/L of water from a small man-made pond. In acidic environments where, for example, acid rain is known to occur, copper birdbaths are likely to produce copper sulfates. However, given that the copper content of the water will be around 2mg/L at year 5, concentrations of copper sulfates will be one or two orders of magnitude lower than the reportedly toxic 600mg/L for copper sulfate.

In a paper published in 2008, Thomas, and McGill make an analysis of the potential toxicology of birds ingesting sintered tungsten–bronze (containing 44.4% copper). Sintered tungsten–bronze is a suggested substitute for lead used in discharged lead shots and fishing weights, which are known to cause lead poisoning in wild birds. Thomas, and McGill simulated the ingestion of eight sintered tungsten–bronze spheres in ducks to observe the effective rate of release of copper into the ducks' digestive system. They conclude:

"The release of 43.17 mg copper/day from eight tungsten–bronze spheres, while exceeding the daily copper requirements of domesticated birds, is far below the levels of copper known to cause copper toxicosis in birds." (Thomas, and McGill 2008)

For a bird to ingest the equivalent of 43.17 mg of copper/day by drinking water from a copper vessel, it would have to drink in excess of 20L of water in a day. If assume the above estimation that a copper birdbath will leach 1mg of copper for each litre of water is wrong by an order of magnitude: if a copper birdbath was to leach 10mg of copper for each litre of water, a wild bird would still need to consume 2L of water per day to approach the copper concentration that Thomas, and McGill say is still safe.

At the Cu concentrations predicted towards steady state (~2 mg/L >Year 5) a bird would need to drink 10 L a day – even at year 1 there would appear to be no significant risk to bird populations frequenting the lake from copper in lake water concentration.

Discussion on other linkages is given in Table 5-3.



Table 5-3 Revised CSM and Linkages adopting 0.4 CSF predictions, mean groundwater consider in light of Section 5.2

Source (S)	Primary Pathway (P) ^[2]	Secondary Pathway (P)	Tertiary Pathway (P)	Receptor (R)	Linkage # (L)	Discussion - RR	Discussion - Q29
S1 – PAF rock in the pit	P1 - Groundwater inflow and contact with exposed oxidised rock / materials	P2 - direct uptake / contact	-	R1 Migratory Birds/ Bats or other fauna accessing the Pit (contact)	L1	Predicted concentrations in the lake are above Bundy TV and ANZG DGV to at least year 30 (at this point only cobalt and copper), where predicted concentrations are above ambient groundwater concentrations and DGV. The predictions likely over-predict lake water concentrations as per Section 5.2. The predictions also do not cater for limnological, hydrological and hydrogeological development of the pit, as per Section 5.2. The concentrations can therefore be viewed as being worst case or close to, which demonstrate an interim period of pit lake recovery that present most risk of harm to migratory species.	Cobalt, copper, and nickel are predicted to be above ecological criteria (Bundy TV and ANZG DGV) and also ambient groundwater at 30 years as the pit reaches steady state. As with RR, the predictions likely over-predict lake water concentrations as per Section 5.2. The predictions also do not cater for limnological, hydrological and hydrogeological development of the pit, as per Section 5.2. The concentrations can therefore be viewed as being worst case or close to, which demonstrate an interim period of pit lake recovery that present most risk of harm to migratory species.
	P1 - Groundwater inflow (and/ or rainfall) and contact with exposed oxidised rock / materials	P3 - Lateral migration of solutes away from the Pit	P4 - Abstraction	R2 Future Human Use	L2	There is no known likelihood of abstraction occurring or being proposed to occur for drinking water purposes. The reported concentrations in the lakes would be above drinking water criteria, but where abstraction and prolonged drinking is avoided then the risk associated with this linkage is not significant.	There is no known likelihood of abstraction occurring or being proposed to occur for drinking water purposes. The reported concentrations in the lakes would be above drinking water criteria, but where abstraction and prolonged drinking is avoided then the risk associated with this linkage is not significant.
			P4 - Abstraction	R3 Stock watering	L3	The predicted concentrations decrease below stock watering generally by year 10 post closure – during this period as the lake is filling the net flow outward is expected to be very minimal – consequently the risk to stock via abstraction for drinking purposes is considered to be low. As the lake level returns to close to pre-mining, the concentrations are less than stock watering – at this point when steady state level is reached, net flow outward is considered likely to increase to become a through flow system. However, as concentrations of CPEC are lower than stock criterion, there is no predicted risk evident.	The predicted concentrations decrease below stock watering generally by year 10 post closure – during this period as the lake is filling the net flow outward is expected to be very minimal – consequently the risk to stock via abstraction for drinking purposes is considered to be low. As the lake level returns to close to pre-mining, the concentrations are less than stock watering – at this point when steady state level is reached, net flow outward is considered likely to increase to become a through flow system. However, as concentrations of CPEC are lower than stock criterion, there is no predicted risk evident.

Source (S)	Primary Pathway (P) ^[2]	Secondary Pathway (P)	Tertiary Pathway (P)	Receptor (R)	Linkage # (L)	Discussion - RR	Discussion - Q29
			P2 - direct uptake / contact	R4 GDE	L4	Predicted concentrations in the lake are above Bundy TV and ANZG DGV to at least year 30 (at this point only cobalt and copper), where predicted concentrations are above ambient groundwater concentrations and DGV. The predictions likely over-predict lake water concentrations as per Section 5.2. The predictions also do not cater for limnological, hydrological and hydrogeological development of the pit, as per Section 5.2. The significant concentrations occur as the lake is filling i.e. the net flow outward is expected to be very minimal such that down hydraulic gradient GDE are not fed by lake water. When steady state is reached then through flow may become apparent. However, at this point the main CPEC are cobalt and copper, these may be overpredicted as per Section 5.2.	Predicted concentrations in the lake are above Bundy TV and ANZG DGV to at least year 30 (at this point only cobalt nickel and copper), where predicted concentrations are above ambient groundwater concentrations and DGV. The predictions likely over-predict lake water concentrations as per Section 5.2. The predictions also do not cater for limnological, hydrological and hydrogeological development of the pit, as per Section 5.2. The significant concentrations occur as the lake is filling i.e. the net flow outward is expected to be very minimal such that down hydraulic gradient GDE are not fed by lake water. When steady state is reached then through flow may become apparent. However, at this point the main CPEC are cobalt nickel and copper, these may be overpredicted as per Section 5.2.
S2 Pit wall rock	P1 - Groundwater inflow and contact with exposed oxidised rock / materials	P2 - direct uptake / contact P3 - Lat eral migration of solutes away from the Pit	-	R1 Migratory Birds (contact)	L5	Discussed in text	Discussed in text
			P4 - Abstraction	R2 Future Human Use	L6	There is no known likelihood of abstraction occurring or being proposed to occur for drinking water purposes. The reported concentrations in the lakes would be above drinking water criteria, but where abstraction and prolonged drinking is avoided then the risk associated with this linkage is not significant.	There is no known likelihood of abstraction occurring or being proposed to occur for drinking water purposes. The reported concentrations in the lakes would be above drinking water criteria, but where abstraction and prolonged drinking is avoided then the risk associated with this linkage is not significant.

Source (S)	Primary Pathway (P) ^[2]	Secondary Pathway (P)	Tertiary Pathway (P)	Receptor (R)	Linkage # (L)	Discussion - RR	Discussion - Q29
			P4 - Abstraction	R3 Stock watering	L7	The predicted concentrations decrease below stock watering generally by year 10 post closure – during this period as the lake is filling the net flow outward is expected to be very minimal – consequently the risk to stock via abstraction for drinking purposes is considered to be low. As the lake level returns to close to pre-mining, the concentrations are less than stock watering – at this point when steady state level is reached, net flow outward is considered likely to increase to become a through flow system. However, as concentrations of CPEC are lower than stock criterion, there is no predicted risk evident.	The predicted concentrations decrease below stock watering generally by year 10 post closure – during this period as the lake is filling the net flow outward is expected to be very minimal – consequently the risk to stock via abstraction for drinking purposes is considered to be low. As the lake level returns to close to pre-mining, the concentrations are less than stock watering – at this point when steady state level is reached, net flow outward is considered likely to increase to become a through flow system. However, as concentrations of CPEC are lower than stock criterion, there is no predicted risk evident.
			P2 - direct uptake / contact	R4 GDE	L8	Predicted concentrations in the lake are above Mount Bundy TV and ANZG DGV to at least year 30 (at this point only cobalt and copper), where predicted concentrations are above ambient groundwater concentrations and DGV. The predictions likely over-predict lake water concentrations as per Section 5.2. The predictions also do not cater for limnological, hydrological and hydrogeological development of the pit, as per Section 5.2. The significant concentrations occur as the lake is filling i.e. the net flow outward is expected to be very minimal such that down hydraulic gradient GDE are not fed by lake water. When steady state is reached then through flow may become apparent. However, at this point the main CPEC are cobalt and copper and these may be overpredicted as per Section 5.2.	Predicted concentrations in the lake are above Mount Bundy TV and ANZG DGV to at least year 30 (at this point only cobalt nickel and copper), where predicted concentrations are above ambient groundwater concentrations and DGV. The predictions likely over-predict lake water concentrations as per Section 5.2. The predictions also do not cater for limnological, hydrological and hydrogeological development of the pit, as per Section 5.2. The significant concentrations occur as the lake is filling i.e. the net flow outward is expected to be very minimal such that down hydraulic gradient GDE are not fed by lake water. When steady state is reached then through flow may become apparent. However, at this point the main CPEC are cobalt, nickel and copper and these may be overpredicted as per Section 5.2.

6 CONCLUSIONS

Key conclusions are as follows:

1. There are variations of in pit submerged storage options:
 - o Option 1a - Simple Underwater Disposal
 - o Option 1b - Underwater Disposal with a Surface Barrier
 - o Option 1c - Underwater Disposal with Groundwater Barriers
 - o Option 1d - Underwater Disposal with Surface and Groundwater Barriers.

It is understood that Option 1a is proposed.

2. With respect to Rustlers Roost (RR) Pit Lake, the scaled up leach (accounting for 1.6 Mt of rock in RR) adjusted for a literature based CSF with mean groundwater composition predicts:
 - a. Lake water in RR pit is predicted to have high concentrations of CPEC (relative to screening criteria) for Years 1 – 5 after mining has ceased. This is largely driven by the surface water run-off contacting the PAF rock in pit walls (refer Section 5.2 for discussion on the likely overestimation of this term).
 - b. In year 10 copper is predicted to be elevated above the ANZECC & ARMCANZ 2000 Long-Term Irrigation Water and also the Bundy TV, ANZG 2018 DGV and ambient groundwater.
 - c. At this point the calculations assume pit wall run-off is contributing to <20% inflow. This decreases further at year 20 and copper continues to exceed ANZECC & ARMCANZ 2000 Long-Term Irrigation Water due to the strong pit wall run-off signature (refer Section 5.2).
 - d. By Year 30, most CPEC are at ambient groundwater concentrations except cobalt and copper which exceed the average ambient ground water concentration (and Bundy TV).
3. With respect to Quest 29 (Q29) Pit Lake, the scaled up leach (accounting for 0.35 Mt rock in Q29) adjusted for a literature based CSF with mean groundwater composition predicts:
 - a. When adopting the CSF and mean groundwater concentrations, lake water in Q29 pits is predicted to have high concentrations of CPEC (relative to screening criteria) for Years 1 – 5 after mining has ceased. This is largely driven by the surface water run-off contacting the PAF rock in pit walls (refer Section 5.2 for discussion on the likely overestimation of this term).
 - b. In year 10, cobalt, copper, nickel, and zinc are predicted to be elevated above the ANZECC & ARMCANZ 2000 Long-Term Irrigation Water and also the Mount Bundy TV, ANZG 2018 DGV and ambient groundwater. At this point the calculations assume pit wall run-off is contributing to 20% inflow. This decreases at year 20 and only copper continues to exceed ANZECC & ARMCANZ 2000 Long-Term Irrigation Water due to the strong pit wall run-off signature (refer Section 5.2). By Year 30, most CPEC are at ambient groundwater concentrations except cobalt, copper, and nickel, which exceed the average ambient ground water concentration (and maximum concentration, nickel excepted).



4. The calculations of course over simplify the development of the lakes. The calculations make several necessary simplifications and assumptions, most key being:
 - a. the in pit PAF continues to leach CPEC and act as a source term over the 30 year period despite being covered by lake water;
 - b. the assumption that release rates represent all PAF rock in the pit and in the pit walls. A Monte Carlo type distribution of release rates married to a block model of lithology and S ratios with subsequent scaling concentrations would provide a fairer representation of CPEC release rate distribution over pit wall surfaces and in pit (or external to pit) waste rock storage/ placement.
5. Eight linkages were identified in the conceptual site model, concerning potential impacts to migratory avian species (and bats), human receptors (abstraction for drinking water external to the Site), stock watering and supply of water for groundwater dependant ecosystems.
 - a. Given the presumed nature of lakes recovery, the elevated concentrations predicted occur in the early recovery period where net flow outwards is minimal during recovery.
 - b. When the lakes recover the flow may become through flow and at this point the predicted concentrations are either below groundwater concentrations, laboratory limits of reporting or in the case of cobalt, copper and nickel are still elevated above ecological criteria (i.e. ANZG 2018 DGV). The risk then may be mitigated by reactive retardation as the groundwater flows outwards from the pits, with respect to down hydraulic gradient receptors (groundwater dependant ecosystems).
 - c. Note that concentrations are not predicted to exceed stock watering criteria by year 10 post mining i.e. during the net inflow period. Tier 2 review of avian toxicity data does not indicate an unacceptable risk profile to migratory birds using the lakes during the recovery period or post steady state.
6. In reality, if the PAF rock is stored / managed appropriately to mitigate oxidation of sulfidic material, then release rates could be much lower, and subsequent leach concentrations would be lower.
7. Further, when the in pit material is covered and oxidation of sulfidic material lessens, the ongoing flux of CPEC to the water column would also diminish.
8. The current assumptions and simplifications also use no CSF or generic CSF, which also will likely overestimate CPEC concentrations.
9. It is possible that the CPEC may bind with available ferric oxyhydroxides (FeOH) or organic matter in terms of stratification and therefore have colloidal behaviour. Stratification due to salinity or temperature may develop and this may affect the distribution of elements in the lake water column.
10. When the pit is allowed to flood and contacts the in pit and wall PAF rock, this may cause a 'super' flush of acidity and metals/ metalloids to groundwater (potential risk where lake water flows outwards from the pit).
11. Interim management measures that mitigate oxidation and generation of acidity (and metal/ metalloids release) from stored PAF rock should be considered. It is understood that an acid mine drainage plan has been prepared.



12. Pit wall rock may represent a notable source of CPEC containing leach depending on rainfall events / volume and drainage from run-off will need to be managed accordingly to mitigate risk to external receptors.

Please note the statement of limitations as Appendix H.



7 RECOMMENDATIONS

We provide the following recommendations:

1. Consider oxygen consumption tests on PAF and PAF-LC rock to assess:
 - a. Annual rate of acidity generation (per kg, per m² and wt% FeS₂ – depending on material)
 - b. The reactive lifetime of the material
 - c. Timing and magnitude of peak acidity
 - d. Rate of ANC consumption
 - e. 'Lag time' or onset to acid conditions

Oxygen consumption tests can be used to directly measure the sulfide oxidation rate of a material, supplementing yet overcoming the limitations of column leach and humidity cell tests (note that these are tests have not been approved for use by any regulator):

- c. OxCon Rapid Oxygen Consumption Cell Test:
 - i. Determination of intrinsic sulfide oxidation rate, reactive lifetime of materials and the rate of ANC consumption under simulated site conditions.
 - d. OxCon Wallrock Oxygen Consumption:
 - ii. Determination of intrinsic sulfide oxidation rate, reactive lifetime of materials and the rate of ANC consumption.
 - iii. Sulfide oxidation rate as a function of surface area (m²) under simulated site conditions.
2. Create a block model of the geology/ lithology to better understand the distribution of PAF rock and magnitude of release rates per area of pit wall – this should then allow refinement of the pit wall source and possibly an adjustment to the in pit release rate profile too.
3. Consider reactive transport modelling for cobalt, copper and nickel at year 30 post closure to provide additional level of redundancy in terms of understanding fate and transport of these CPEC to down hydraulic gradient receptors assuming predications are not as conservative as believed to be.
4. Review the predictions and discussions made within this report against the current acid mine/ rock drainage management plan to ensure consistency in proposed management measures with respect to the linkages identified and requirements for drainage management.

Please note the statement of limitations as Appendix H.



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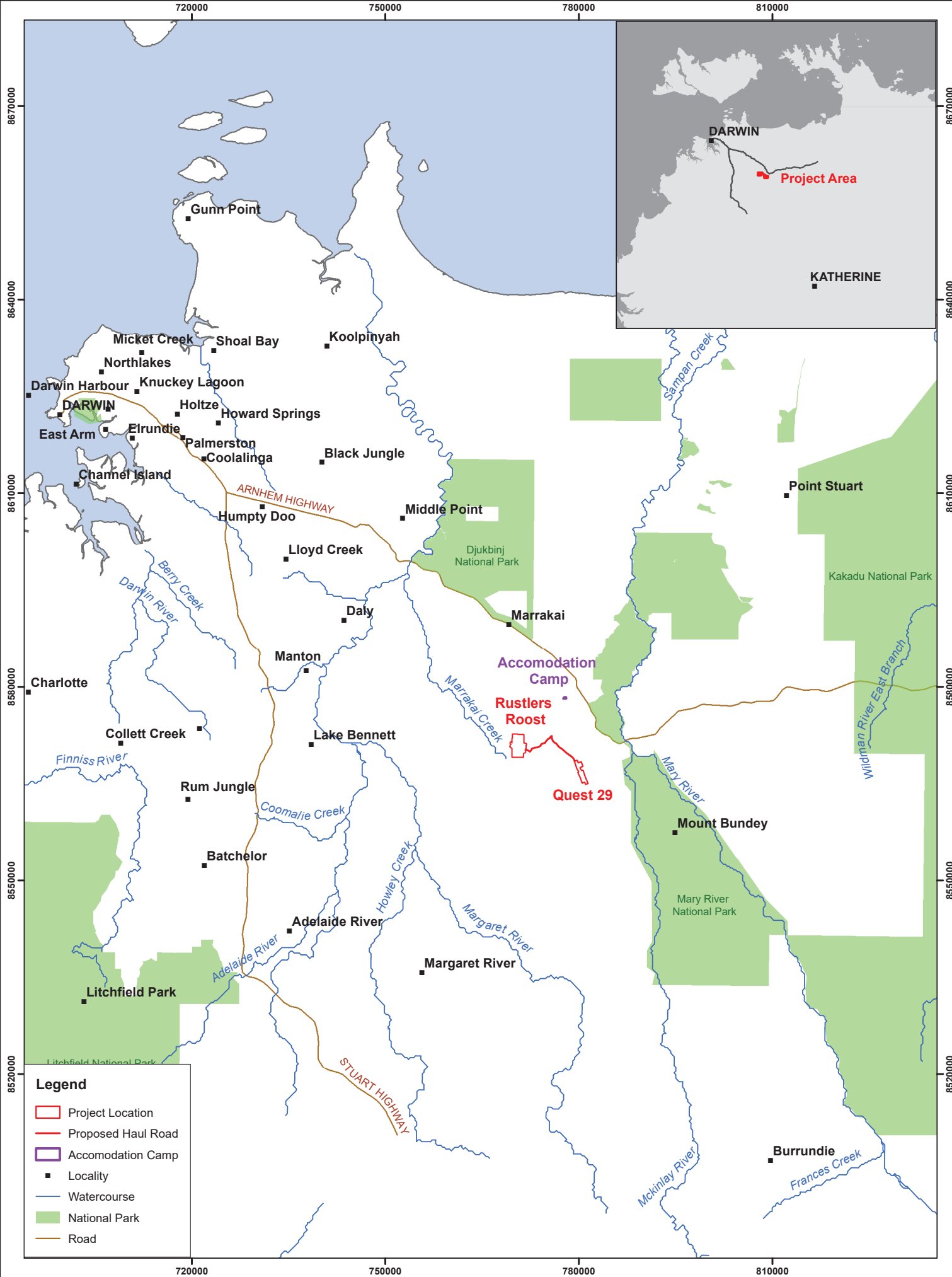
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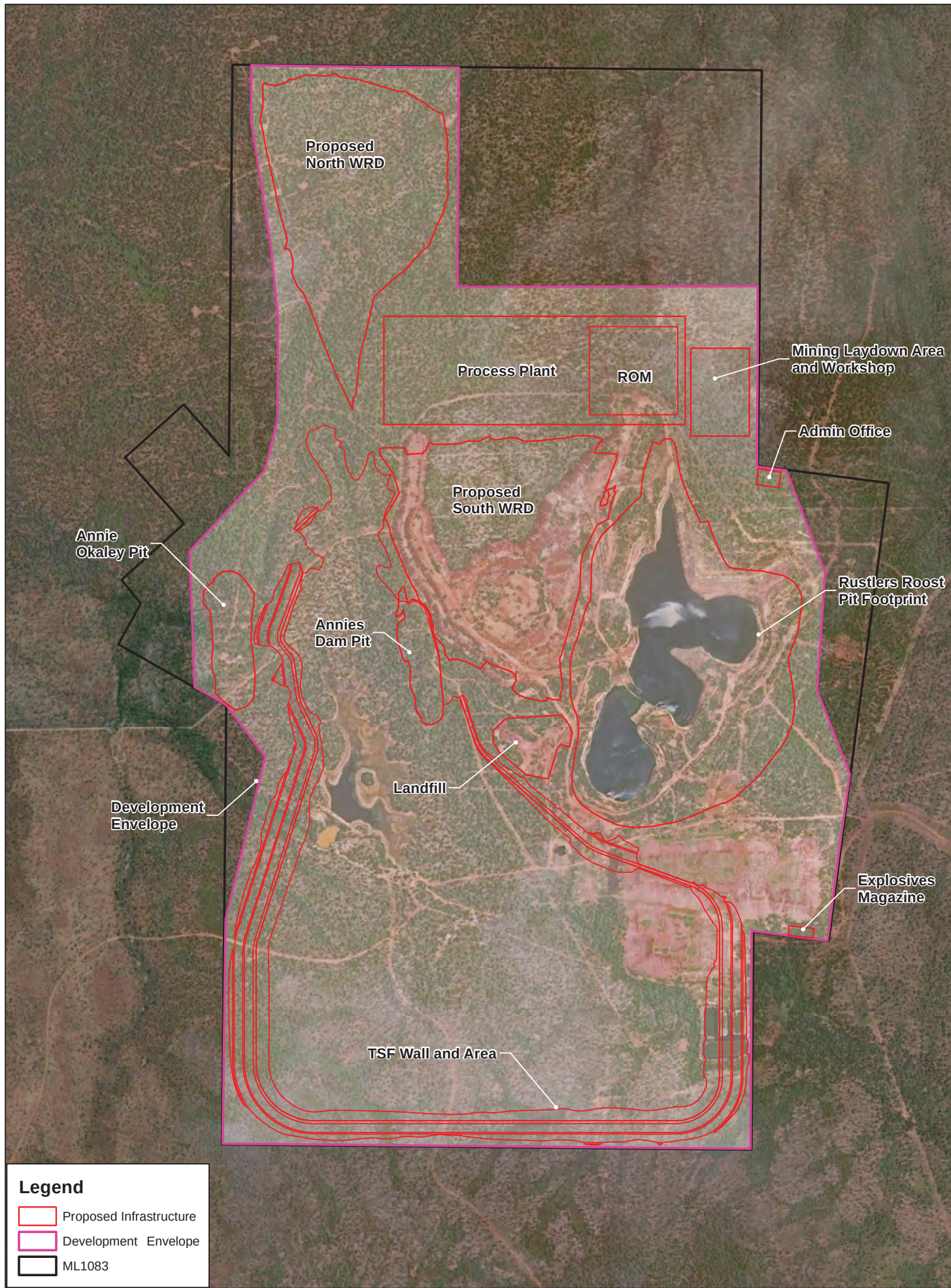
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APPENDIX A – FIGURES







Legend

- Proposed Infrastructure
- Development Envelope
- ML1083

R Details		Date	©COPYRIGHT CDM SMITH This drawing is confidential and shall only be used for the purpose of this project.				DISCLAIMER CDM Smith has endeavoured to ensure accuracy and completeness of the data. CDM Smith assumes no legal liability or responsibility for any decisions or actions resulting from the information contained within this map.		DESIGNER	CLIENT	FIGURE 1-2
1	First Draft	30/06/21	DESIGNED	SS	CHECKED	TK		CDM Smith has endeavoured to ensure accuracy and completeness of the data. CDM Smith assumes no legal liability or responsibility for any decisions or actions resulting from the information contained within this map.			Rustlers Roost Development Envelope and Infrastructure
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			APPROVED	TK	DATE	27/07/21					
Notes:							DATA SOURCE QLD Government Open Source Data				

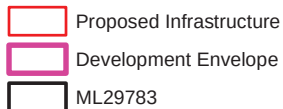


FIGURE 1-3

Quest 29 Development Envelope and Infrastructure

ORG Ref: 1001087-EIS-04-4.4

APPENDIX B– WATER QUALITY DATA



4.4.5 Groundwater Quality

4.4.5.1 Rustlers Roost Historical investigations

An assessment of the groundwater quality at and near Rustlers Roost was undertaken as part of the EES 1993 hydrogeological study (Environmental and Earth Sciences Pty Ltd, January 1993). EES concluded that the groundwater showed minimal dissolution of major ions from the bedrock and no detectable copper, lead, zinc, cadmium, chromium, arsenic or mercury in the groundwater. Water quality throughout the lease was good with total dissolved solids (TDS) ranging from 10 to 50 mg/L. All parameters were within the ANZECC agricultural water quality guidelines.

The water is dominated by bicarbonate with chloride, potassium, sodium and magnesium subdominant. The bicarbonate levels most likely represent atmospheric carbon dioxide together with carbonate minerals dissolving in the groundwater whilst the other elements such as sodium, calcium, potassium and magnesium would be sourced from the fractured bedrock.

The low dissolved element levels indicate that there is minimal elemental dissolution from the rock and that a high level of meteoric rainfall infiltration into the folded and fractured turbidite sediments is occurring.

The bicarbonate to chloride ratios indicate that the water is relatively young with a low buffering capacity and pH values ranging from 4.9 to 5.5. The low to non-existent sulphate levels suggest that pyrite or other sulphides are absent or in minimal quantities in the oxidised and transitional weathering zones. The acidity is likely to be due to dissolved CO₂, particularly as bicarbonate is the dominant anion. Due to the presence of dissolved CO₂, the water is likely to be corrosive.

4.4.5.2 Rustlers Roost 2020-2021 Water Quality

Field water quality parameters measured during the 2020-2021 monitoring program and analysis results of groundwater and open pit sample are presented in Appendix A-1. A statistical summary of the groundwater analysis results is presented in Table 4-16.

4 Description of Environmental Values

Table 4-16 Rustlers Roost Statistical Summary of Groundwater Analysis Results

Analyte				Results > LOR					Exceedances				
				No. Results	Minimum	Average	Maximum	StDev	Toms Gully SSTV (8th percentile)	Tropical Australia Lowland Rivers	ANZG 218 freshwater - 95% species protection	ANZECC 2 Livestock Watering (beef cattle)	ANZECC 2 long term irrigation
Alkalinity													
Bicarbonate Alkalinity	mg/L	40	1	39	2	68.0769	195	48.7228	-	-	-	-	-
Carbonate Alkalinity	mg/L	40	40	-	-	-	-	-	-	-	-	-	-
Hydroxide Alkalinity	mg/L	40	40	-	-	-	-	-	-	-	-	-	-
Total Alkalinity	mg/L	40	1	39	2	68.0769	195	48.7228	-	-	-	-	-
Field Measurements													
Dissolved Oxygen (%sat) (field)	%	40	-	40	1	13.2335	39.9	12.0022	-	-	-	-	-
Electrical Conductivity (field)	µS/cm	40	-	40	36.1	155.3000	305.4	89.1028	Yes	-	-	-	-
ORP (field)	mV	40	-	40	-118	84.7425	271	86.0935	-	-	-	-	-
pH (field)	-	40	-	40	3.77	5.6970	6.78	0.7671	Yes	Yes	-	-	-
Salinity (field)	ppt	38	-	38	0.02	1.8726	44.2	8.0644	-	-	-	-	-
Temperature (field)	°C	40	-	40	30.8	32.5125	34.8	0.9079	-	-	-	-	-
Total Dissolved Solids (field)	mg/L	39	-	39	23.4	105.3269	196.4	56.6634	-	-	-	-	-
Turbidity (field)	NTU	40	-	40	0.42	27.2033	576	100.1201	Yes	-	-	-	-
Major Ions													
Calcium	mg/L	40	8	32	1	11.8438	50	12.6417	-	-	-	-	-
Chloride	mg/L	40	-	40	2	3.3000	6	0.9392	-	-	-	-	-
Magnesium	mg/L	40	5	35	1	5.9143	15	4.5463	-	-	-	-	-
Sodium	mg/L	40	-	40	1	7.2750	28	6.9393	-	-	-	-	-
Sulphate	mg/L	40	14	26	1	8.5385	31	8.6775	-	-	-	-	-
Metals (dissolved)													
Aluminium (dissolved)	mg/L	40	25	15	0.01	0.0747	0.19	0.0437	-	-	-	-	-
Arsenic (dissolved)	mg/L	40	11	29	0.001	0.0099	0.07	0.0169	Yes	-	Yes	-	-
Cadmium (dissolved)	mg/L	40	40	-	-	-	-	-	-	-	-	-	-
Chromium (dissolved)	mg/L	40	38	2	0.001	0.0015	0.002	0.0007	-	-	Yes	-	-

4 Description of Environmental Values

Analyte	Units	No. Results	No. Results <LOR	Results > LOR					Exceedances				
				No. Results	Minimum	Average	Maximum	StDev	Toms Gully SSTV (8th percentile)	Tropical Australia Lowland Rivers	ANZG 218 freshwater - 95% species protection	ANZECC 2 Livestock Watering (beef cattle)	ANZECC 2 long term irrigation
Cobalt (dissolved)	mg/L	40	27	13	0.001	0.0055	0.015	0.0039	-	-	-	-	-
Copper (dissolved)	mg/L	40	19	21	0.001	0.0096	0.033	0.0103	Yes	-	Yes	-	-
Iron (dissolved)	mg/L	40	24	16	0.05	0.8831	2.47	0.8770	-	-	-	-	Yes
Lead (dissolved)	mg/L	40	37	3	0.003	0.0047	0.006	0.0015	1	-	2	-	-
Manganese (dissolved)	mg/L	40	2	38	0.001	0.1531	0.627	0.1821	-	-	-	-	Yes
Nickel (dissolved)	mg/L	40	18	22	0.001	0.0024	0.006	0.0015	-	-	-	-	-
Selenium (dissolved)	mg/L	40	40	-	-	-	-	-	-	-	-	-	-
Tin (dissolved)	mg/L	40	40	-	-	-	-	-	-	-	-	-	-
Uranium (dissolved)	mg/L	40	40	-	-	-	-	-	-	-	-	-	-
Zinc (dissolved)	mg/L	40	7	33	0.005	0.0222	0.078	0.0200	Yes	-	Yes	-	-
Metals (total)													
Aluminium (total)	mg/L	40	14	26	0.01	0.2031	1.29	0.2852	-	-	-	-	-
Arsenic (total)	mg/L	40	10	30	0.001	0.0106	0.083	0.0185	-	-	Yes	-	-
Cadmium (total)	mg/L	40	39	1	0.0002	0.0002	0.0002	#DIV/0!	-	-	-	-	-
Chromium (total)	mg/L	40	37	3	0.001	0.0017	0.002	0.0006	-	-	Yes	-	-
Cobalt (total)	mg/L	40	27	13	0.001	0.0069	0.018	0.0046	-	-	-	-	-
Copper (total)	mg/L	40	17	23	0.001	0.0114	0.041	0.0122	-	-	Yes	-	-
Ferrous Iron	mg/L	40	25	15	0.1	0.8853	2.89	0.9061	-	-	-	-	-
Iron (total)	mg/L	40	18	22	0.05	0.9682	2.59	0.8238	-	-	-	-	-
Lead (total)	mg/L	40	36	4	0.001	0.0023	0.003	0.0010	-	-	-	-	-
Manganese (total)	mg/L	40	4	36	0.001	0.1745	0.608	0.1877	-	-	-	-	Yes
Nickel (total)	mg/L	40	15	25	0.001	0.0027	0.008	0.0018	-	-	-	-	-
Selenium (total)	mg/L	40	40	-	-	-	-	-	-	-	-	-	-
Tin (total)	mg/L	40	40	-	-	-	-	-	-	-	-	-	-
Uranium (total)	mg/L	40	40	-	-	-	-	-	-	-	-	-	-
Zinc (total)	mg/L	40	6	34	0.007	0.0237	0.07	0.0188	-	-	Yes	-	-

4 Description of Environmental Values

AnalyteUnitsNo. ResultsNo. Results <LOR				Results > LOR					Exceedances				
				No. Results	Minimum	Average	Maximum	StDev	Toms Gully SSTV (8th percentile)	Tropical Australia Lowland Rivers	ANZG 218 freshwater - 95% species protection	ANZECC 2 Livestock Watering (beef cattle)	ANZECC 2 long term irrigation
Nutrients													
Ammonia	mg/L	40	27	13	0.01	0.2585	1.29	0.3873	-	Yes	1	-	-
Nitrate + Nitrite	mg/L	40	12	28	0.01	0.1371	1.6	0.2920	-	-	-	-	-
Total Kjeldahl Nitrogen as N	mg/L	40	35	5	0.3	0.8400	2.1	0.7301	-	-	-	-	-
Total Nitrogen as N	mg/L	40	28	12	0.1	0.6000	3.7	1.0000	-	-	-	-	-
Total Phosphorus	mg/L	40	6	34	0.01	0.1674	0.8	0.2317	-	Yes	-	-	Yes
Physico-chemical													
Total Hardness	mg/L	40	5	35	4	51.4000	187	45.3004	-	-	-	-	-
Total Suspended Solids	mg/L	40	27	13	5	30.0769	182	49.3684	Yes	-	-	-	-
Turbidity (lab)	NTU	40	13	27	0.1	20.3556	348	67.0665	Yes	-	-	-	-

Hydrogeochemistry

Based on the field water quality parameters, it can be concluded that the groundwater at Rustlers Roost:

- Is acidic to slightly acidic, with pH levels varying from 3.77 to 6.78, with an average of 5.7. Time series of field pH versus rainfall are presented in Figure 4-15. To a minor degree, pH levels vary with rainfall. pH levels in monitoring well RRMB07 are more acidic (i.e. between 3.8 and 4.4) than in the other monitoring wells (i.e. between 5.1 and 6.8). RRMB07 is located north of the open pit;
- Is fresh, with electrical conductivity (EC) varying from 36 $\mu\text{S}/\text{cm}$ to 305 $\mu\text{S}/\text{cm}$, with an average of 155 $\mu\text{S}/\text{cm}$, and total dissolved solids (TDS) varying from 23 mg/L to 196 mg/L, with an average of 105 mg/L. Time series of field EC versus rainfall are presented in Figure 4-16;
- Has low dissolved oxygen levels, ranging from 1% to 40% saturation, with an average of 13%; and
- Has bicarbonate alkalinity (as CaCO_3) ranging from 2 mg/L to 195 mg/L, with an average of 68 mg/L.

Piper diagrams of groundwater (historical and current data) and open pit water are presented on Figure 4-17. Based on the ionic composition:

- The groundwater at wells RRMB02, RRMB03, RRMB04, RRMB05, RRMB06, RRMB07 and RRMB08 can be classified as a “calcium-magnesium-bicarbonate” water type;
- The groundwater at well RRMB01 can be classified as a “mixed sodium-bicarbonate-chloride” water type. Monitoring well RRMB01 is located adjacent to the former heap leach pad. Groundwater quality in well RRMB01 shows evidence of influence from potential waste rock leachate; and
- The water in the open pit can be classified as a “calcium-magnesium-bicarbonate” water type.

4 Description of Environmental Values

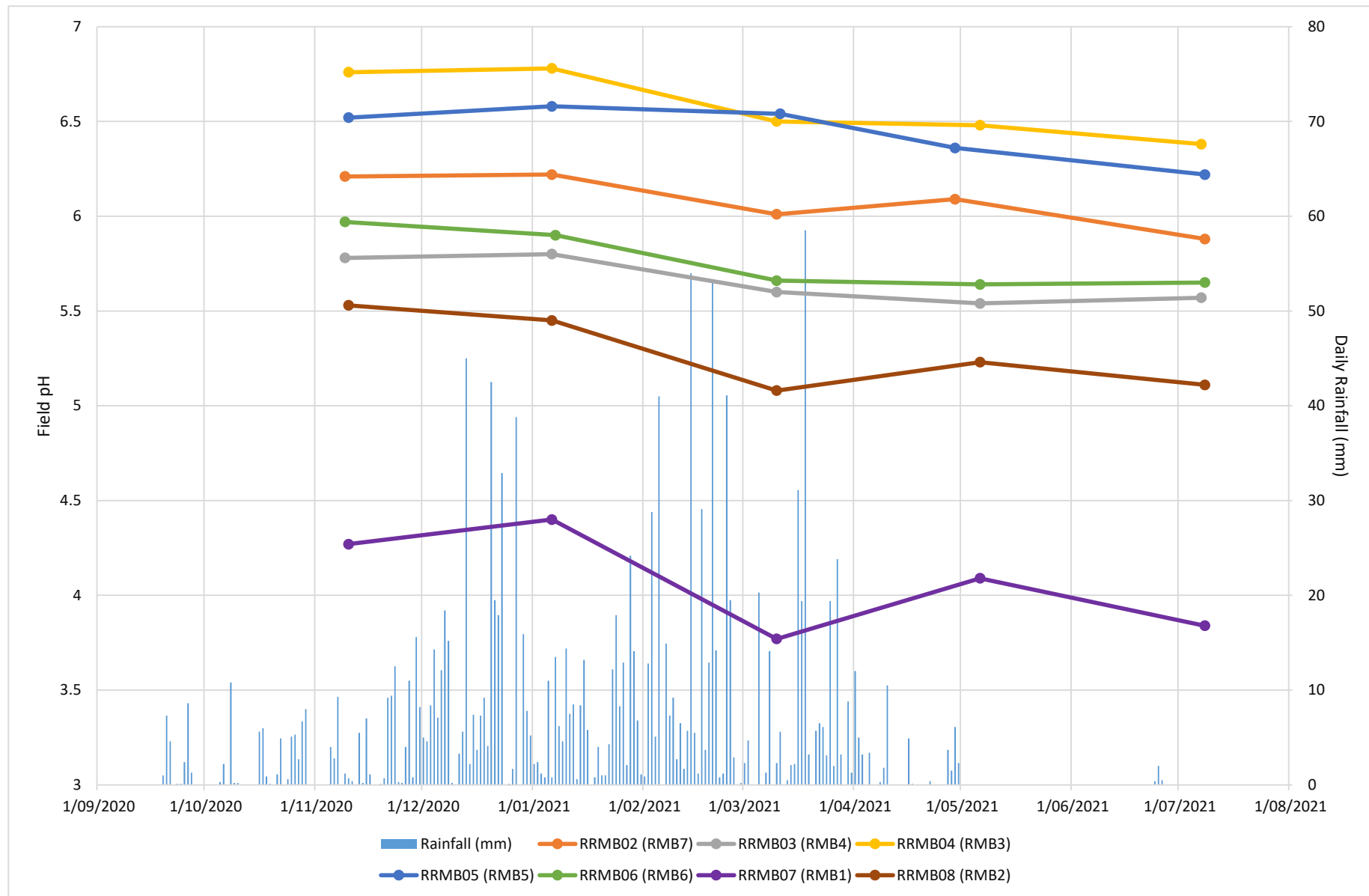


Figure 4-15 Field pH versus Rainfall in Monitoring Wells at Rustlers Roost

4 Description of Environmental Values

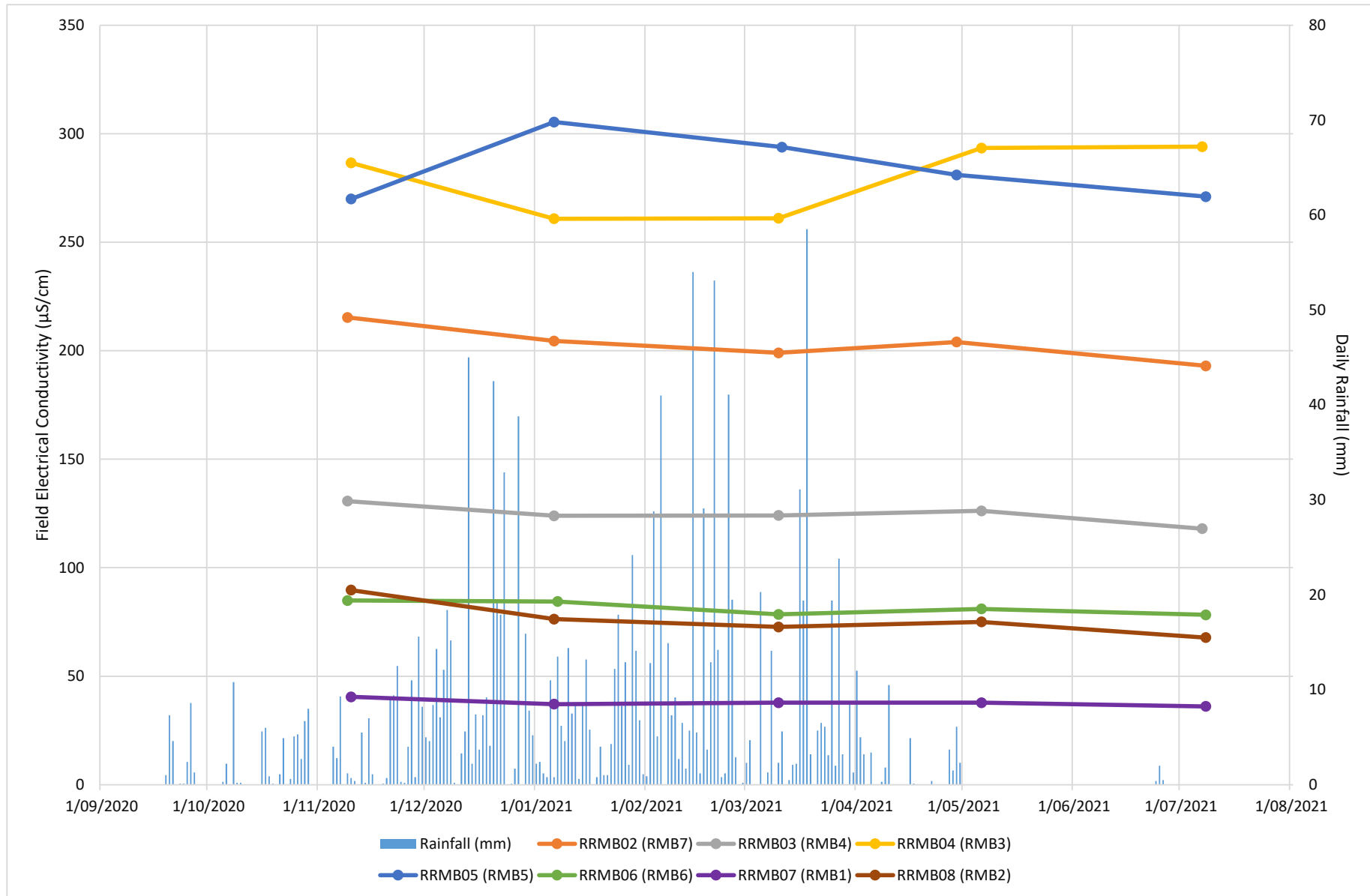


Figure 4-16 Field Electrical Conductivity versus Rainfall in Monitoring Wells at Rustlers Roost

4 Description of Environmental Values

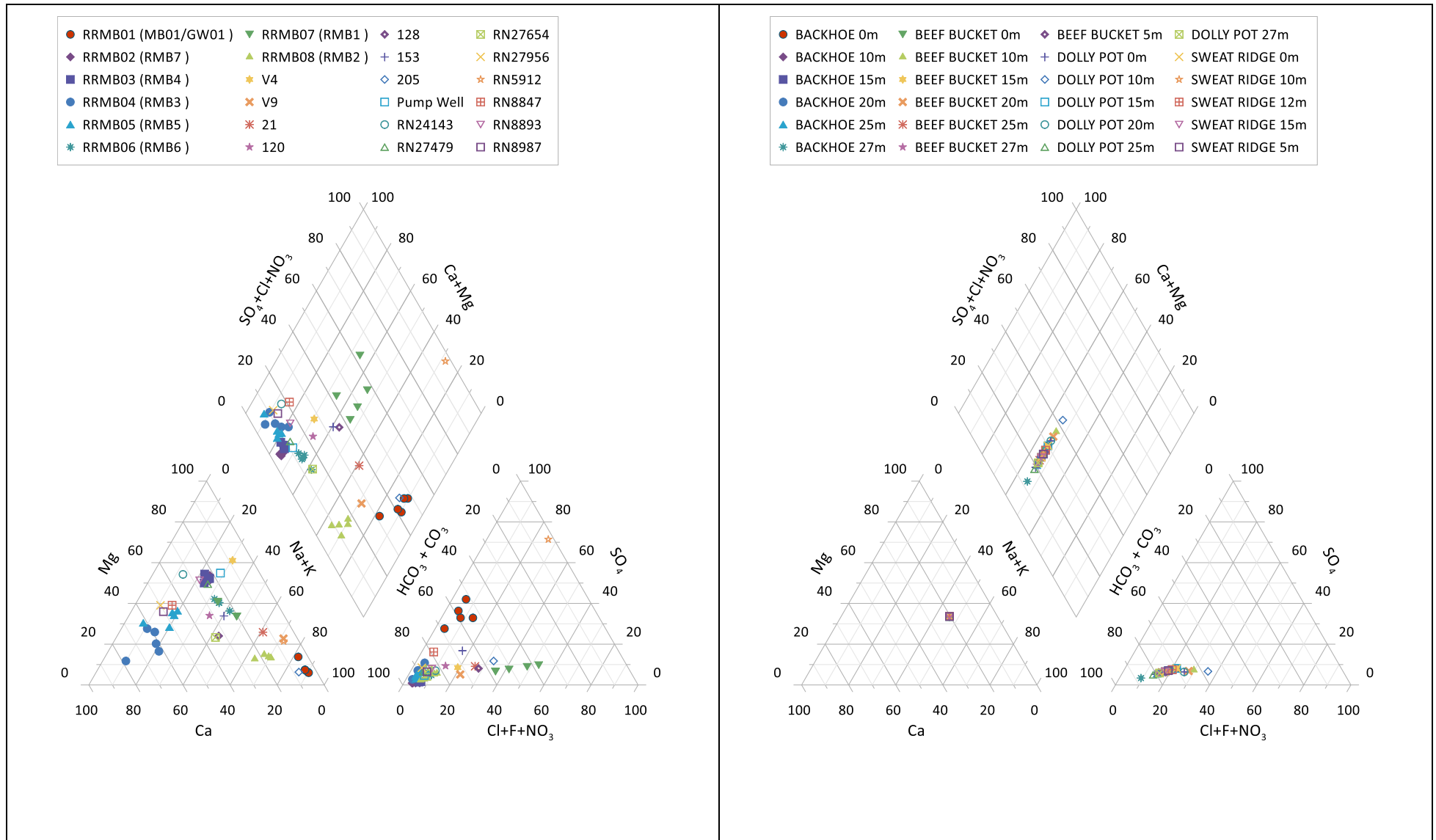


Figure 4-17 Piper Diagram – Groundwater and Open Pit Water at Rustlers Roost

4 Description of Environmental Values

Baseline Water Quality

Detailed groundwater, open pit and surface water analysis results, with comparison against the adopted water quality guidelines/trigger values are presented in Appendix A.

With respect to the groundwater exceedances of the adopted water quality guidelines/trigger values:

- Exceedances of the adopted trigger values for aquatic ecosystems are summarised in Table 4-17. It must be noted that, given the absence of GDEs in the Project area and the absence of groundwater discharge into local creeks and drainages, these trigger values are only relevant in case of abstraction of groundwater and discharge to surface water (e.g. for pit dewatering);
- There were no exceedances of the water quality guidelines for livestock watering; and
- Exceedances of the long-term irrigation guideline values were observed for iron, manganese and total phosphorus in some of the wells.

Table 4-17 Rustlers Roost Summary of Groundwater Exceedances of Aquatic Ecosystem Trigger Values

Analyte	RRMB01	RRMB02	RRMB03	RRMB04	RRMB05	RRMB06	RRMB07	RRMB08
Field Readings								
Electrical Conductivity	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes
pH	Yes	-	Yes	-	-	Yes	Yes	Yes
Turbidity	-	-	-	-	-	-	-	-
Metals (dissolved)								
Arsenic	-	-	-	-	Yes	Yes	-	-
Chromium	-	-	-	Yes	-	-	-	-
Copper	Yes	Yes	Yes	-	-	Yes	Yes	Yes
Lead	-	-	Yes	-	-	-	Yes	-
Zinc	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes
Nutrients								
Ammonia	Yes	-	-	-	-	-	-	-
Physico-chemical								
pH (lab)	Yes	-	-	-	-	-	-	-
Total Suspended Solids	Yes	-	-	-	-	-	-	-
Turbidity	Yes	-	-	-	-	-	-	-

Notes:

Light green highlight: only exceeds the Toms Gully SSTV

Light blue highlight: only exceeds the ANZG 2018 trigger value

Box and Whisker plots for selected analytes are presented in Appendix A. A summary description of selected water quality parameters for groundwater monitoring and analysis results obtained during the 2020-2021 monitoring program is presented in Table 4-18.

4 Description of Environmental Values

Table 4-18 Baseline Groundwater Quality at Rustlers Roost

Parameter	Water quality summary
Field Measurements	
Dissolved Oxygen (%sat) (field)	Based on 40 readings, values ranged from 1 % (at RRGB05) to 39.9 % (at RRGB07), with an average of 13.2 %. The DO values were outside the Tropical Australia Lowland Rivers guideline range of 85% to 120%.
Electrical Conductivity (field)	Based on 40 readings, values ranged from 36.1 $\mu\text{S}/\text{cm}$ (at RRGB07) to 305.4 $\mu\text{S}/\text{cm}$ (at RRGB05), with an average of 155.3 $\mu\text{S}/\text{cm}$. Exceedances of the Tropical Australia Lowland Rivers guideline range (20 – 250 $\mu\text{S}/\text{cm}$) were observed at wells RRGB04 and RRGB05.
pH	Based on 40 readings, values ranged from 3.77 (at RRGB07) to 6.78 (at RRGB04), with an average of 5.697, indicating that the groundwater was acidic to near neutral. Lowest, most acidic pH levels were observed at RRGB07. Values outside the adopted trigger value range were observed at wells RRGB01, RRGB03, RRGB06, RRGB07 and RRGB08.
Turbidity (field)	Based on 40 readings, values ranged from 0.42 NTU (at RRGB03) to 57.6 NTU (at RRGB01), with an average of 7.8 NTU.
Alkalinity	
Bicarbonate Alkalinity as CaCO_3	Based on 39 readings, values ranged from 2 mg/L (at RRGB07) to 195 mg/L (at RRGB05), with an average of 68.1 mg/L. The low levels are reflected by the measured pH <7 and indicate the reduced buffer capability, hence reduced acid neutralising ability of the groundwater.
Physico-Chemical	
Total Hardness	Based on 35 readings, values ranged from 4 mg/L (at RRGB01) to 187 mg/L (at RRGB05), with an average of 51.4 mg/L, indicating that the groundwater hardness varies from soft to moderately hard.
Major Ions	
Calcium	Based on 32 readings, values ranged from 1 mg/L (at RRGB01) to 50 mg/L (at RRGB05), with an average of 11.8 mg/L.
Chloride	Based on 40 readings, values ranged from 2 mg/L (at RRGB01) to 6 mg/L (at RRGB01), with an average of 3.3 mg/L.
Magnesium	Based on 35 readings, values ranged from 1 mg/L (at RRGB01) to 15 mg/L (at RRGB05), with an average of 5.9 mg/L.
Sodium	Based on 40 readings, values ranged from 1 mg/L (at RRGB04) to 28 mg/L (at RRGB01), with an average of 7.3 mg/L.
Sulphate	Based on 26 readings, values ranged from 1 mg/L (at RRGB07) to 31 mg/L (at RRGB01), with an average of 8.5 mg/L.
Metals	
Aluminium	Based on 15 readings, values ranged from 0.01 mg/L (at RRGB05) to 0.19 mg/L (at RRGB01), with an average of 0.075 mg/L. There are no trigger values for dissolved aluminium when pH is less than 6.5.
Arsenic	Based on 29 readings, values ranged from 0.001 mg/L (at RRGB01) to 0.07 mg/L (at RRGB05), with an average of 0.0099 mg/L. Exceedances of the adopted trigger values were observed only in wells RRGB05 and RRGB06.
Chromium	Based on 2 readings, values ranged from 0.001 mg/L (at RRGB04) to 0.002 mg/L (at RRGB04), with an average of 0.0015 mg/L. Exceedances of the adopted trigger values were observed only in well RRGB02.
Copper	Based on 21 readings, values ranged from 0.001 mg/L (at RRGB01) to 0.033 mg/L (at RRGB07), with an average of 0.0096 mg/L. Exceedances of the adopted trigger values were observed in most wells.
Manganese	Based on 38 readings, values ranged from 0.001 mg/L (at RRGB02) to 0.627 mg/L (at RRGB04), with an average of 0.153 mg/L.

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Parameter	Water quality summary
Zinc	Based on 33 readings, values ranged from 0.005 mg/L (at RRGB02) to 0.078 mg/L (at RRGB03), with an average of 0.022 mg/L. Exceedances of the adopted trigger values were observed in all wells, except in RRGB05
Nutrients	
Ammonia	Based on 13 readings, values ranged from 0.01 mg/L (at RRGB03) to 1.29 mg/L (at RRGB01), with an average of 0.26 mg/L. Exceedances of the adopted trigger values were observed only in well RRGB01.
Total Nitrogen as N	Based on 12 readings, values ranged from 0.1 mg/L (at RRGB04) to 3.7 mg/L (at RRGB01), with an average of 0.6 mg/L.
Total Phosphorus	Based on 34 readings, values ranged from 0.01 mg/L (at RRGB07) to 0.8 mg/L (at RRGB06), with an average of 0.16 mg/L.

Summary

Overall, the groundwater quality monitoring has shown groundwater is typically fresh, acidic to near neutral and has exceedances of aquatic ecosystems guideline values (GVs) for some metals and nutrients at some sampling occasions and locations. The elevated phosphorus and metal concentrations may be associated with underlying mineralogical deposits entailing weathered zones.

The groundwater monitoring bores show limited impacts from previous mining activities. Only RRGB01, which is located next to the heap leach pad, shows signals of influence from potential waste rock leachate.

4.4.5.3 Quest 29 2020-2021 Water Quality

Field water quality parameters measured during the 2020-2021 monitoring program and analysis results of groundwater and open pit sample are presented in Appendix B. A statistical summary of the groundwater analysis results is presented in Table 4-19.

4 Description of Environmental Values

Table 4-19 Quest 29 Statistical Summary of Groundwater Analysis Results

Analyte				Results > LOR					Exceedances				
				No. Results	Minimum	Average	Maximum	StDev	Toms Gully SSTV (8th percentile)	Tropical Australia Lowland Rivers	ANZG 218 freshwater - 95% species protection	ANZECC 2 Livestock Watering (beef cattle)	ANZECC 2 long term irrigation
Alkalinity													
Bicarbonate Alkalinity	mg/L	66	2	64	12	136.0313	255	53.6127	-	-	-	-	-
Carbonate Alkalinity	mg/L	69	63	6	5	41.6667	133	57.9333	-	-	-	-	-
Hydroxide Alkalinity	mg/L	48	48	-	-	-	-	-	-	-	-	-	-
Total Alkalinity	mg/L	48	-	48	12	129.6042	255	58.9792	-	-	-	-	-
Field Measurements													
Dissolved Oxygen (%sat) (field)	%	45	-	45	1	8.6022	59.9	13.5569	-	-	-	-	-
Electrical Conductivity (field)	µS/cm	64	-	64	4.29	473.6889	1213	337.6680	Yes	-	-	-	-
ORP (field)	mV	45	-	45	-237	-22.1800	192	88.6116	-	-	-	-	-
pH (field)	-	68	-	68	4.47	6.3775	7.6	0.6408	Yes	Yes	-	-	-
Salinity (field)	ppt	44	-	44	0.02	0.1880	0.51	0.1229	-	-	-	-	-
Temperature (field)	°C	45	-	45	30.7	32.0911	33.7	0.7147	-	-	-	-	-
Total Dissolved Solids (field)	mg/L	45	-	45	25.1	247.2600	676	168.0982	-	-	-	-	-
Turbidity (field)	NTU	58	-	58	0.32	34.8486	400	93.3683	Yes	-	-	-	-
Major Ions													
Calcium	mg/L	69	-	69	3	54.0043	140	43.6974	-	-	-	-	-
Chloride	mg/L	68	-	68	2	6.2588	16	3.0799	-	-	-	-	-
Magnesium	mg/L	26	-	26	8	13.0000	19	3.9192	-	-	-	-	-
Sodium	mg/L	68	-	68	2	12.6426	44	9.2435	-	-	-	-	-
Sulphate	mg/L	67	-	67	1	105.3448	445	159.1398	Yes	-	-	-	-
Metals (dissolved)													
Aluminium (dissolved)	mg/L	67	52	15	0.01	0.0327	0.31	0.0768	Yes	-	-	-	-
Arsenic (dissolved)	mg/L	67	5	62	0.00185	0.0406	0.2	0.0471	Yes	-	Yes	-	Yes
Cadmium (dissolved)	mg/L	67	52	15	0.0001	0.0002	0.00113	0.0003	Yes	-	Yes	-	-

4 Description of Environmental Values

Analyte	Units	No. Results	No. Results <LOR	Results > LOR					Exceedances				
				No. Results	Minimum	Average	Maximum	StDev	Toms Gully SSTV (8th percentile)	Tropical Australia Lowland Rivers	ANZG 218 freshwater - 95% species protection	ANZECC 2 Livestock Watering (beef cattle)	ANZECC 2 long term irrigation
Chromium (dissolved)	mg/L	67	51	16	0.001	0.0041	0.011	0.0029	Yes	-	Yes	-	-
Cobalt (dissolved)	mg/L	67	36	31	0.001	0.0016	0.005	0.0010	-	-	-	-	-
Copper (dissolved)	mg/L	67	49	18	0.001	0.0029	0.009	0.0026	Yes	-	Yes	-	-
Iron (dissolved)	mg/L	67	5	62	0.01	3.1869	19	5.1002	Yes	-	-	-	Yes
Lead (dissolved)	mg/L	67	56	11	0.001	0.0014	0.005	0.0012	-	-	Yes	-	-
Manganese (dissolved)	mg/L	67	-	67	0.013	0.4864	1.5	0.3831	-	-	-	-	Yes
Nickel (dissolved)	mg/L	67	34	33	0.001	0.0046	0.02	0.0048	Yes	-	4	-	-
Selenium (dissolved)	mg/L	45	45	-	-	-	-	-	-	-	-	-	-
Tin (dissolved)	mg/L	45	45	-	-	-	-	-	-	-	-	-	-
Uranium (dissolved)	mg/L	57	57	-	-	-	-	-	-	-	-	-	-
Zinc (dissolved)	mg/L	67	14	53	0.001	0.0208	0.0846	0.0208	Yes	-	Yes	-	-
Metals (total)													
Aluminium (total)	mg/L	45	28	17	0.01	0.0518	0.29	0.0889	-	-	-	-	-
Arsenic (total)	mg/L	45	5	40	0.004	0.0568	0.209	0.0577	-	-	Yes	-	Yes
Cadmium (total)	mg/L	66	61	5	0.0001	0.0007	0.0028	0.0012	-	-	Yes	-	-
Chromium (total)	mg/L	66	66	-	-	-	-	-	-	-	-	-	-
Cobalt (total)	mg/L	59	41	18	0.001	0.0022	0.004	0.0010	-	-	-	-	-
Copper (total)	mg/L	66	50	16	0.002	0.0057	0.013	0.0036	-	-	Yes	-	-
Ferrous Iron	mg/L	45	7	38	0.1	1.6971	5.38	1.4392	-	-	-	-	-
Iron (total)	mg/L	45	4	41	0.13	1.7354	4.56	1.2349	-	-	-	-	-
Lead (total)	mg/L	66	62	4	0.001	0.0123	0.044	0.0212	-	-	Yes	-	-
Manganese (total)	mg/L	66	19	47	0.0005	0.3599	1.08	0.2724	-	-	-	-	Yes
Nickel (total)	mg/L	45	22	23	0.001	0.0063	0.025	0.0058	-	-	Yes	-	-
Selenium (total)	mg/L	45	45	-	-	-	-	-	-	-	-	-	-
Tin (total)	mg/L	45	44	1	0.001	0.0010	0.001	-	-	-	-	-	-
Uranium (total)	mg/L	45	45	-	-	-	-	-	-	-	-	-	-

4 Description of Environmental Values

Analyte	Units	No. Results	No. Results <LOR	Results > LOR					Exceedances				
				No. Results	Minimum	Average	Maximum	StDev	Toms Gully SSTV (8th percentile)	Tropical Australia Lowland Rivers	ANZG 218 freshwater - 95% species protection	ANZECC 2 Livestock Watering (beef cattle)	ANZECC 2 long term irrigation
Zinc (total)	mg/L	66	19	47	0.0012	0.0323	0.472	0.0688	-	-	Yes	-	-
Nutrients													
Ammonia	mg/L	45	21	24	0.01	0.0571	0.23	0.0666	-	Yes	-	-	-
Nitrate + Nitrite	mg/L	45	28	17	0.02	0.0506	0.15	0.0378	-	-	-	-	-
Total Kjeldahl Nitrogen as N	mg/L	45	36	9	0.1	0.1889	0.3	0.0601	-	-	-	-	-
Total Nitrogen as N	mg/L	45	35	10	0.1	0.2100	0.3	0.0568	-	-	-	-	-
Total Phosphorus	mg/L	45	7	38	0.01	0.0658	0.14	0.0380	-	Yes	-	-	Yes
Physico-chemical													
Total Hardness	mg/L	48	-	48	7	165.6667	455	118.9485	-	-	-	-	-
Total Suspended Solids	mg/L	68	24	44	5	35.2273	470	71.8949	Yes	-	-	-	-
Turbidity (lab)	NTU	45	2	43	0.2	8.5093	29.9	8.2711	-	-	-	-	-

Hydrogeochemistry

Based on the field water quality parameters, it can be concluded that the groundwater at Quest 29:

- Is acidic to neutral, with pH levels varying from 4.47 to 7.6, with an average of 6.38. Time series of field pH versus rainfall are presented in Figure 4-18. To a minor degree, pH levels vary with rainfall. pH levels in monitoring well Q29MB03 are more acidic (i.e. between 4.47 and 5.86) than in the other monitoring wells (i.e. between 4.73 and 7.33);
- Is fresh, with electrical conductivity (EC) varying from 4.3 $\mu\text{S}/\text{cm}$ to 1,213 $\mu\text{S}/\text{cm}$, with an average of 473 $\mu\text{S}/\text{cm}$, and total dissolved solids (TDS) varying from 25 mg/L to 676 mg/L, with an average of 247 mg/L. Time series of field EC versus rainfall are presented in Figure 4-19;
- Has low dissolved oxygen levels, ranging from 1% to 60% saturation, with an average of 9%; and
- Has bicarbonate alkalinity (as CaCO_3) ranging from 12 mg/L to 255 mg/L, with an average of 136 mg/L.

Piper diagrams of groundwater and open pit water are presented on Figure 4-20. Based on the ionic composition:

- The groundwater at wells Q29MB03, Q29MB04, Q29MB05, Q29MB06, Q29MB07, Q29MB08 and Q29MB09 can be classified as a “calcium-magnesium-bicarbonate” water type;
- The groundwater at wells Q29MB01 and Q29MB02 can be classified as a “calcium-magnesium-sulphate” water type. These wells are located near the BHS heap leach pad and groundwater may have been impacted by leachate from the heap leach pad; and
- The water in the open pit can be classified as a “sodium-chloride” water type.

4 Description of Environmental Values

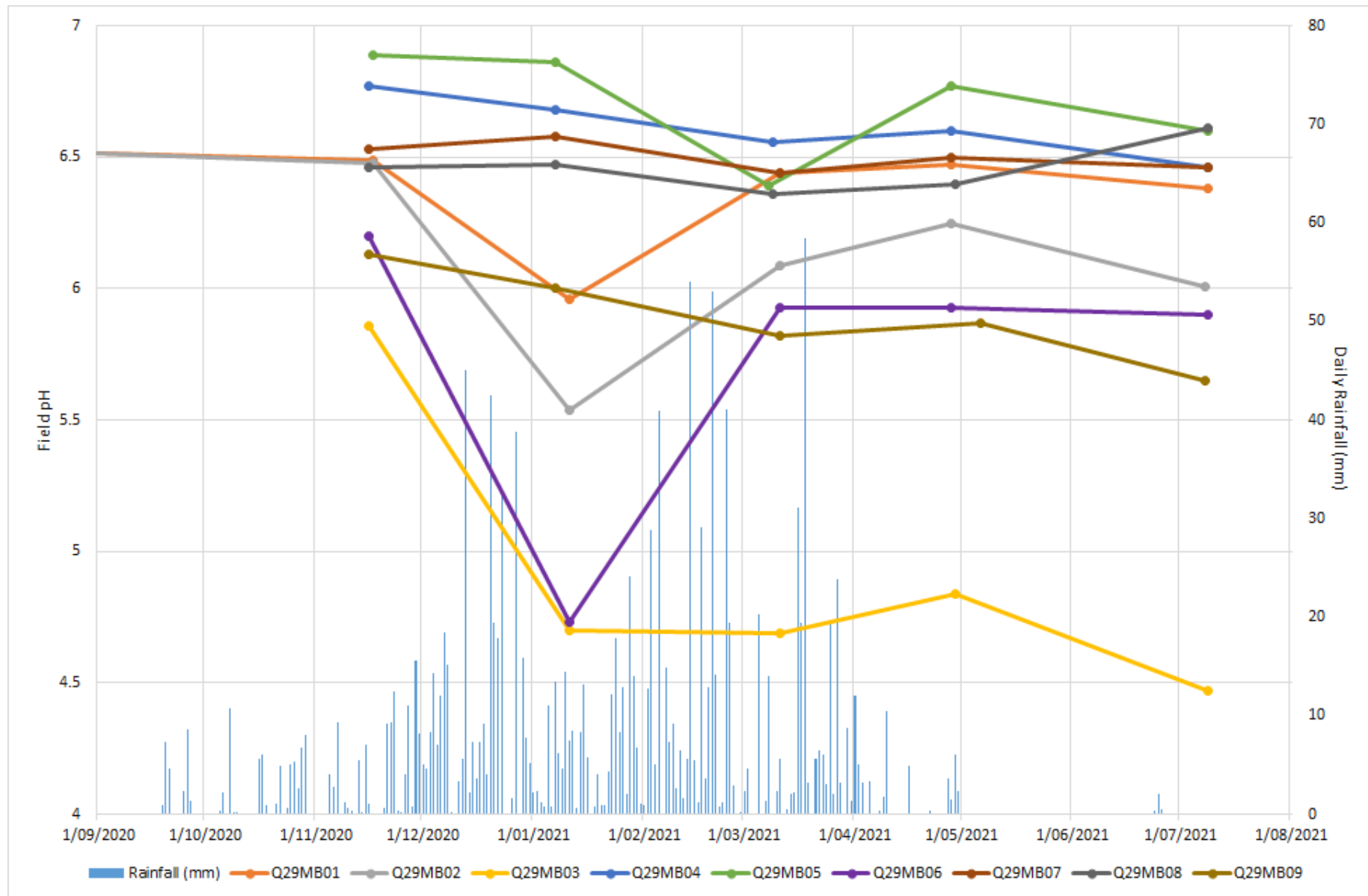


Figure 4-18 Field pH versus Rainfall in Monitoring Wells at Quest 29

4 Description of Environmental Values

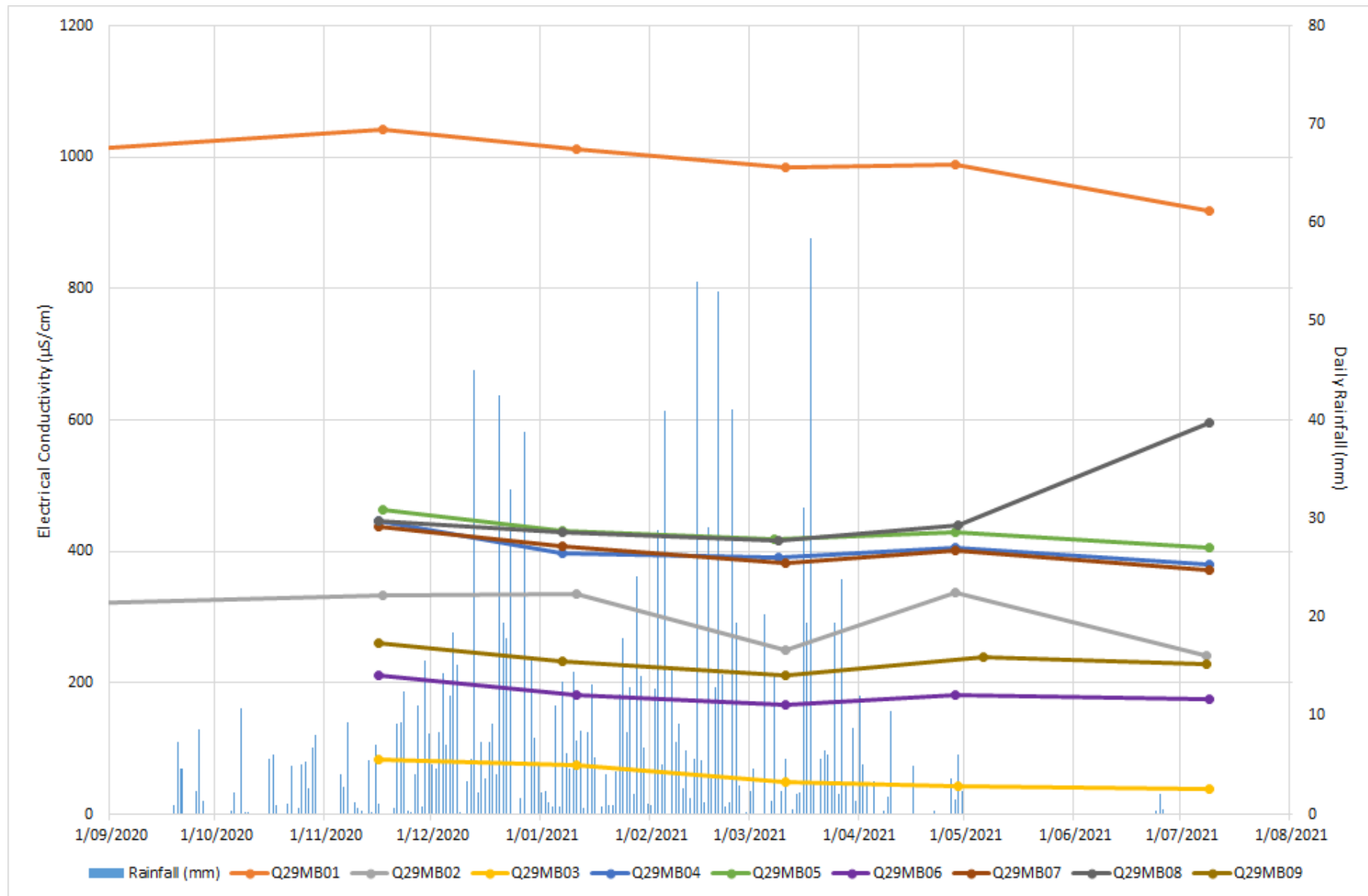


Figure 4-19 Field Electrical Conductivity versus Rainfall in Monitoring Wells at Quest 29

4 Description of Environmental Values

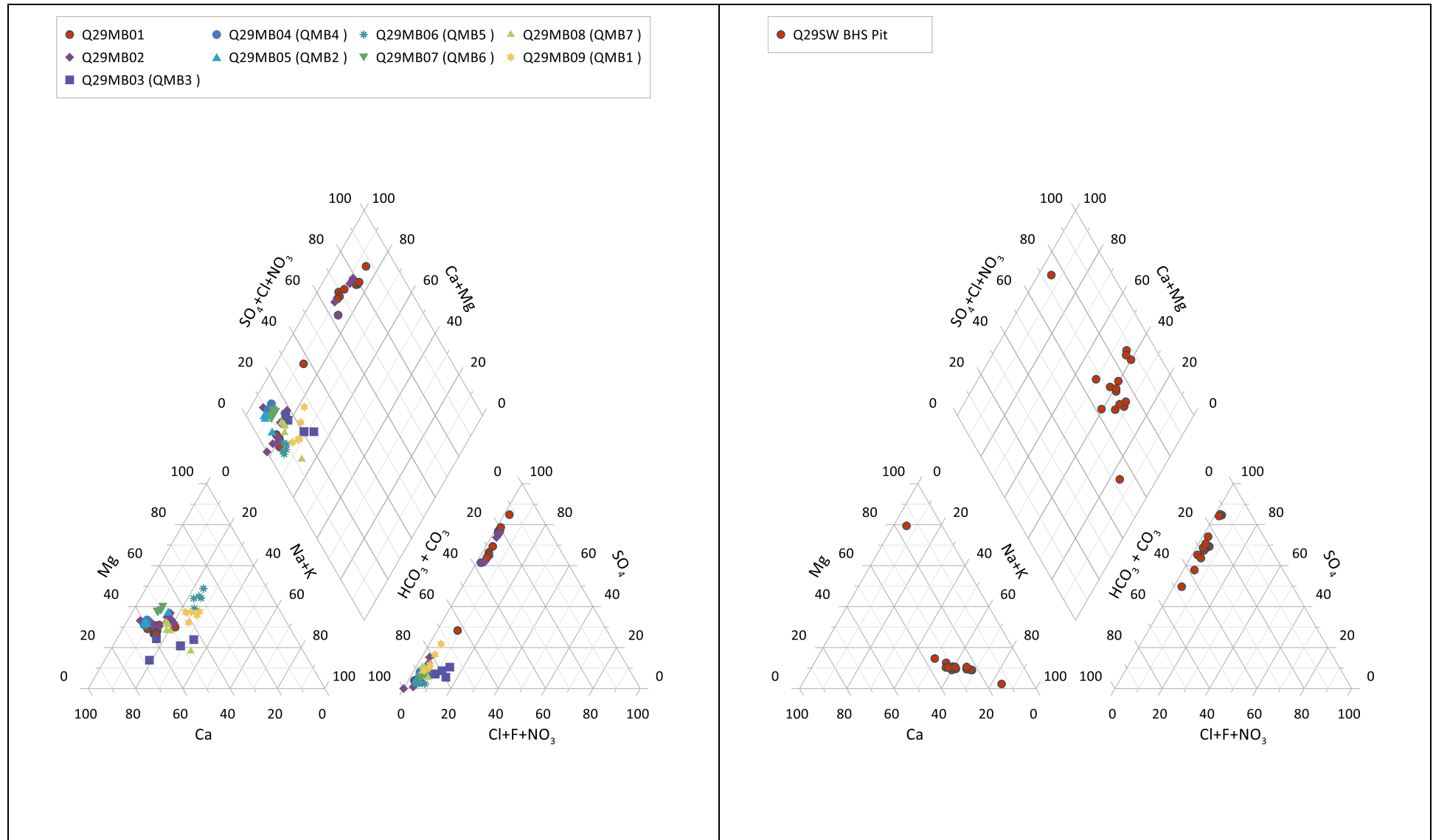


Figure 4-20 Piper Diagram – Groundwater and Open Pit Water at Quest 29

4 Description of Environmental Values

Baseline Water Quality

Detailed groundwater, open pit and surface water analysis results, with comparison against the adopted water quality guidelines/trigger values are presented in Appendix B.

With respect to the groundwater exceedances of the adopted water quality guidelines/trigger values:

- Exceedances of the adopted trigger values for aquatic ecosystems are summarised in Table 4-20. It must be noted that, given the absence of GDEs in the Project area and the absence of groundwater discharge into local creeks and drainages, these trigger values are only relevant in case of abstraction of groundwater and discharge to surface water (e.g. for pit dewatering);
- There were no exceedances of the water quality guidelines for livestock watering; and
- Exceedances of the long-term irrigation guideline values were observed for arsenic, iron, manganese and total phosphorus in most wells.

Table 4-20 Quest 29 Summary of Groundwater Exceedances of Aquatic Ecosystem Trigger Values

Analyte	Q29 MB01	Q29 MB02	Q29 MB03	Q29 MB04	Q29 MB05	Q29 MB06	Q29 MB07	Q29 MB08	Q29 MB09
Field Readings									
Electrical Conductivity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
pH	-	Yes	Yes	-	-	Yes	-	-	Yes
Turbidity	Yes	Yes	-	-	-	-	-	-	-
Major Ions									
Sulphate	Yes	Yes	-	-	-	-	-	-	-
Metals (dissolved)									
Aluminium	Yes	-	-	-	-	-	-	-	-
Arsenic	Yes	Yes	-	Yes	Yes	-	Yes	-	-
Cadmium	Yes	-	-	-	-	-	-	-	-
Chromium	Yes	Yes	-	-	-	-	-	-	-
Copper	Yes	-	Yes	-	-	-	-	-	Yes
Iron	Yes	Yes	-	-	-	-	Yes	-	-
Lead	-	Yes	-	-	-	-	-	-	-
Nickel	-	-	Yes	Yes	-	-	-	-	-
Zinc	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physico-chemical									
Total Suspended Solids	Yes	Yes	-	-	-	-	-	-	-

Notes:

Light green highlight: only exceeds the Toms Gully SSTV

Light blue highlight: only exceeds the ANZG 2018 trigger value

Box and Whisker plots for selected analytes are presented in Appendix B. A summary description of selected water quality parameters for groundwater monitoring and analysis results obtained during the 2020-2021 monitoring program is presented in Table 4-21.

4 Description of Environmental Values

Table 4-21 Baseline Groundwater Quality at Quest 29

Parameter	Water quality summary
Field Measurements	
Dissolved Oxygen (%sat) (field)	Based on 45 readings, values ranged from 1 % (at Q29MB07) to 59.9 % (at Q29MB03), with an average of 8.6%. The DO values were outside the Tropical Australia Lowland Rivers guideline range of 85% to 120%.
Electrical Conductivity (field)	Based on 64 readings, values ranged from 4.29 $\mu\text{S}/\text{cm}$ (at Q29MB05) to 1213 $\mu\text{S}/\text{cm}$ (at Q29MB01), with an average of 473 $\mu\text{S}/\text{cm}$. Exceedances of the Tropical Australia Lowland Rivers guideline range (20 – 250 $\mu\text{S}/\text{cm}$) were observed at in all monitoring wells. However, the groundwater is still classified as “fresh”.
pH	Based on 68 readings, values ranged from 4.47 (at Q29MB03) to 7.6 (at Q29MB02), with an average of 6.3, indicating that the groundwater was acidic to near neutral. Lowest, most acidic pH levels were observed at Q29MB03. Values outside the adopted trigger value range were observed at wells Q29MB01, Q29MB02, Q29MB03, Q29MB06 and Q29MB09.
Turbidity (field)	Based on 58 readings, values ranged from 0.32 NTU (at Q29MB02) to 400 NTU (at Q29MB02), with an average of 34.8 NTU. Exceedances of the adopted trigger value were observed at wells Q29MB01 and Q29MB02.
Alkalinity	
Bicarbonate Alkalinity as CaCO_3	Based on 64 readings, values ranged from 12 mg/L (at Q29MB03) to 255 mg/L (at Q29MB08), with an average of 136.0 mg/L. The low levels are reflected by the measured pH <7 and indicate the reduced buffer capability, hence reduced acid neutralising ability of the groundwater.
Physico-Chemical	
Total Hardness	Based on 48 readings, values ranged from 7 mg/L (at Q29MB03) to 455 mg/L (at Q29MB02), with an average of 165.7 mg/L, indicating that the groundwater hardness varies from soft to hard.
Major Ions	
Calcium	Based on 69 readings, values ranged from 3 mg/L (at Q29MB03) to 140 mg/L (at Q29MB01), with an average of 54.0 mg/L.
Chloride	Based on 68 readings, values ranged from 2 mg/L (at Q29MB03) to 16 mg/L (at Q29MB08), with an average of 6.3 mg/L.
Magnesium	Based on 26 readings, values ranged from 8 mg/L (at Q29MB06) to 19 mg/L (at Q29MB07), with an average of 13 mg/L.
Sodium	Based on 68 readings, values ranged from 2 mg/L (at Q29MB03) to 44 mg/L (at Q29MB08), with an average of 12.6 mg/L.
Sulphate	Based on 67 readings, values ranged from 1 mg/L (at Q29MB03) to 445 mg/L (at Q29MB01), with an average of 105.3 mg/L.
Metals	
Aluminium	Based on 15 readings, values ranged from 0.01 mg/L (at Q29MB01) to 0.31 mg/L (at Q29MB01), with an average of 0.033 mg/L. Exceedances of the adopted trigger values were observed only in well Q29MB01.
Arsenic	Based on 62 readings, values ranged from 0.00185 mg/L (at Q29MB01) to 0.2 mg/L (at Q29MB04), with an average of 0.041 mg/L. Exceedances of the adopted trigger values were observed in all wells, except Q29MB03, Q29MB06, Q29MB08 and Q29MB09.
Cadmium	Based on 15 readings, values ranged from 0.0001 mg/L (at Q29MB01) to 0.00113 mg/L (at Q29MB01), with an average of 0.00024 mg/L. Exceedances of the adopted trigger values were observed only in well Q29MB01.
Chromium	Based on 16 readings, values ranged from 0.001 mg/L (at Q29MB01) to 0.011 mg/L (at Q29MB01), with an average of 0.004 mg/L. Exceedances of the adopted trigger values were observed only in wells Q29MB01 and Q29MB02.
Copper	Based on 18 readings, values ranged from 0.001 mg/L (at Q29MB01) to 0.009 mg/L (at Q29MB03), with an average of 0.0029 mg/L. Exceedances of the adopted trigger values were observed only in wells Q29MB01, Q29MB03 and Q29MB09.

4 Description of Environmental Values

Parameter	Water quality summary
Lead	Based on 11 readings, values ranged from 0.001 mg/L (at Q29MB01) to 0.005 mg/L (at Q29MB02), with an average of 0.00136 mg/L. Exceedances of the adopted trigger values were observed only in well Q29MB02.
Zinc	Based on 53 readings, values ranged from 0.001 mg/L (at Q29MB01) to 0.0846 mg/L (at Q29MB01), with an average of 0.0208 mg/L. Exceedances of the adopted trigger values were observed in all wells.
Nutrients	
Ammonia	Based on 24 readings, values ranged from 0.01 mg/L (at Q29MB01) to 0.23 mg/L (at Q29MB02), with an average of 0.0571 mg/L. There were no exceedances of the adopted trigger values.
Total Nitrogen as N	Based on 10 readings, values ranged from 0.1 mg/L (at Q29MB02) to 0.3 mg/L (at Q29MB02), with an average of 0.21 mg/L.
Total Phosphorus	Based on 38 readings, values ranged from 0.01 mg/L (at Q29MB03) to 0.14 mg/L (at Q29MB02), with an average of 0.066 mg/L.

Summary

Overall, the groundwater at Quest 29 is acidic to neutral and fresh. Exceedances of the adopted aquatic freshwater trigger values were observed for several analytes in all monitoring wells. All monitoring bores, except for Q29MB01 and Q29MB02, showed similar water chemistry with small variations indicating limited impacts from previous mining activities.

Existing water quality results indicate that groundwater may have been locally impacted by historical mining activities (i.e. at Q29MB01 and Q29MB02), as evidenced by the elevated sulphate levels observed in these bores. Bores Q29MB01 and Q29MB02 are located in proximity to the BHS leach pad and appear to be impacted by rock solutes with elevated sulphate levels.

Recent monitoring of Q29MB01 shows elevated EC and dissolved metals in comparison to other sites. pH values range between 6.09 to 7.33, and elevated EC, well above the aquatic ecosystem protection GV of 250 $\mu\text{S}/\text{cm}$ (ranging from 210 to 1,213 $\mu\text{S}/\text{cm}$) and exceedance of the ecosystem protection GV of Al, As, Cd, Cr, Cu and Zn.

Q29MB02 located west of the heap leach ponds and pad has had elevated EC and occasional exceedances of the aquatic ecosystem protection GV of As, Cd, Cr, Cu, Pb and Zn. pH values range from slightly acidic (6.49) to slightly alkaline (7.6), and elevated EC, above the aquatic ecosystem protection GV of 250 $\mu\text{S}/\text{cm}$ (ranging from 210 to 336 $\mu\text{S}/\text{cm}$).

4.4.6 Groundwater Recharge and Discharge

Groundwater recharge within the mining lease is considered to result from direct rainfall infiltration during runoff and, to a much lesser extent, from small dams located within the lease area. These dams would give localised groundwater “highs” which are superimposed on the regional flow pattern (Environmental and Earth Sciences Pty Ltd, January 1993).

Groundwater discharge would be mainly through limited seepage within the existing open pits or regionally through discharge into creeks and surface water drainages/bodies.

APPENDIX C – SOURCE TERM



C-1 RUSTLERS ROOST

Job Number: W-AA
Appendix C1- Rustlers Roost Leachate Results SOURCE TERM
Project: Hanking Khefic Geochemical Assessment - Rustlers Roost
Job Number: W-AA-06
Client: CDW Smith

ChemCentre ID	20S4984003	20S4984006	20S4984013	20S4984018	20S4984023	20S4984028	20S4984033	20S4984038	20S4984043	20S4984048	20S4984053	20S4984058	20S4984063
Client ID	RR102 & RR103 M0	RR102 & RR103 M1	RR102 & RR103 M2	RR102 & RR103 M3	RR102 & RR103 M4	RR102 & RR103 M5	RR102 & RR103 M6	RR102 & RR103 M7	RR102 & RR103 M8	RR102 & RR103 M9	RR102 & RR103 M10	RR102 & RR103 M11	RR102 & RR103 M12
Lithology	Psh tr	Psh tr	Psh tr	Psh tr	Psh tr	Psh tr	Psh tr	Psh tr	Psh tr	Psh tr	Psh tr	Psh tr	Psh tr
Sampled	not provided	not provided	not provided	30/08/2021	27/09/2021	44494	44522	2012/2021	17/01/2022	14/02/2022	14/03/2022	11/04/2022	9/05/2022

Analyte	Method Code	Limits of Reporting	Units	Groundwater	ANZG Default GV 95%	Bundy Creek TV's	Stock Watering (Beef)	ANZECC & ARMCANZ 2000 Short-Term Irrigation Water	ANZECC & ARMCANZ 2000 Long-Term Irrigation Water	7700	2500	3400	3200	3100	2800	2900	3200	3600	4000	3800	6700	7500
Acidity	IACDIWATI	2	mg/L	88	0.0005					0.0002	<0.0001	0.0003	0.0001	0.0028	0.0019	0.0013	0.0002	0.0004	0.0003	<0.0001	<0.0001	0.0003
Al	IMETIWICP	0.005	mg/L	0.19		Al (pH>6.5) 295	5	20	5	1100	360	500	420	360	360	310	330	370	390	340	580	620
Alkalin	IALKIWATI	1	mg/L							<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
As	IMETIWCMS	0.001	mg/L	0.07				2	0.1	0.021	0.006	0.015	0.022	0.027	0.026	0.029	0.052	0.11	0.23	0.13	0.37	0.71
Ba	IMETIWCMS	0.0001	mg/L							0.038	0.0048	0.0019	0.0012	0.0019	0.0016	0.001	0.0013	0.0009	0.0008	0.0015	0.001	0.0005
Be	IMETIWICP	0.001	mg/L																			
Be	IMETIWCMS	0.0001	mg/L							0.26	0.13	0.16		0.12	0.082	0.049	0.049	0.049	0.036	0.026	0.022	0.035
Cd	IMETIWCMS	0.0001	mg/L		0.0002	0.0004	0.01	0.05	0.01	0.079	0.067	0.09	0.069	0.067	0.047	0.03	0.025	0.022	0.017	0.01	0.008	0.0096
Co	IMETIWICP	0.005	mg/L	0.015	0.0014		1			10	2.9	3.9	3.2									
Co	IMETIWCMS	0.0001	mg/L	0.015	0.0014		1	0.1	0.05					2.7	2.1	1.4	1.1	1.2	1.2	0.82	1.1	1.3
Cr	IMETIWCMS	0.0005	mg/L	0.002			1	1	0.1	0.5	0.12	0.22	0.19	0.21	0.18	0.14	0.15	0.2	0.24	0.17	0.3	0.39
Cs	IMETIWCMS	0.0001	mg/L							0.0022	0.0003	0.0002	0.0003	0.0004	0.0002	0.0002	0.0001	<0.0001	0.0001	<0.0001	<0.0001	0.0002
Cu	IMETIWICP	0.002	mg/L	0.033	0.0014		2			82	30	37	30	23	16	10	8.4	7	5.3	2.6	2.7	
Cu	IMETIWCMS	0.0001	mg/L	0.033	0.0014	0.0018	2	5	0.2													
ECCond	IECTIWZSE	0.2	mS/m			41				814	281	441	426	400	ISS	379	414	439	466	402	662	666
F	IFIWASE	0.05	mg/L							0.41	0.12	0.09	0.08	4.5	4.3	4.0	3.6	3.4	2.5	2.7	2.8	
Fe	IMETIWICP	0.005	mg/L	2.5		2.7**		10	0.2	450	49	100	130	150	220	240	330	410	510	460	1200	1400
Hg	IMETIWCMS	0.0001	mg/L		0.0006					<0.0001	<0.0001	<0.0001	<0.0001	0.001	0.0003	0.0004	<0.0001	0.0004	0.0002	0.0003	<0.0001	0.0002
Li	IMETIWICP	0.005	mg/L																			
Li	IMETIWCMS	0.0001	mg/L							0.66	0.48	0.4	0.35	0.26	0.24	0.22	0.21	0.26	0.19	0.18	0.28	0.31
Mn	IMETIWICP	0.001	mg/L							44	18	22	19	16	14	11	12	14	14	10	18	18
Mo	IMETIWCMS	0.001	mg/L					0.05	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001		
Ni	IMETIWICP	0.01	mg/L	0.006			1		0.2	6	2.5	3.5		2.5	2.4	2	1.3	1.2	1.3	0.89	1.5	1.8
Ni	IMETIWCMS	0.001	mg/L	0.006		0.013	1	2														
P	IMETIWICP	0.1	mg/L	0.8						0.4	0.1	0.2	0.3	0.4	0.4	0.4	0.7	0.9	1.1	0.5	0.011	0.0053
Pb	IMETIWCMS	0.0001	mg/L	0.006	0.0034	0.0056	0.1	5	2	0.0049	0.0061	0.0099	0.006	0.008	0.024	0.0087	0.015	0.0071	0.0037	0.0058	0.0013	0.0018
Rb	IMETIWCMS	0.0001	mg/L							0.1	0.018	0.016	0.019	0.019	0.015	0.0079	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052
S	IMETIWICP	0.1	mg/L			70*				2900	850	1000	1100	990	930	840	930	1100	1300	1000	6300	6600
SO4	IMETIWICP	Calculated	mg/L			210*	1000			8700	2550	3000	3300	2970	2790	2520	2790	3300	3900	3000	<0.0001	0.0002
Se	IMETIWCMS	0.0001	mg/L							0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0037	0.0061
Se	IMETIWCMS	0.001	mg/L		0.011		0.02	0.05	0.02	0.14	0.1	0.13	0.085	0.085	0.077	0.061	0.051	0.063	0.06	0.04	0.004	0.003
Si	IMETIWICP	0.05	mg/L							35	13	13	13	12	11	12	13	12	13	8.8	13	13
Sr	IMETIWICP	0.002	mg/L							0.2	0.045	0.026	0.015	0.011	0.006	0.006	0.005	0.005	0.004	0.006	0.19	0.21
Th	IMETIWCMS	0.0001	mg/L							0.18	0.061	0.14	0.099	0.19	0.2	0.14	0.21	0.21	0.12	<0.0001	<0.0001	0.27
Ti	IMETIWCMS	0.0001	mg/L							0.0003	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.017	0.025
U	IMETIWCMS	0.0001	mg/L		0.0005		0.2	0.1	0.01	0.32	0.15	0.24	0.2	0.17	0.13	0.083	0.072	0.053	0.04	0.021	0.14	0.12
V	IMETIWICP	0.005	mg/L		0.006			0.5	0.1	0.01	<0.005	0.014	0.024	0.03	0.042	0.043	0.055	0.065	0.08	0.056	170	180
Volume	VOLUME	0.1	mL							200	160	160	160	160	160	170	160	160	170	160		
Zn	IMETIWICP	0.005	mg/L	0.078	0.008		20			12	4.1	5.7	4.6	3.7			2.1	1.6	1.8	1.8	1.4	1.7
Zn	IMETIWCMS	0.001	mg/L	0.078	0.008	0.014	20	5	2											2.3	2.3	2.3
pH	IPHIWASE	0.1		5.7		5.8-8.0				3.2	3.7	2.9	2.8	2.7	2.7	2.6	2.5	2.5	2.5	2.5	2.3	2.3

-

+

..

**

Sulfate

Sulfate as S

Fe

Mn

210

70

2700

2500

mg/L

mg/L

ug/L

ug/L

based on background Fe data from Bundy Creek

based on background Fe data from Bundy Creek

Max
7700
1100
0
0.71
0.038
0.14
0.26
0.09
10
2.7
0.5
0.0002
82
0
814
4.6
1400
0.001
0.35
0.66
44
0.002
6
2.5
1.1
0.06
2200
6600
8700
0.061
13
35
0.21
0.27
0.025
180
200
12
2.3
3.2

C-2 QUEST 29

Appendix C2 - Quest 29 Leachate Results SOURCE TERM
Project: Hanking Kinetic Geochemical Assessment - Quest29
Job Number: W-AA-06
Client: CDM Smith

ChemCentre Id		20S4886/002	20S4886/007	20S4886/012	20S4886/017	20S4886/022	20S4886/027	20S4886/032	20S4886/037	20S4886/042	20S4886/047	20S4886/052	20S4886/057
Client Id		HKR34157 & HKR34089 M0	HKR34157 & HKR34089 M1	HKR34157 & HKR34089 M2	HKR34157 & HKR34089 M3	HKR34157 & HKR34089 M4	HKR34157 & HKR34089 M5	HKR34157 & HKR34089 M6	HKR34157 & HKR34089 M7	HKR34157 & HKR34089 M8	HKR34157 & HKR34089 M9	HKR34157 & HKR34089 M10	HKR34157 & HKR34089 M11
Lithology		S bs fr	S bs fr	S bs fr	S bs fr	S bs fr	S bs fr	S bs fr	S bs fr	S bs fr	S bs fr	S bs fr	S bs fr
Sampled		31/05/2021	28/06/2021	26/07/2021	23/08/2021	21/09/2021	19/10/2021	16/11/2021	14/12/2021	11/01/2022	8/02/2022	8/03/2022	5/04/2022

Analyte	Method Code	Limits of Reporting	Units	Bundy Creek TV's	ANZECC & ARMCANZ 2000 Short-Term Irrigation Water	ANZECC & ARMCANZ 2000 Long-Term Irrigation Water	1000	2100	3300	3100	3000	2600	3500	3200	2800	2900	420	5700
Acidity	IACID1WATI	2	mg/L				1000	2100	3300	3100	3000	2600	3500	3200	2800	2900	420	5700
Ag	IMET1WCMS	0.0001	mg/L				0.0003	0.0011	0.0001	0.0003	0.0008	0.0005	<0.0001	0.0001	0.0001	0.0002	<0.0001	0.0002
Al	IMET1WCICP	0.005	mg/L	Al (pH>6.5) 295	20	5	110	290	430	450	400	320	340	330	350	390	35	860
Alkaline	IALK1WATI	1	mg/L				<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
As	IMET1WCICP	0.05	mg/L															
As	IMET1WCMS	0.001	mg/L	0.042	2	0.1	0.14	0.12	0.078	0.049	0.028	0.03	0.021	0.014	0.013	0.013	0.002	0.014
B	IMET1WCICP	0.02	mg/L															
B	IMET1WCMS	0.005	mg/L				0.11	0.048	0.024	0.016	0.008	0.025	0.031	0.028	0.024	0.031	0.011	0.011
Ba	IMET1WCMS	0.0001	mg/L				0.014	0.0029	0.0027	0.0017	0.0015	0.0008	0.0012	0.0015	0.0014	0.0018	0.002	0.0006
Be	IMET1WCMS	0.0001	mg/L				0.025	0.083	0.12	0.086	0.061	0.066	0.08	0.064	0.05	0.06	0.0059	0.07
CO3	IALK1WATI	1	mg/L				<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ca	IMET1WCICP	0.1	mg/L				270	212	168	114	72.7	61.7	63.3	49.9	45.6	44.5	11.1	57.9
Cd	IMET1WCMS	0.0001	mg/L	0.0004	0.05	0.01	0.18	0.15	0.14	0.1	0.055	0.063	0.043	0.03	0.025	0.023	0.0038	0.036
Cl	ICOWCDA	1	mg/L				ISS	13	10	8	8	3	4	3	2	3	<1	4
Co	IMET1WCICP	0.005	mg/L															
Co	IMET1WCMS	0.0001	mg/L	0.1	0.05		3.7						1.9	1.3	1.3	1.3	0.16	2.5
Cr	IMET1WCMS	0.0005	mg/L	1	0.1		0.02	0.075	0.13	0.12	0.068	0.2	0.16	0.12	0.13	0.13	0.0041	0.1
Cs	IMET1WCMS	0.0001	mg/L				0.0002	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cu	IMET1WCICP	0.002	mg/L				32	69	68	61	31	32	27	19	15	14		16
Cu	IMET1WCMS	0.0001	mSim	0.0018	5	0.2											1.4	
ECond	IEC1WZSE	0.2	mg/L	41			491	417	521	499	397	392	384	379	367	404	73.7	642
F	IF1WASE	0.05	mg/L				11	0.28	0.38	0.11	5.2	5.5	7	5.1	5.3	5.6	0.76	1.2
Fe	IMET1WCICP	0.005	mg/L	2.7**	10	0.2	62	64	180	190	170	160	170	180	190	210	11	260
HCO3	IALK1WATI	1	mg/L				<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Hg	IMET1WCMS	0.0001	mg/L	0.002	0.002		<0.0001	<0.0001	<0.0001	0.0002	0.0007	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
K	IMET1WCICP	0.1	mg/L				69.6	2	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Li	IMET1WCMS	0.0001	mg/L				0.21	0.42	0.58	0.46	0.54	0.78	0.71	0.74	0.74	0.86	0.069	1.3
Mg	IMET1WCICP	0.1	mg/L				469	338	415	364	192	275	234	221	234	222	20.6	461
Mn	IMET1WCICP	0.001	mg/L				16	13	13	12	6	8	6.8	6.2	6.2	6.2		13
Mn	IMET1WCMS	0.0001	mg/L	2.5**	10	0.2											0.67	
Mo	IMET1WCMS	0.001	mg/L	0.05	0.01		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Na	IMET1WCICP	0.1	mg/L				28.3	7.7	0.8	0.3	0.1	0.2	0.1	0.1	0.1	0.1	<0.1	0.1
Ni	IMET1WCICP	0.01	mg/L				11	13	16	16	9.7	10	8.2	6.9	6.3	6.4		12
Ni	IMET1WCMS	0.001	mg/L	0.013	2	0.2											0.77	
OH	IALK1WATI	1	mg/L				<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
P	IMET1WCICP	0.1	mg/L				<0.1	<0.1	<0.1	<0.1	<0.1	0.2	0.1	0.1	0.1	<0.1	<0.1	0.1
Pb	IMET1WCICP	0.02	mg/L															
Pb	IMET1WCMS	0.0001	mg/L	0.0056	5	2	0.018	0.0018	0.014	0.016	0.02	0.064	0.03	0.019	0.013	0.0064	0.0002	0.0011
Rb	IMET1WCMS	0.0001	mg/L				0.11	0.014	0.0039	0.0018	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012
S	IMET1WCICP	0.1	mg/L	70*			970	1000	1500	1500	1100	940	960	1000	1000	1100	2200	
SO4	Calculated		mg/L	210*			2910	3000	4900	4500	3300	3000	2820	2880	3000	3000	330	6600
Sb	IMET1WCMS	0.0001	mg/L				0.0001	0.0002	0.0002	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Se	IMET1WCMS	0.001	mg/L	0.05	0.05	0.02	0.18	0.2	0.23	0.22	0.19	0.13	0.11	0.1	0.12	0.15	0.02	0.29
Si	IMET1WCICP	0.05	mg/L				33	21	19	19	31	13	18	19	17	21	1.7	20
Sr	IMET1WCICP	0.002	mg/L				0.34	0.029	0.007	0.006	0.005	0.003	0.004	0.004	0.004	0.004	0.002	0.008
Th	IMET1WCMS	0.0001	mg/L				0.0025	0.0081	0.02	0.025	0.016	0.03	0.02	0.029	0.026	0.026	<0.0001	0.025
Tl	IMET1WCMS	0.0001	mg/L				0.0012	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
U	IMET1WCMS	0.0001	mg/L	8.1	0.01		0.11	0.31	0.42	0.4	0.21	0.28	0.22	0.19	0.16	0.12	0.0090	0.17
V	IMET1WCICP	0.005	mg/L	0.5	0.1		<0.005	0.006	0.024	0.028	0.013	0.01	0.007	<0.005	<0.005	<0.005	<0.005	0.006
Volume	IVOLUME	0.1	ml				160	230	220	230	210	230	250	240	220	220	330	260
Zn	IMET1WCICP	0.005	mg/L				21	20	21	20	9.9	11	8.1	6.2	5.2	4.8		8.8
Zn	IMET1WCMS	0.001	mg/L	0.014	5	2											0.76	
pH	IPH1WASE	0.1	mg/L	5.8-8.0			3.8	3.3	3.5	3	4.3	3	3	3	3.1	2.9	3.3	2.9

Long-term irrigation value
Short-term irrigation value
* Sulfate 210 mg/L
* Sulfate as S 70 mg/L
** Fe 2700 ug/L based on background Fe data from Bundy Creek
** Mn 2500 ug/L based on background Fe data from Bundy Creek

APPENDIX D – RELEASE RATES



DR002
†McPherson et al., 2014
‡RIVM 2020

[illegible]Average

verapamil

Appendix D2 - Release Rates Q29

†McPherson et al., 2014
‡RIVM 2020

[illegible]

			Predicted / Estimated Leach Concentrations from WRD																												
			Annual																												
			A Release	tonne	Kg rock	mg	Bulk Density t/m3	m3	Possible Footprint (m2)	Rainfall (mm)	L per m2	Litres per footprint	Weekly	Per event	mg/L																
As Release (Cumulative)	mg/kg	3720	Arsenic	0.001	4.70E+05	9.40E+07	1.29E+05	2.60E+00	1.81E+05	9.00E+04	1430	1430	1.29E+08	2.48E+06	0.001																
	%		Cobalt	0.049	4.70E+05	9.40E+07	4.64E+06	2.60E+00	1.81E+05	9.00E+04	1430	1430	1.29E+08	2.48E+06	0.036																
	mg/kg/week		Copper	0.62	4.70E+05	9.40E+07	5.83E+07	2.60E+00	1.81E+05	9.00E+04	1430	1430	1.29E+08	2.48E+06	0.453																
			Cadmium	0.00	4.70E+05	9.40E+07	2.82E+05	2.60E+00	1.81E+05	9.00E+04	1430	1430	1.29E+08	2.48E+06	0.002																
Cobalt Release	mg/kg	50.3	Chromium	0.00	4.70E+05	9.40E+07	2.14E+05	2.60E+00	1.81E+05	9.00E+04	1430	1430	1.29E+08	2.48E+06	0.002																
	%		nickel	0.22	4.70E+05	9.40E+07	2.11E+07	2.60E+00	1.81E+05	9.00E+04	1430	1430	1.29E+08	2.48E+06	0.164																
	mg/kg/week		lead	0.00	4.70E+05	9.40E+07	2.98E+04	2.60E+00	1.81E+05	9.00E+04	1430	1430	1.29E+08	2.48E+06	0.000																
			selenium	0.00	4.70E+05	9.40E+07	3.39E+05	2.60E+00	1.81E+05	9.00E+04	1430	1430	1.29E+08	2.48E+06	0.003																
Copper Release	mg/kg	426	uranium	0.005	4.70E+05	9.40E+07	4.27E+05	2.60E+00	1.81E+05	9.00E+04	1430	1430	1.29E+08	2.48E+06	0.003																
	%		zinc	0.29	4.70E+05	9.40E+07	2.70E+07	2.60E+00	1.81E+05	9.00E+04	1430	1430	1.29E+08	2.48E+06	0.210																
	mg/kg/week		Table 6-6 of CDM Smith																												
			Acidity	mg/kg	110																										
Acidity Release	%																														
	mg/kg/week																														
			Predicted / Estimated Leach Concentrations from Rock Pile in Pit																												
			Annual																												
			A Release	tonne	Kg rock	mg	Bulk Density t/m3	m3	Possible Footprint (m2)	Rainfall (mm)	L per m2	Litres per footprint	Weekly	Per event	mg/L																
As Release (Cumulative)	mg/kg	3720	Arsenic	0.001	3.50E+05	7.00E+07	9.64E+04	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06	0.001																
	%		Cobalt	0.049	3.50E+05	7.00E+07	3.45E+06	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06	0.026																
	mg/kg/week		Copper	0.62	3.50E+05	7.00E+07	4.34E+07	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06	0.331																
			Cadmium	0.00	3.50E+05	7.00E+07	2.10E+05	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06	0.002																
Cobalt Release	mg/kg	50.3	Chromium	0.00	3.50E+05	7.00E+07	1.59E+05	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06	0.001																
	%		nickel	0.22	3.50E+05	7.00E+07	1.57E+07	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06	0.120																
	mg/kg/week		lead	0.00	3.50E+05	7.00E+07	2.22E+04	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06	0.000																
			selenium	0.00	3.50E+05	7.00E+07	2.53E+05	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06	0.002																
Copper Release	mg/kg	426	uranium	0.005	3.50E+05	7.00E+07	3.18E+05	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06	0.002																
	%		zinc	0.29	3.50E+05	7.00E+07	2.01E+07	2.60E+00	1.35E+05	9.16E+04	1430	1430	1.31E+08	2.52E+06	0.154																
	mg/kg/week		Table 6-6 of CDM Smith																												
			Acidity	mg/kg	110																										
Acidity Release	%																														
	mg/kg/week																														

APPENDIX E– PIT WALL CONTRIBUTIONS



E-1 RUSTLERS ROOST (NO CSF)



Appendix E1 Rock Wall Loading Estimates - no CSF
DR002

Parameter	Unit	aluminium	arsenic	cobalt	copper	cadmium	chromium	manganese	nickel
		Value	Value	Value	Value	Value	Value	Value	Value
Area of exposed wall rock	m ²	1	1	1	1	1	1	1	1
Average assumed pit wall side slope angle	Degrees	45	45	45	45	45	45	45	45
Effective volume based on slope of 45 degrees	m ³	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41
Density of pit wall rock	Tonne/m ³	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Depth of blast fractured zone	m	1	1	1	1	1	1	1	1
Depth of blast influenced zone	m	3	3	3	3	3	3	3	3
Mass of rock in blast fractured zone	tonne	3.807	3.807	3.807	3.807	3.807	3.807	3.807	3.807
Total volume of wall rock in the 4 m deep blast influenced zone	m ³	5.64	5.64	5.64	5.64	5.64	5.64	5.64	5.64
Total mass of wall rock in the 4 m deep blast affected zone	tonne	15.2	15.2	15.228	15.228	15.228	15.228	15.2	15.228
	kg	15,228	15,228	15,228	15,228	15,228	15,228	15,228	15,228
Mean annual precipitation	mm/year	1430	1430	1430	1430	1430	1430	1430	1430
Mean annual precipitation volume (per 1m ² of exposed unsubmerged wall rock)	m ³	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
Mass loading rates									
Mass loading rate - week	mg/kg/wk	314	0.0032	0.0407	0.3328	0.0009	0.0044	0.38	0.0559
Mass loading rate - annual	mg/kg/yr	16328.0	0.2	2.1	17.3	0.0	0.2	19.8	2.9
Wall rock loading rate with CSF of 0.4	mg/kg/yr	6.53E+03	6.66E-02	8.46E-01	6.92E+00	1.79E-02	9.15E-02	7.90E+00	1.16E+00
Mass loading predictions									
Total mass of rock in the blast damaged zones per 1 m ²	t	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2
	kg	15,228	15,228	15,228	15,228	15,228	15,228	15,228	15,228
Area of PAF rock	m ²	436,200	436,200	436,200	436,200	436,200	436,200	436,200	436,200
Total mass of PAF rock available	tonnes	6630240	6630240	6630240	6630240	6630240	6630240	6630240	6630240
Total mass of PAF rock available	kg	6642453600	6642453600	6642453600	6642453600	6642453600	6642453600	6642453600	6642453600
Annual mass loading per 1m ² of unsubmerged rock	mg/yr per m ²	248642784	2534	32215	263520	272	1394	300905	17715
	kg/yr per m ²	248.6428	0.0025	0.0322	0.2635	0	0	0.3009	0
Total annual contact water available per 1 m ² of unsubmerged rock (per 1m ²)	L per year	1,224	1,224	1,224	1,224	1,224	1,224	1,224	1,224
Annual average wall rock runoff concentration (calculated/ predicted) per 1m ²	mg/L per m ²	203104.8	2.1	26.3	215.3	0.2	1.1	245.8	14.5
Annual mass loading from the pit walls to the pit lake for PAF unsubmerged rock	mg/yr	1.08E+14	1.11E+09	1.41E+10	1.15E+11	1.19E+08	6.08E+08	1.31E+11	7.73E+09
Rainfall	L per year	1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08
Run-off	L per year	3.76E+08	3.76E+08	3.76E+08	3.76E+08	3.76E+08	3.76E+08	3.76E+08	3.76E+08
Total annual contact water available per PAF unsubmerged rock	L per year	5.34E+08	5.34E+08	5.34E+08	5.34E+08	5.34E+08	5.34E+08	5.34E+08	5.34E+08
Annual average wall rock runoff concentration for PAF - arsenic	flux mg/L	203104.8	2.1	26.3	215.3	0.2	1.1	245.8	14.5
Lake Volume	L	3.80E+10	3.80E+10	3.80E+10	3.80E+10	3.80E+10	3.80E+10	3.80E+10	3.80E+10
Dilution factor	Factor	9.89E-03	9.89E-03	9.89E-03	9.89E-03	9.89E-03	9.89E-03	9.89E-03	9.89E-03
Predicted lake water concentration from PAF rock post dilution in lake volume	mg/L	2.01E+03	2.05E-02	2.60E-01	2.13E+00	2.20E-03	1.13E-02	2.43E+00	1.43E-01

E-2 QUEST 29 (NO CSF)

Appendix E-2 Q29 Rock Wall Loading Estimates - no CSF

Parameter	Unit	aluminium	arsenic	cobalt	copper	cadmium	chromium	manganese	nickel	lead	selenium	uranium	zinc
		Value	Value	Value	Value	Value	Value	Value	Value	Value	Value	Value	Value
Area of exposed wall rock	m ²	1	1	1	1	1	1	1	1	1	1	1	1
Average assumed pit wall side slope angle	Degrees	45	45	45	45	45	45	45	45	45	45	45	45
Effective volume based on slope of 45 degrees	m ³	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41
Density of pit wall rock	Tonne/m ³	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Depth of blast fractured zone	m	1	1	1	1	1	1	1	1	1	1	1	1
Depth of blast influenced zone	m	3	3	3	3	3	3	3	3	3	3	3	3
Mass of rock in blast fractured zone	tonne	3.666	3.666	3.666	3.666	3.666	3.666	3.666	3.666	3.666	3.666	3.666	3.666
Total volume of wall rock in the 4 m deep blast influenced zone	m ³	5.64	5.64	5.64	5.64	5.64	5.64	5.64	5.64	5.64	5.64	5.64	5.64
Total mass of wall rock in the 4 m deep blast affected zone	tonne	14.664	14.664	14.664	14.664	14.664	14.664	14.664	14.664	14.664	14.664	14.664	14.664
	kg	14,664	14,664	14,664	14,664	14,664	14,664	14,664	14,664	14,664	14,664	14,664	14,664
Mean annual precipitation	mm/year	1430	1430	1430	1430	1430	1430	1430	1430	1430	1430	1430	1430
Mean annual precipitation volume (per 1m ² of exposed unsubmerged wall rock)	m ³	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
Mass loading rates													
Mass loading rate - week	mg/kg/wk	9.2	0.0007	0.0460	0.66	0.0012	0.0023	0.17	0.2120	0.0004	0.0029	0.0046	0.21
Mass loading rate - annual	mg/kg/yr	478.4	0.0	2.4	34.5	0.1	0.1	8.8	11.0	0.0	0.2	0.2	11.0
Wall rock loading rate (from Table 5-4) with CSF of 0.4	mg/kg/yr	1.91E+02	1.51E-02	9.58E-01	1.38E+01	2.59E-02	4.74E-02	3.54E+00	4.41E+00	7.69E-03	6.08E-02	9.53E-02	4.38E+00
Mass loading predictions													
Total mass of rock in the blast damaged zones per 1 m ²	t	15.2	15.2	15.2	15.2	15.2	16.2	15.2	16.2	16.2	16.2	16.2	16.2
	kg	15200	15200	15200	15200	15200	16200	15200	16200	16200	16200	16200	16200
Area of PAF rock	m ²	34.257	34.257	34.257	34.257	34.257	34.257	34.257	34.257	34.257	34.257	34.257	34.257
Total mass of PAF rock available	tonnes	520706	520706	520706	520706	520706	554963	520706	554963	554963	554963	554963	554963
Total mass of PAF rock available	kg	520706400	520706400	520706400	520706400	520706400	554963400	520706400	554963400	554963400	554963400	554963400	554963400
Annual mass loading per 1m ² of unsubmerged rock	mg/yr per m ²	7271680	573	36396	524944	394	768	134368	71438	125	984	1544	70963
	kg/yr per m ²	7.2717	0.0006	0.0364	0.5249	0	0	0.1344	0	0	0	0	0
Total annual contact water available per 1 m ² of unsubmerged rock (per 1m ²)	L per year	876	876	876	876	876	876	876	876	876	876	876	876
Annual average wall rock runoff concentration (calculated/ predicted) per 1m ²	mg/L per m ²	8303.5	0.7	41.6	599.4	0.4	0.9	153.4	81.6	0.1	1.1	1.8	81.0
Annual mass loading from the pit walls to the pit lake for PAF unsubmerged rock	mg/yr	2.49E+11	1.96E+07	1.25E+09	1.80E+10	1.35E+07	2.63E+07	4.60E+09	2.45E+09	4.27E+06	3.37E+07	5.29E+07	2.43E+09
Rainfall	L per year	9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06
Run-off	L per year	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07
Total annual contact water available per PAF unsubmerged rock	L per year	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07
Annual average wall rock runoff concentration for PAF - arsenic	flux mg/L	8303.5	0.7	41.6	599.4	0.4	0.9	153.4	81.6	0.1	1.1	1.8	81.0
Lake Volume	L	2.60E+09	2.60E+09	3.80E+10	3.80E+10	3.80E+10	3.80E+10	2.60E+09	3.80E+10	3.80E+10	3.80E+10	3.80E+10	3.80E+10
Dilution factor	Factor	8.08E-03	8.08E-03	5.53E-04	5.53E-04	5.53E-04	5.53E-04	8.08E-03	5.53E-04	5.53E-04	5.53E-04	5.53E-04	5.53E-04
Predicted lake water concentration from PAF rock post dilution in lake volume	mg/L	6.71E+01	5.28E-03	2.30E-02	3.31E-01	2.48E-04	4.85E-04	1.24E+00	4.51E-02	7.86E-05	6.21E-04	9.74E-04	4.48E-02

E-3 RUSTLERS ROOST (+ CSF)

Appendix E3 Rock Wall Loading Estimates - with CSF

Parameter	Unit	aluminium	arsenic	cobalt	copper	cadmium	chromium	manganese	nickel
		Value	Value	Value	Value	Value	Value	Value	Value
Area of exposed wall rock	m ²	1	1	1	1	1	1	1	1
Average assumed pit wall side slope angle	Degrees	45	45	45	45	45	45	45	45
Effective volume based on slope of 45 degrees	m ³	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41
Density of pit wall rock	Tonne/m ³	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Depth of blast fractured zone	m	1	1	1	1	1	1	1	1
Depth of blast influenced zone	m	3	3	3	3	3	3	3	3
Mass of rock in blast fractured zone	tonne	3.807	3.807	3.807	3.807	3.807	3.807	3.807	3.807
Total volume of wall rock in the 4 m deep blast influenced zone	m ³	5.64	5.64	5.64	5.64	5.64	5.64	5.64	5.64
Total mass of wall rock in the 4 m deep blast affected zone	tonne	15.228	15.228	15.228	15.228	15.228	15.228	15.228	15.228
	kg	15,228	15,228	15,228	15,228	15,228	15,228	15,228	15,228
Mean annual precipitation	mm/year	1430	1430	1430	1430	1430	1430	1430	1430
Mean annual precipitation volume (per 1m ² of exposed unsubmerged wall rock)	m ³	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
Mass loading rates									
Mass loading rate - week	mg/kg/wk	314	0.0032	0.0407	0.3328	0.0009	0.0044	0.38	0.0559
Mass loading rate - annual	mg/kg/yr	16328.0	0.2	2.1	17.3	0.0	0.2	19.8	2.9
Wall rock loading rate (from Table 5-4) with CSF of 0.4	mg/kg/yr	6.53E+03	6.66E-02	8.46E-01	6.92E+00	1.79E-02	9.15E-02	7.90E+00	1.16E+00
Mass loading predictions									
Total mass of rock in the blast damaged zones per 1 m ²	t	15.2	15.2	15.2	15.2	15.2	16.2	15.2	16.2
	kg	15200	15200	15200	15200	15200	16200	15200	16200
Area of PAF rock	m ²	436,200	436,200	436,200	436,200	436,200	436,200	436,200	436,200
Total mass of PAF rock available	tonnes	6630240	6630240	6630240	6630240	6630240	7066440	6630240	7066440
Total mass of PAF rock available	kg	6630240000	6630240000	6630240000	6630240000	6630240000	7066440000	6630240000	7066440000
Annual mass loading per 1m ² of unsubmerged rock	mg/yr per m ²	99274240	1012	12,862	105,214	271	1483	120141	18,845
	kg/yr per m ²	9.93E+01	1.01E-03	1.29E-02	1.05E-01	2.71E-04	1.48E-03	1.20E-01	1.88E-02
Total annual contact water available per 1 m ² of unsubmerged rock (per 1m ²)	L per year	1,430	1,430	1,430	1,430	1,430	1,430	1,430	1,430
Annual average wall rock runoff concentration (calculated/ predicted) per 1m ²	mg/L per m ²	69422.5	0.7	9.0	73.6	0.2	1.0	84.0	13.2
Annual mass loading from the pit walls to the pit lake for PAF unsubmerged rock	mg/yr	4.33E+13	4.41E+08	5.61E+09	4.59E+10	1.18E+08	6.47E+08	5.24E+10	8.22E+09
Rainfall	L per year	1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08
Run-off	L per year	3.76E+08	3.76E+08	3.76E+08	3.76E+08	3.76E+08	3.76E+08	3.76E+08	3.76E+08
Total annual contact water available per PAF unsubmerged rock	L per year	5.34E+08	5.34E+08	5.34E+08	5.34E+08	5.34E+08	5.34E+08	5.34E+08	5.34E+08
Annual average wall rock runoff concentration for PAF - arsenic	flux mg/L	81092.55	0.83	10.5	85.9	0.22	1.2	98.14	15.4
Lake Volume	L	3.80E+10	3.80E+10	3.80E+10	3.80E+10	3.80E+10	3.80E+10	3.80E+10	3.80E+10
Dilution factor	Factor	9.89E-03	9.89E-03	9.89E-03	9.89E-03	9.89E-03	9.89E-03	9.89E-03	9.89E-03
Predicted lake water concentration from PAF rock post dilution in lake volume	mg/L	8.02E+02	8.18E-03	1.04E-01	8.50E-01	2.19E-03	1.20E-02	9.71E-01	1.52E-01

E-4 QUEST 29 (+ CSF)

Appendix E-4 Q29 Rock Wall Loading Estimates + CSF

		aluminium	arsenic	cobalt	copper	cadmium	chromium	manganese	nickel	lead	selenium	uranium	zinc
Parameter	Unit	Value	Value	Value	Value	Value	Value	Value	Value	Value	Value	Value	Value
Area of exposed wall rock	m²	1	1	1	1	1	1	1	1	1	1	1	1
Average assumed pit wall side slope angle	Degrees	45	45	45	45	45	45	45	45	45	45	45	45
Effective volume based on slope of 45 degrees	m³	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41
Density of pit wall rock	Tonne/m³	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Depth of blast fractured zone	m	1	1	1	1	1	1	1	1	1	1	1	1
Depth of blast influenced zone	m	3	3	3	3	3	3	3	3	3	3	3	3
Mass of rock in blast fractured zone	tonne	3.807	3.807	3.807	3.807	3.807	3.807	3.807	3.807	3.807	3.807	3.807	3.807
Total volume of wall rock in the 4 m deep blast influenced zone	m³	5.64	5.64	5.64	5.64	5.64	5.64	5.64	5.64	5.64	5.64	5.64	5.64
Total mass of wall rock in the 4 m deep blast affected zone	tonne	15.228	15.228	15.228	15.228	15.228	15.228	15.228	15.228	15.228	15.228	15.228	15.228
	kg	15,228	15,228	15,228	15,228	15,228	15,228	15,228	15,228	15,228	15,228	15,228	15,228
Mean annual precipitation	mm/year	1430	1430	1430	1430	1430	1430	1430	1430	1430	1430	1430	1430
Mean annual precipitation volume (per 1m² of exposed unsubmerged wall rock)	m³	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
Mass loading rates													
Mass loading rate - week	mg/kg/wk	9.2	0.0007	0.0460	0.6642	0.0012	0.0023	0.17	0.21	0.0004	0.0029	0.0046	0.21
Mass loading rate - annual	mg/kg/yr	478.4	0.0	2.4	34.5	0.1	0.1	8.8	11.0	0.0	0.2	0.2	11.0
Wall rock loading rate (from Table 5-4) with CSF of 0.4	mg/kg/yr	1.91E+02	1.51E-02	9.58E-01	1.38E+01	2.59E-02	4.74E-02	3.54E+00	4.41E+00	7.69E-03	6.08E-02	9.53E-02	4.38E+00
Mass loading predictions													
Total mass of rock in the blast damaged zones per 1 m²	t	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2
	kg	15200	15200	15200	15200	15200	15200	15200	15200	15200	15200	15200	15200
Area of PAF rock	m²	34,257	34,257	34,257	34,257	34,257	34,257	34,257	34,257	34,257	34,257	34,257	34,257
Total mass of PAF rock available	tonnes	520706	520706	520706	520706	520706	520706	520706	520706	520706	520706	520706	520706
Total mass of PAF rock available	kg	520706400	520706400	520706400	520706400	520706400	520706400	520706400	520706400	520706400	520706400	520706400	520706400
Annual mass loading per 1m² of unsubmerged rock	mg/yr per m²	2908672	229	14,558	209,978	394	721	53747	67,028	117	924	1,449	66,583
	kg/yr per m²	2.91E+00	2.29E-04	1.46E-02	2.10E-01	3.94E-04	7.21E-04	5.37E-02	6.70E-02	1.17E-04	9.24E-04	1.45E-03	6.66E-02
Total annual contact water available per 1 m² of unsubmerged rock (per 1m²)	L per year	1,430	1,430	1,430	1,430	1,430	1,430	1,430	1,430	1,430	1,430	1,430	1,430
Annual average wall rock runoff concentration (calculated/ predicted) per 1m²	mg/L per m²	2034.0	0.2	10.2	146.8	0.3	0.5	37.6	46.9	0.1	0.6	1.0	46.6
Annual mass loading from the pit walls to the pit lake for PAF unsubmerged rock	mg/yr	9.96E+10	7.85E+06	4.99E+08	7.19E+09	1.35E+07	2.47E+07	1.84E+09	2.30E+09	4.00E+06	3.16E+07	4.96E+07	2.28E+09
Rainfall	L per year	9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06
Run-off	L per year	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07
Total annual contact water available per PAF unsubmerged rock	L per year	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07
Annual average wall rock runoff concentration for PAF - arsenic	flux mg/L	3321.41	0.26	16.6	239.8	0.45	0.8	61.37	76.5	0.1	1.1	1.7	76.0
Lake Volume	L	2.60E+09	2.60E+09	2.60E+09	2.60E+09	2.60E+09	2.60E+09	2.60E+09	2.60E+09	2.60E+09	2.60E+09	2.60E+09	2.60E+09
Dilution factor	Factor	8.08E-03	8.08E-03	8.08E-03	8.08E-03	8.08E-03	8.08E-03	8.08E-03	8.08E-03	8.08E-03	8.08E-03	8.08E-03	8.08E-03
Predicted lake water concentration from PAF rock post dilution in lake volume.	mg/L	2.68E+01	2.11E-03	1.34E-01	1.94E+00	3.63E-03	6.65E-03	4.96E-01	6.18E-01	1.08E-03	8.52E-03	1.34E-02	6.14E-01

APPENDIX F – WATER QUALITY PREDICTIONS

F-1 RUSTLERS ROOST (NO CSF)



Appendix F1 Combined S1 and S2 Predictions (Scaled) - no CSF

	Parameter	Value	Source/ Reference/ Rationale	Groundwater	ANZG Default GV 95%	Bundy Creek TV's	Stock Watering (Beef)	ANZECC & ARMCANZ 2000 Short-Term Irrigation Water	ANZECC & ARMCANZ 2000 Long-Term Irrigation Water	Source S2	Year 1	Year 5	Year 10	Year 20	Year 30
Sources	Time (weeks) for in pit	S2 – refer value for 52 weeks in Appendix A, which mimics 1 year of oxidation.	Arbitrary extrapolation – can be extended forward to any week value.							52	52	52	52	52	52
	Mass of Waste PAF Rock (kg)	1.90E+07								1.60E+06	1.60E+06	1.60E+06	1.60E+06	1.60E+06	1.60E+06
	Rainfall (L)									1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08
	Run-off Volume (L)									5.70E+08	3.76E+08	3.76E+08	3.76E+08	3.76E+08	3.76E+08
	Groundwater Influx (L)	Variable per stage of recovery	CDM Smith (2021)							1.27E+09	6.33E+09	1.27E+10	2.53E+10	3.80E+10	
	Cumulative (L)									1.80E+09	6.86E+09	1.32E+10	2.59E+10	3.85E+10	
	Ratio Run-off/Groundwater									2.09E-01	5.48E-02	2.85E-02	1.45E-02	9.76E-03	
	Run-off Contribution	Fraction								0.8	0.6	0.1	0.05	0	
	Aluminium	(mg/kg/rock per week)	314							0.00320	0.00320	0.00320	0.00320	0.00320	0.00320
	Aluminium	mg/L								1.48E-04	3.88E-05	2.02E-05	1.03E-05	6.91E-06	
	Arsenic	(mg/kg/rock per week)	0.003							0.00320	0.00320	0.00320	0.00320	0.00320	0.00320
	Arsenic	mg/L								1.48E-04	3.88E-05	2.02E-05	1.03E-05	6.91E-06	
	Cobalt	(mg/kg/rock per week)	0.038							0.038	0.038	0.038	0.038	0.038	0.038
	Cobalt	mg/L								1.78E-03	4.61E-04	2.40E-04	1.22E-04	8.21E-05	
	Copper	(mg/kg/rock per week)	0.290							0.29	0.29	0.29	0.29	0.29	
	Copper	mg/L								215.3	1.34E-02	3.52E-03	1.83E-03	9.33E-04	6.36E-04
	Cadmium	(mg/kg/rock per week)	0.001							0.001	0.001	0.001	0.001	0.001	0.001
	Cadmium	mg/L								0.222	3.24E-05	8.48E-06	4.41E-06	2.25E-06	1.51E-06
	Chromium	(mg/kg/rock per week)	0.004							0.004	0.004	0.004	0.004	0.004	0.004
	Chromium	mg/L								1.138	1.70E-04	4.46E-05	2.31E-05	1.18E-05	7.95E-06
	Manganese	(mg/kg/rock per week)	0.380							0.004	0.004	0.004	0.004	0.004	0.004
	Manganese	mg/L								246	1.70E-04	4.46E-05	2.32E-05	1.18E-05	7.95E-06
	Nickel	(mg/kg/rock per week)	0.052								0.052	0.052	0.052	0.052	0.052
	Nickel	mg/L								14.5	2.40E-03	6.30E-04	3.28E-04	1.67E-04	1.12E-04
	Lead	(mg/kg/rock per week)	0.000								0.000	0.000	0.000	0.000	0.000
	Lead	mg/L								0.098	1.39E-05	3.64E-06	1.89E-06	9.55E-07	6.40E-07
	Selenium	(mg/kg/rock per week)	0.001							0.001	0.001	0.001	0.001	0.001	0.001
	Selenium	mg/L								0.383	6.47E-05	1.70E-05	8.63E-06	4.51E-06	3.02E-06
	Uranium	(mg/kg/rock per week)	0.002								0.002	0.002	0.002	0.002	0.002
	Uranium	mg/L								0.591	1.06E-04	2.77E-05	1.44E-05	7.35E-06	4.93E-06
	Zinc	(mg/kg/rock per week)	0.060								0.060	0.060	0.060	0.060	0.060
	Zinc	mg/L								15.5	2.77E-03	7.27E-04	3.78E-04	1.93E-04	1.30E-04
Groundwater	Aluminium	mg/L	Mean	0.203	0.055	0.295	5	20	5	0.203	0.203	0.203	0.203	0.203	0.203
	Aluminium	mg/L	Maximum	1.29	0.055	0.295	5	20	5		1.29	1.29	1.29	1.29	1.29
	Arsenic	mg/L	Mean	0.07	0.013	0.042	0.5	2	0.1	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099
	Arsenic	mg/L	Maximum	0.07	0.013	0.042	0.5	2	0.1	0.07	0.07	0.07	0.07	0.07	0.07
	Cobalt	mg/L	Mean	0.015	0.0014	0.0014	1	0.1	0.05	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055
	Cobalt	mg/L	Maximum	0.015	0.0014	0.0014	1	0.1	0.05		0.015	0.015	0.015	0.015	0.015
	Copper	mg/L	Mean	0.033	0.0014	0.0018	2	5	0.2	0.0096	0.0096	0.0096	0.0096	0.0096	0.0096
	Copper	mg/L	Maximum	0.033	0.0014	0.0018	2	5	0.2		0.03	0.03	0.03	0.03	0.03
	Cadmium	mg/L	Mean	0.0002	0.0002	0.0004	0.01	0.05	0.01	0.001	0.001	0.001	0.001	0.001	0.001
	Cadmium	mg/L	Maximum	0.0002	0.0002	0.0004	0.01	0.05	0.01		0.001	0.001	0.001	0.001	0.001
	Chromium	mg/L	Mean	0.002	0.001	0.001	1	1	0.1	0.0015	0.001	0.001	0.001	0.001	0.001
	Chromium	mg/L	Maximum	0.002	0.001	0.001	1	1	0.1		0.0015	0.0015	0.0015	0.0015	0.0015
	Manganese	mg/L	Mean	1.9	0.17	2.5	10	10	0.2	0.170	0.170	0.170	0.170	0.170	0.170
	Manganese	mg/L	Maximum	0.61	1.9	2.5	10	10	0.2		0.610	0.610	0.610	0.610	0.610
	Nickel	mg/L	Mean	0.006	0.011	0.013	1	2	0.2	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024
	Nickel	mg/L	Maximum	0.006	0.011	0.013	1	2	0.2		0.006	0.006	0.006	0.006	0.006
	Lead	mg/L	Mean	0.006	0.0034	0.0056	0.1	5	2	0.0047	0.0047	0.0047	0.0047	0.0047	0.0047
	Lead	mg/L	Maximum	0.006	0.0034	0.0056	0.1	5	2		0.01	0.01	0.01	0.01	0.01
	Selenium	mg/L	Mean	0.011	0.011		0.02	0.05	0.02	0.001	0.001	0.001	0.001	0.001	0.001
	Selenium	mg/L	Maximum	0.011	0.011		0.02	0.05	0.02		0.00	0.00	0.00	0.00	0.00
	Uranium	mg/L	Mean	0.0005	0.0005		0.2	0.1	0.01	0.001	0.001	0.001	0.001	0.001	0.001
	Uranium	mg/L	Maximum	0.0005	0.0005		0.2	0.1	0.01		0.00	0.00	0.00	0.00	0.00
	Zinc	mg/L	Mean	0.078	0.008	0.014	20	5	2	0.0222	0.0222	0.0222	0.0222	0.0222	0.0222
	Zinc	mg/L	Maximum	0.078	0.008	0.014	20	5	2		0.08	0.08	0.08	0.08	0.08
Combined	Aluminium	mg/L	Mean - groundwater	0.203	0.055	0.295	5	20	5		Year 1	Year 5	Year 10	Year 20	Year 30
	Aluminium	mg/L	Maximum - groundwater	1.29	0.055	0.295	5	20	5		33942	6677	580	149	1.29
	Arsenic	mg/L	Mean - groundwater	0.07	0.013	0.042	0.5	2	0.1		0.36	0.08	0.02	0.01	0.01
	Arsenic	mg/L	Maximum - groundwater	0.07	0.013	0.042	0.5	2	0.1		0.42	0.14	0.08	0.07	0.07
	Cobalt	mg/L	Mean - groundwater	0.015	0.0014	0.0014	1	0.1	0.05		4.4	0.91	0.12	0.06	0.044
	Cobalt	mg/L	Maximum - groundwater	0.015	0.0014	0.0014	1	0.1	0.05		4.5	0.92	0.13	0.07	0.033
	Copper	mg/L	Mean - groundwater	0.033	0.0014	0.0018	2	5	0.2		3.5	7	0.82	0.17	0.01
	Copper	mg/L	Maximum - groundwater	0.033	0.0014	0.0018	2	5	0.2		3.6	7	0.85	0.19	0.03
	Cadmium	mg/L	Mean - groundwater	0.0002	0.0002	0.0004	0.01	0.05	0.01		0.04	0.008	0.00	0.00	0.00
	Cadmium	mg/L	Maximum - groundwater	0.0002	0.0002	0.0004	0.01	0.05	0.01						

F-2 QUEST 29 (NO CSF)

Appendix F-2 Q29 Combined S1 and S2 Predictions (Scaled) no CSF

	Source S2													
	Year 1	Year 5	Year 10	Year 20	Year 30									
Parameter	Value	Leach	Groundwater	ANZG Default GV 95%	Bundy Creek TV's	Stock Watering (Beef)	ANZECC & ARMCANZ 2000 Short-Term Irrigation Water	ANZECC & ARMCANZ 2000 Long-Term Irrigation Water						
Time (weeks) for In pit	52 – refer value for 52 weeks in Appendix A which mimics 1 year of oxidation.	Arbitrary extrapolation – can be extended forward to any week value.							52	52	52	52	52	52
Mass of Waste PAF Rock (kg)	1.90E+07									3.50E+05	3.50E+05	3.50E+05	3.50E+05	3.50E+05
Rainfall (L)										9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06
Run-off Volume (L)														
									5.70E+08	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07
Groundwater Influx (L)	Variable per stage of recovery	CDM Smith (2021)												
Cumulative (L)										9.50E+07	4.75E+08	6.00E+08	6.00E+08	6.00E+08
Ratio Run-off:Groundwater										1.25E+08	5.05E+08	6.30E+08	6.30E+08	6.30E+08
Run-off Contribution	Fraction									1.68E-01	4.16E-02	3.33E-02	3.33E-02	3.33E-02
aluminium (mg/kg/rock per week)		9.2								0.8	0.2	0.1	0.05	0
aluminium mg/L		363								9.20000	9.20000	9.20000	9.20000	9.20000
arsenic (mg/kg/rock per week)		0.001								8304	1.34E+00	3.32E-01	2.66E-01	2.66E-01
arsenic mg/L		0.050								0.00072	0.00072	0.00072	0.00072	0.00072
cobalt (mg/kg/rock per week)		0.040								0.654	1.05E-04	2.59E-05	2.08E-05	2.08E-05
cobalt mg/L		2.460								0.040	0.040	0.040	0.040	0.040
copper (mg/kg/rock per week)		0.660								41.561	5.82E-03	1.44E-03	1.16E-03	1.16E-03
copper mg/L		33.500								0.66	0.66	0.66	0.66	0.66
cadmium (mg/kg/rock per week)		0.001								599.434	9.61E-02	2.38E-02	1.91E-02	1.91E-02
cadmium mg/L		0.070								0.001	0.001	0.001	0.001	0.001
chromium (mg/kg/rock per week)		0.002								0.449	1.75E-04	4.32E-05	3.47E-05	3.47E-05
chromium mg/L		0.110								0.002	0.002	0.002	0.002	0.002
nickel (mg/kg/rock per week)		0.210								0.877	2.91E-04	7.21E-05	5.78E-05	5.78E-05
nickel mg/L		9.500								0.210	0.210	0.210	0.210	0.210
lead (mg/kg/rock per week)		0.000								81.575	3.06E-02	7.57E-03	6.07E-03	6.07E-03
lead mg/L		0.020								0.000	0.000	0.000	0.000	0.000
selenium (mg/kg/rock per week)		0.003								0.142	5.24E-05	1.30E-05	1.04E-05	1.04E-05
selenium mg/L		0.150								0.003	0.003	0.003	0.003	0.003
uranium (mg/kg/rock per week)		0.005								1.124	4.22E-04	1.05E-04	8.38E-05	8.38E-05
uranium mg/L		0.220								0.005	0.005	0.005	0.005	0.005
zinc (mg/kg/rock per week)		0.210								1.763	6.55E-04	1.62E-04	1.30E-04	1.30E-04
zinc mg/L		11.6								0.210	0.210	0.210	0.210	0.210
									81.033	3.06E-02	7.57E-03	6.07E-03	6.07E-03	6.07E-03

aluminium	mg/L	Mean	0.01	0.055	0.295	5	20	5		0.01	0.01	0.01	0.01	0.01
aluminium	mg/L	Maximum	1.3	0.055	0.295	5	20	5		0.01	0.01	0.01	0.01	0.01
arsenic	mg/L	Mean	0.04	0.013	0.042	0.5	2	0.1		0.04	0.04	0.04	0.04	0.04
arsenic	mg/L	Maximum	0.20	0.013	0.042	0.5	2	0.1		0.20	0.20	0.20	0.20	0.20
cobalt	mg/L	Mean	0.0016	0.0014		1	0.1	0.05		0.0016	0.0016	0.0016	0.0016	0.0016
cobalt	mg/L	Maximum	0.005	0.0014		1				0.005	0.005	0.005	0.005	0.005
copper	mg/L	Mean	0.0029	0.0014	0.0018	2	5	0.2		0.0029	0.0029	0.0029	0.0029	0.0029
copper	mg/L	Maximum	0.009	0.0014		2				0.01	0.01	0.01	0.01	0.01
cadmium	mg/L	Mean	0.0002	0.0002	0.0004	0.01	0.05	0.01		0.0002	0.0002	0.0002	0.0002	0.0002
cadmium	mg/L	Maximum	0.00113	0.0002	0.0004	0.01	0.05	0.01		0.001	0.001	0.001	0.001	0.001
chromium	mg/L	Mean	0.0041	0.001		1	1	0.1		0.0041	0.0041	0.0041	0.0041	0.0041
chromium	mg/L	Maximum	0.011	0.001		1	1	0.1		0.011	0.011	0.011	0.011	0.011
manganese	mg/L	Mean	0.49	1.9	2.5	1	10	0.2		0.490	0.490	0.490	0.490	0.490
manganese	mg/L	Maximum	1.5	1.9	2.5	1	10	0.2		1.500	1.500	1.500	1.500	1.500
nickel	mg/L	Mean	0.0046	0.011	0.013	1	2	0.2		0.0046	0.0046	0.0046	0.0046	0.0046
nickel	mg/L	Maximum	0.02	0.011		1				0.020	0.020	0.020	0.020	0.020
lead	mg/L	Mean	0.0014	0.0034	0.0056	0.1	5	2		0.0014	0.0014	0.0014	0.0014	0.0014
lead	mg/L	Maximum	0.005	0.0034	0.0056	0.1	5	2		0.01	0.01	0.01	0.01	0.01
selenium	mg/L	Mean	0.001	0.011		0.02	0.05	0.02		0.001	0.001	0.001	0.001	0.001
selenium	mg/L	Maximum	0.001	0.011		0.02	0.05	0.02		0.00	0.00	0.00	0.00	0.00
uranium	mg/L	Mean	0.001	0.0005		0.2	0.1	0.01		0.001	0.001	0.001	0.001	0.001
uranium	mg/L	Maximum	0.001	0.0005		0.2	0.1	0.01		0.00	0.00	0.00	0.00	0.00
zinc	mg/L	Mean	0.021	0.008		20	5	2		0.021	0.021	0.021	0.021	0.021
zinc	mg/L	Maximum	0.0846	0.008	0.014	20				0.08	0.08	0.08	0.08	0.08

aluminium	mg/L	Mean	0.01	0.055	0.295	5	20	5		Year 1	Year 5	Year 10	Year 20	Year 30
aluminium	mg/L	Maximum	1.3	0.055	0.295	5	20	5		1117	69	28	14	0.28
arsenic	mg/L	Mean	0.04	0.013	0.042	0.5	2	0.1		1117	69	28	14	0.28
arsenic	mg/L	Maximum	0.20	0.013	0.042	0.5	2	0.1		0.13	0.045	0.042	0.041	0.040
cobalt	mg/L	Mean	0.0016	0.0014		1				0.29	0.205	0.202	0.201	0.200
cobalt	mg/L	Maximum	0.005	0.0014		1	0.1	0.05		5.63	0.39	0.18	0.11	0.042
copper	mg/L	Mean	0.0029	0.0014		2	5	0.2		5.63	0.39	0.18	0.11	0.045
copper	mg/L	Maximum	0.009	0.0014	0.0018	2				81	5.012	2.020	1.02	0.022
cadmium	mg/L	Mean	0.0002	0.0002	0.0004	0.01				81	5.018	2.026	1.03	0.028
cadmium	mg/L	Maximum	0.00113	0.0002	0.0004	0.01	0.05	0.01		0.06	0.004	0.002	LOR	LOR
chromium	mg/L	Mean	0.0041	0.001		1	1	0.1		0.06	0.005	0.003	0.002	0.001
chromium	mg/L	Maximum	0.011	0.001		1	1	0.1		0.12	0.01	0.01	0.01	0.004
manganese	mg/L	Mean	0.49	1.9	2.5	1	10	0.2		0.13	0.02	0.01	0.01	0.011
manganese	mg/L	Maximum	1.5	1.9	2.5	1	10	0.2		0.61	0.50	0.49	0.49	0.49
nickel	mg/L	Mean	0.0046	0.011	0.013	1				1.62	1.51	1.50	1.50	1.50
nickel	mg/L	Maximum	0.02	0.011	0.013	1	2	0.2		11.00	0.69	0.28	0.147	0.011
lead	mg/L	Mean	0.0014	0.0034	0.0056	0.1	5	2		11.01	0.71	0.30	0.162	0.028
lead	mg/L	Maximum	0.005	0.0034	0.0056	0.1	5	2		0.021	0.003	0.002	0.002	0.001
selenium	mg/L	Mean	0.001	0.011		0.02	0.05	0.02		0.024	0.006	0.005	0.005	0.005
selenium	mg/L	Maximum	0.001	0.011		0.02	0.05	0.02		0.15	0.010	0.005	0.003	0.001
uranium	mg/L	Mean	0.001	0.0005		0.2	0.1	0.01		0.15	0.010	0.005	0.003	0.001
uranium	mg/L	Maximum	0.001	0.0005		0.2	0.1	0.01		0.24	0.02	0.007	0.004	0.001
zinc	mg/L	Mean	0.021	0.008	0.014	20				0.24	0.02	0.007	0.004	0.001
zinc	mg/L	Maximum	0.0846	0.008	0.014	20	5	2		10.94	0.703	0.297	0.162	0.027
										11.01	0.766	0.361	0.226	0.091

F-3 RUSTLERS ROOST (+CSF)

Appendix F3 Combined S1 and S2 Predictions (Scaled) - with CSF of 0.4

Predicted Concentration = $\frac{HC\ Load\ x\ Time\ x\ Mass\ of\ Rock\ in\ Dump}{Volume\ of\ Infiltrating\ Water}$

										Source S2	Year 1	Year 5	Year 10	Year 20	Year 30
Parameter	Value	Release	Groundwater	ANZG Default GV 95%	Bundy Creek TV's	Stock Watering (Beef)	ANZECC & ARMCANZ 2000 Short-Term Irrigation Water	ANZECC & ARMCANZ 2000 Long-Term Irrigation Water							
Time (weeks) for in pit	S2 – refer value for 52 weeks in Appendix A, which mimics 1 year of oxidation.									52	52	52	52	52	52
Mass of Waste PAF Rock (kg)	1.90E+07									1.60E+06	1.60E+06	1.60E+06	1.60E+06	1.60E+06	1.60E+06
Rainfall (L)										1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08
Run-off Volume (L)										3.76E+08	3.76E+08	3.76E+08	3.76E+08	3.76E+08	3.76E+08
Groundwater Influx (L)	Variable per stage of recovery	CDM Smith (2021)								1.27E+09	6.33E+09	1.27E+10	2.53E+10	3.80E+10	3.80E+10
Comminution (L)										1.80E+09	6.86E+09	1.32E+10	2.59E+10	3.85E+10	3.85E+10
Ratio Run-off/Groundwater										2.09E-01	5.48E-02	2.85E-02	1.45E-02	9.76E-03	9.76E-03
Run-off Contribution	Fraction									0.8	0.6	0.1	0.05	0	0
aluminium	(mg/kg/rock per week)	314								125.60000	125.60000	125.60000	125.60000	125.60000	125.60000
aluminium	mg/L									81093	5.81E+00	1.52E+00	7.92E-01	4.04E-01	2.71E-01
arsenic	(mg/kg/rock per week)	0.003								0.00028	0.00028	0.00028	0.00028	0.00028	0.00028
arsenic	mg/L									0.83	5.92E-05	1.55E-05	8.07E-06	4.12E-06	2.77E-06
cobalt	(mg/kg/rock per week)	0.038								0.015	0.015	0.015	0.015	0.015	0.015
cobalt	mg/L									10.5	7.03E-04	1.84E-04	9.58E-05	4.89E-05	3.28E-05
copper	(mg/kg/rock per week)	0.290								0.12	0.12	0.12	0.12	0.12	0.12
copper	mg/L									85.9	5.36E-03	1.41E-03	7.31E-04	3.73E-04	2.51E-04
cadmium	(mg/kg/rock per week)	0.001								0.00028	0.00028	0.00028	0.00028	0.00028	0.00028
cadmium	mg/L									0.22	1.29E-05	1.39E-06	1.77E-06	9.01E-07	6.05E-07
chromium	(mg/kg/rock per week)	0.004								0.0014715	0.0014715	0.0014715	0.0014715	0.0014715	0.0014715
chromium	mg/L									1.21	6.80E-05	1.78E-05	9.28E-06	4.74E-06	3.18E-06
manganese	(mg/kg/rock per week)	0.380								0.0208	0.0208	0.0208	0.0208	0.0208	0.0208
manganese	mg/L									98.1	9.61E-04	2.52E-04	1.31E-04	6.69E-05	4.49E-05
nickel	(mg/kg/rock per week)	0.052								6.32E-05	3.31E-06	8.62E-07	2.20E-07	9.84E-08	9.84E-08
nickel	mg/L									15.4	2.92E-06	4.02E-06	5.44E-09	7.08E-10	2.13E-10
lead	(mg/kg/rock per week)	0.000								0.00012	0.00012	0.00012	0.00012	0.00012	0.00012
lead	mg/L									0.10	5.55E-06	1.45E-06	7.57E-07	3.86E-07	2.59E-07
selenium	(mg/kg/rock per week)	0.001								0.00056	0.00056	0.00056	0.00056	0.00056	0.00056
selenium	mg/L									0.41	2.59E-05	6.79E-06	3.53E-06	1.80E-06	1.21E-06
uranium	(mg/kg/rock per week)	0.002								0.00091345	0.00091345	0.00091345	0.00091345	0.00091345	0.00091345
uranium	mg/L									0.629	4.22E-05	1.11E-05	5.76E-06	2.94E-06	1.97E-06
zinc	(mg/kg/rock per week)	0.060								0.024	0.024	0.024	0.024	0.024	0.024
zinc	mg/L									15.5	1.11E-03	2.91E-04	1.51E-04	7.72E-05	5.18E-05
Groundwater	aluminium	mg/L	Mean	0.203	0.055	0.295	5	20	5	0.203	0.203	0.203	0.203	0.203	0.203
	aluminium	mg/L	Maximum	1.29	0.055	0.295	5	20	5	0.0099	1.29	0.0099	1.29	0.0099	1.29
	arsenic	mg/L	Mean	0.07	0.013	0.042	0.5	2	0.1	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099
	arsenic	mg/L	Maximum	0.07	0.013	0.042	0.5	2	0.1	0.07	0.07	0.07	0.07	0.07	0.07
	cobalt	mg/L	Mean	0.015	0.0014		1	0.1	0.05	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055
	cobalt	mg/L	Maximum	0.015	0.0014		1	5	0.2	0.0096	0.015	0.0096	0.015	0.015	0.015
	copper	mg/L	Mean	0.033	0.0014	0.0018	2	5		0.0096	0.0096	0.0096	0.0096	0.0096	0.0096
	copper	mg/L	Maximum	0.033	0.0014	0.0018	2	10		0.03	0.03	0.03	0.03	0.03	0.03
	cadmium	mg/L	Mean		0.0002	0.0004	0.01	0.05	0.01	0.001	0.001	0.001	0.001	0.001	0.001
	cadmium	mg/L	Maximum		0.0002	0.0004	0.01	0.05	0.01	0.001	0.001	0.001	0.001	0.001	0.001
	chromium	mg/L	Mean	0.002	0.001		1	1	0.1	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
	chromium	mg/L	Maximum	0.002	0.001		1	1	0.1	0.002	0.002	0.002	0.002	0.002	0.002
	manganese	mg/L	Mean	0.17	1.9	2.5	0.1	10	0.2	0.170	0.002	0.170	0.002	0.170	0.170
	manganese	mg/L	Maximum	0.61	1.9	2.5	0.1	10	0.2	0.610	0.610	0.610	0.610	0.610	0.610
	nickel	mg/L	Mean	0.006	0.011	0.013	1	2	0.2	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024
	nickel	mg/L	Maximum	0.006	0.011	0.013	1	5	2	0.006	0.006	0.006	0.006	0.006	0.006
	lead	mg/L	Mean	0.006	0.0034	0.0056	0.1	5	2	0.0047	0.0047	0.0047	0.0047	0.0047	0.0047
	lead	mg/L	Maximum	0.006	0.0034	0.0056	0.1	5	2	0.01	0.01	0.01	0.01	0.01	0.01
	selenium	mg/L	Mean		0.011		0.02	0.05	0.02	0.001	0.001	0.001	0.001	0.001	0.001
	selenium	mg/L	Maximum		0.011		0.02	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.00
	uranium	mg/L	Mean		0.0005		0.2	0.1	0.01	0.001	0.001	0.001	0.001	0.001	0.001
	uranium	mg/L	Maximum		0.0005		0.2	0.1	0.01	0.00	0.00	0.00	0.00	0.00	0.00
	zinc	mg/L	Mean	0.078	0.008		20	5	2	0.0222	0.0222	0.0222	0.0222	0.0222	0.0222
	zinc	mg/L	Maximum	0.078	0.008	0.014	20	5	2	0.08	0.08	0.08	0.08	0.08	0.08
Combined	aluminium	mg/L	Mean	0.203	0.055	0.295	5	20	5		Year 1	Year 5	Year 10	Year 20	Year 30
	aluminium	mg/L	Maximum	1.29	0.055	0.295	5	20	5		13667	2667	232	60	0.5
	arsenic	mg/L	Mean	0.07	0.013	0.042	0.5	2	0.1		13669	2668	233	61	1.6
	arsenic	mg/L	Maximum	0.07	0.013	0.042	0.5	2	0.1		0.15	0.04	0.01	0.01	0.01
	cobalt	mg/L	Mean	0.015	0.0014		1	0.1	0.05		0.21	0.10	0.07	0.07	0.07
	cobalt	mg/L	Maximum	0.015	0.0014		1	0.1	0.05		1.78	0.37	0.05	0.03	0.021
	cobalt	mg/L	Maximum	0.015	0.0014		1	0.1	0.05		1.79	0.38	0.060	0.04	0.030
	copper	mg/L	Mean	0.033	0.0014	0.0018	2	5	0.2		14.38	2.84	0.26	0.07	0.01
	copper	mg/L	Maximum	0.033	0.0014	0.0018	2	5	0.2		14.4	2.86	0.26	0.10	0.03
	cadmium	mg/L	Mean	0.0002	0.0002	0.0004	0.01	0.05	0.01		0.04	0.01	0.002	LOR	LOR
	cadmium	mg/L	Maximum	0.0002	0.0002	0.0004	0.01	0.05	0.01		0.04	0.01	0.002	LOR	LOR
	chromium	mg/L	Mean	0.002	0.001		1	1	0.1		0.20	0.04	0.01	0.002	0.002
	chromium	mg/L	Maximum	0.002	0.001		1	1	0.1		0.20	0.04	0.01	0.00	0.002
	manganese	mg/L	Mean	0.17	1.9	2.5	0.1	10	0.2		16.57	3.40	0.45	0.24	0.17
	manganese	mg/L	Maximum	0.61	1.9	2.5	0.1	10	0.2		17.01	3.44	0.59	0.45	0.61
	nickel	mg/L	Mean	0.006	0.011	0.013	1	2	0.2		2.37	0.51	0.05	0.01	0.002
	nickel	mg/L	Maximum	0.006	0.011	0.013	1	2	0.2		2.38	0.51	0.05	0.02	0.006
	lead	mg/L	Mean	0.006	0.0034	0.0056	0.1	5	2		0.02	0.008	0.005	0.005	0.005
	lead	mg/L	Maximum	0.006	0.0034	0.0056	0.1	5	2		0.02	0.009	0.006	0.006	0.006
	selenium	mg/L	Mean		0.011		0.02	0.05	0.02		0.07	0.01	0.002	LOR	LOR
	selenium	mg/L	Maximum		0.011		0.02	0.05	0.02		0.07	0.01	0.002	LOR	LOR
	uranium	mg/L	Mean		0.0005		0.2	0.1	0.01		0.11	0.022	0.003	LOR	LOR
	uranium	mg/L	Maximum		0.0005		0.2	0.1	0.01		0.11	0.022	0.003	LOR	LOR
	zinc	mg/L	Mean	0.078	0.008	0.014	20	5	2		2.61	0.63	0.067	0.03	0.02
	zinc	mg/L	Maximum	0.078	0.008	0.014	20	5	2		2.67	0.69	0.122	0.069	0.078

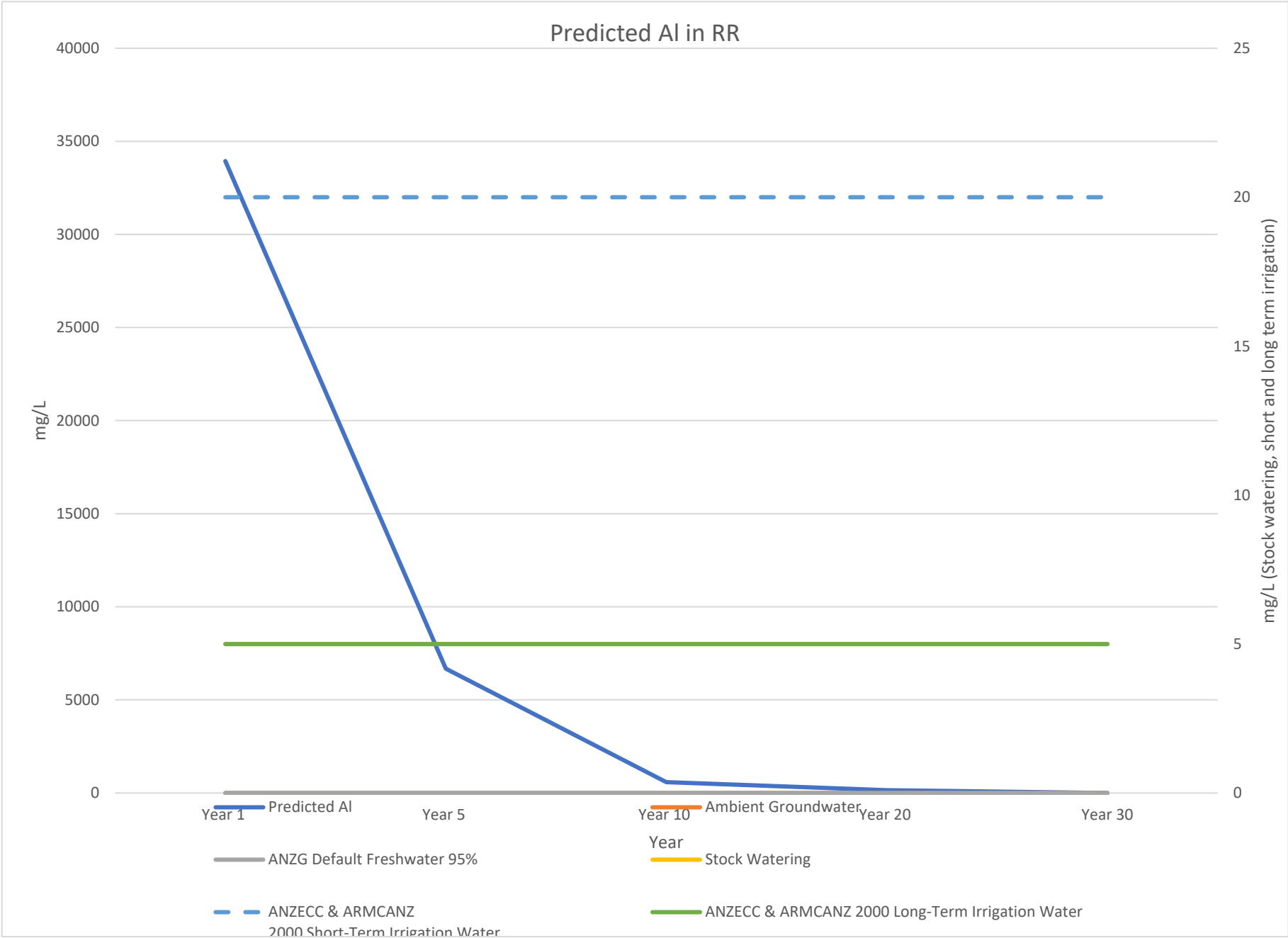
F-4 QUEST 29 (+ CSF)

Appendix F-4 Q29 Combined S1 and S2 Predictions (Scaled) + CSF

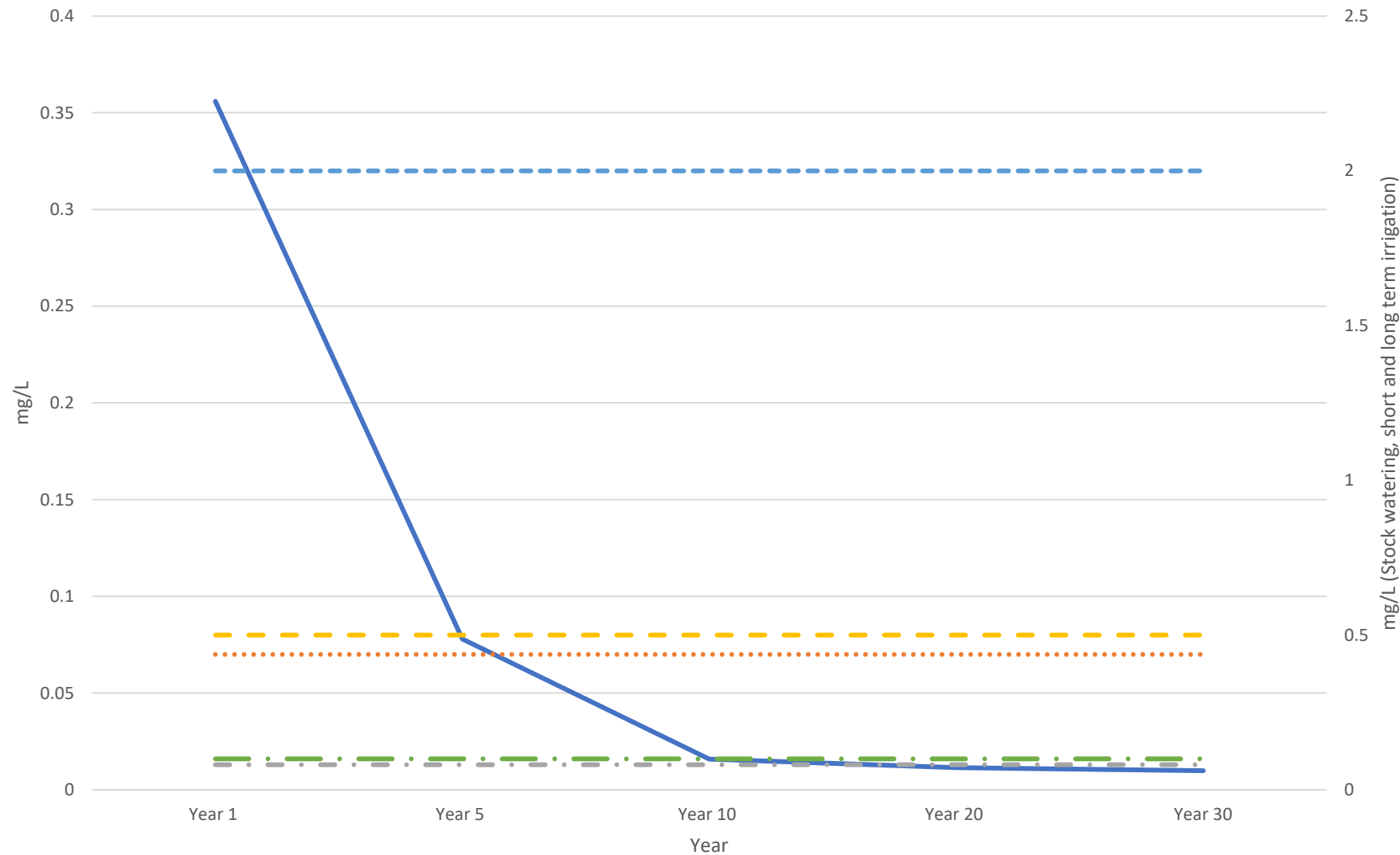
									Source S2	Year 1	Year 5	Year 10	Year 20	Year 30
	Parameter	Value	Leach	Groundwater	ANZG Default GV 95%	Bundy Creek TV's	Stock Watering (Beef)	ANZECC & ARMCANZ 2000 Short-Term Irrigation Water	ANZECC & ARMCANZ 2000 Long-Term Irrigation Water					
Sources	Time (weeks) for In pit	52 – refer value for 52 weeks in Appendix A which mimics 1 year of oxidation.	Arbitrary extrapolation – can be extended forward to any week value.							52	52	52	52	52
	Mass of Waste PAF Rock (kg)	1.90E+07								3.50E+05	3.50E+05	3.50E+05	3.50E+05	3.50E+05
	Rainfall (L)									9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.00E+06
	Run-off Volume (L)									5.70E+08	2.10E+07	2.10E+07	2.10E+07	2.10E+07
	Groundwater Influx (L)	Variable per stage of recovery	CDM Smith (2021)							-	9.50E+07	4.75E+08	6.00E+08	6.00E+08
	Cumulative (L)									1.25E+08	5.05E+08	6.30E+08	6.30E+08	6.30E+08
	Ratio Run-off:Groundwater									1.68E-01	4.16E-02	3.33E-02	3.33E-02	3.33E-02
	Run-off Contribution	Fraction								0.8	0.2	0.1	0.05	0
	aluminium (mg/kg/rock per week)		9.2							9.20000	9.20000	9.20000	9.20000	9.20000
	aluminium mg/L		363							3321	1.34E+00	3.32E-01	2.66E-01	2.66E-01
	arsenic (mg/kg/rock per week)		0.001							0.00072	0.00072	0.00072	0.00072	0.00072
	arsenic mg/L		0.050							0.26	1.05E-04	2.59E-05	2.08E-05	2.08E-05
	cobalt (mg/kg/rock per week)		0.040							0.040	0.040	0.040	0.040	0.040
	cobalt mg/L		2.460							16.624	5.82E-03	1.44E-03	1.16E-03	1.16E-03
	copper (mg/kg/rock per week)		0.660							0.66	0.66	0.66	0.66	0.66
	copper mg/L		33.500							239.773	9.61E-02	2.38E-02	1.91E-02	1.91E-02
	cadmium (mg/kg/rock per week)		0.001							0.001	0.001	0.001	0.001	0.001
	cadmium mg/L		0.070							0.449	1.75E-04	4.32E-05	3.47E-05	3.47E-05
	chromium (mg/kg/rock per week)		0.002							0.002	0.002	0.002	0.002	0.002
	chromium mg/L		0.110							0.823	2.91E-04	7.21E-05	5.78E-05	5.78E-05
Groundwater	nickel (mg/kg/rock per week)		0.210							0.210	0.210	0.210	0.210	0.210
	nickel mg/L		9.500							61.374	3.06E-02	7.57E-03	6.07E-03	6.07E-03
	lead (mg/kg/rock per week)		0.000							0.000	0.000	0.000	0.000	0.000
	lead mg/L		0.020							0.133	5.24E-05	1.30E-05	1.04E-05	1.04E-05
	selenium (mg/kg/rock per week)		0.003							0.003	0.003	0.003	0.003	0.003
	selenium mg/L		0.150							1.055	4.22E-04	1.05E-04	8.38E-05	8.38E-05
	uranium (mg/kg/rock per week)		0.005							0.005	0.005	0.005	0.005	0.005
	uranium mg/L		0.220							1.654	6.55E-04	1.62E-04	1.30E-04	1.30E-04
	zinc (mg/kg/rock per week)		0.210							0.210	0.210	0.210	0.210	0.210
	zinc mg/L		11.6							76.031	3.06E-02	7.57E-03	6.07E-03	6.07E-03
	aluminium	mg/L	Mean	0.01	0.055	0.295	5	20	5		0.01	0.01	0.01	0.01
	aluminium	mg/L	Maximum	1.3	0.055	0.295	5	20	5		0.01	0.01	0.01	0.01
	arsenic	mg/L	Mean	0.04	0.013	0.042	0.5	2	0.1		0.04	0.04	0.04	0.04
	arsenic	mg/L	Maximum	0.20	0.013	0.042	0.5	2	0.1		0.20	0.20	0.20	0.20
	cobalt	mg/L	Mean	0.0016	0.0014		1	0.1	0.05		0.0016	0.0016	0.0016	0.0016
	cobalt	mg/L	Maximum	0.005	0.0014		1				0.005	0.005	0.005	0.005
	copper	mg/L	Mean	0.0029	0.0014	0.0018	2	5	0.2		0.0029	0.0029	0.0029	0.0029
	copper	mg/L	Maximum	0.009	0.0014		2				0.01	0.01	0.01	0.01
	cadmium	mg/L	Mean	0.0002	0.0002	0.0004	0.01	0.05	0.01		0.0002	0.0002	0.0002	0.0002
	cadmium	mg/L	Maximum	0.00113	0.0002	0.0004	0.01	0.05	0.01		0.001	0.001	0.001	0.001
	chromium	mg/L	Mean	0.0041	0.001		1	1	0.1		0.0041	0.0041	0.0041	0.0041
	chromium	mg/L	Maximum	0.011	0.001		1	1	0.1		0.011	0.011	0.011	0.011
	manganese	mg/L	Mean	0.49	1.9	2.5	1	10	0.2		0.490	0.490	0.490	0.490
	manganese	mg/L	Maximum	1.5	1.9	2.5	1	10	0.2		1.500	1.500	1.500	1.500
	nickel	mg/L	Mean	0.0046	0.011	0.013	1	2	0.2		0.0046	0.0046	0.0046	0.0046
	nickel	mg/L	Maximum	0.02	0.011		1				0.020	0.020	0.020	0.020
	lead	mg/L	Mean	0.0014	0.0034	0.0056	0.1	5	2		0.0014	0.0014	0.0014	0.0014
	lead	mg/L	Maximum	0.005	0.0034	0.0056	0.1	5	2		0.01	0.01	0.01	0.01
	selenium	mg/L	Mean	0.001	0.011		0.02	0.05	0.02		0.001	0.001	0.001	0.001
	selenium	mg/L	Maximum	0.001	0.011		0.02	0.05	0.02		0.00	0.00	0.00	0.00
	uranium	mg/L	Mean	0.001	0.0005		0.2	0.1	0.01		0.001	0.001	0.001	0.001
	uranium	mg/L	Maximum	0.001	0.0005		0.2	0.1	0.01		0.00	0.00	0.00	0.00
	zinc	mg/L	Mean	0.021	0.008		20	5	2		0.021	0.021	0.021	0.021
	zinc	mg/L	Maximum	0.0846	0.008	0.014	20				0.08	0.08	0.08	0.08
Combined	aluminium	mg/L	Mean	0.01	0.055	0.295	5	20	5		448	28	11.3	5.8
	aluminium	mg/L	Maximum	1.3	0.055	0.295	5	20	5		448	28	11.3	5.8
	arsenic	mg/L	Mean	0.04	0.013	0.042	0.5	2	0.1		0.08	0.042	0.041	0.040
	arsenic	mg/L	Maximum	0.20	0.013	0.042	0.5	2	0.1		0.24	0.202	0.201	0.200
	cobalt	mg/L	Mean	0.0016	0.0014		1				2.28	0.18	0.10	0.07
	cobalt	mg/L	Maximum	0.005	0.0014		1	0.1	0.05		2.28	0.18	0.10	0.07
	copper	mg/L	Mean	0.0029	0.0014	0.0018	2	5	0.2		32.32	2.02	0.821	0.422
	copper	mg/L	Maximum	0.009	0.0014		2				32.33	2.03	0.827	0.428
	cadmium	mg/L	Mean	0.0002	0.0002	0.0004	0.01	0.05	0.01		0.06	0.004	0.002	LOR
	cadmium	mg/L	Maximum	0.00113	0.0002	0.0004	0.01	0.05	0.01		0.06	0.005	0.003	0.002
	chromium	mg/L	Mean	0.0041	0.001		1	1	0.1		0.12	0.01	0.01	0.01
	chromium	mg/L	Maximum	0.011	0.001		1	1	0.1		0.12	0.02	0.01	0.01
	manganese	mg/L	Mean	0.49	1.9	2.5	10	10	0.2		0.6	0.5	0.5	0.5
	manganese	mg/L	Maximum	1.5	1.9	2.5	10	10	0.2		1.6	1.5	1.5	1.5
	nickel	mg/L	Mean	0.0046	0.011	0.013	1				8.28	0.52	0.22	0.113
	nickel	mg/L	Maximum	0.02	0.011		1	2	0.2		8.30	0.54	0.23	0.128
	lead	mg/L	Mean	0.0014	0.0034	0.0056	0.1	5	2		0.019	0.003	0.002	0.002
	lead	mg/L	Maximum	0.005	0.0034	0.0056	0.1	5	2		0.023	0.006	0.005	0.005
	selenium	mg/L	Mean	0.001	0.011		0.02	0.05	0.02		0.14	0.010	0.005	0.003
	selenium	mg/L	Maximum	0.001	0.011		0.02	0.05	0.02		0.14	0.010	0.005	0.003
	uranium	mg/L	Mean	0.001	0.0005		0.2	0.1	0.01		0.22	0.01	0.007	0.004
	uranium	mg/L	Maximum	0.001	0.0005		0.2	0.1	0.01		0.22	0.01	0.007	0.004
	zinc	mg/L	Mean	0.021	0.008	0.014	20	5	2		10.27	0.661	0.281	0.154
	zinc	mg/L	Maximum	0.0846	0.008		20				10.33	0.725	0.344	0.217

APPENDIX G– CPEC PLOTS NO CSF





Predicted As in RR



— Prdicted As

— • — ANZG Default Freshwater 95%

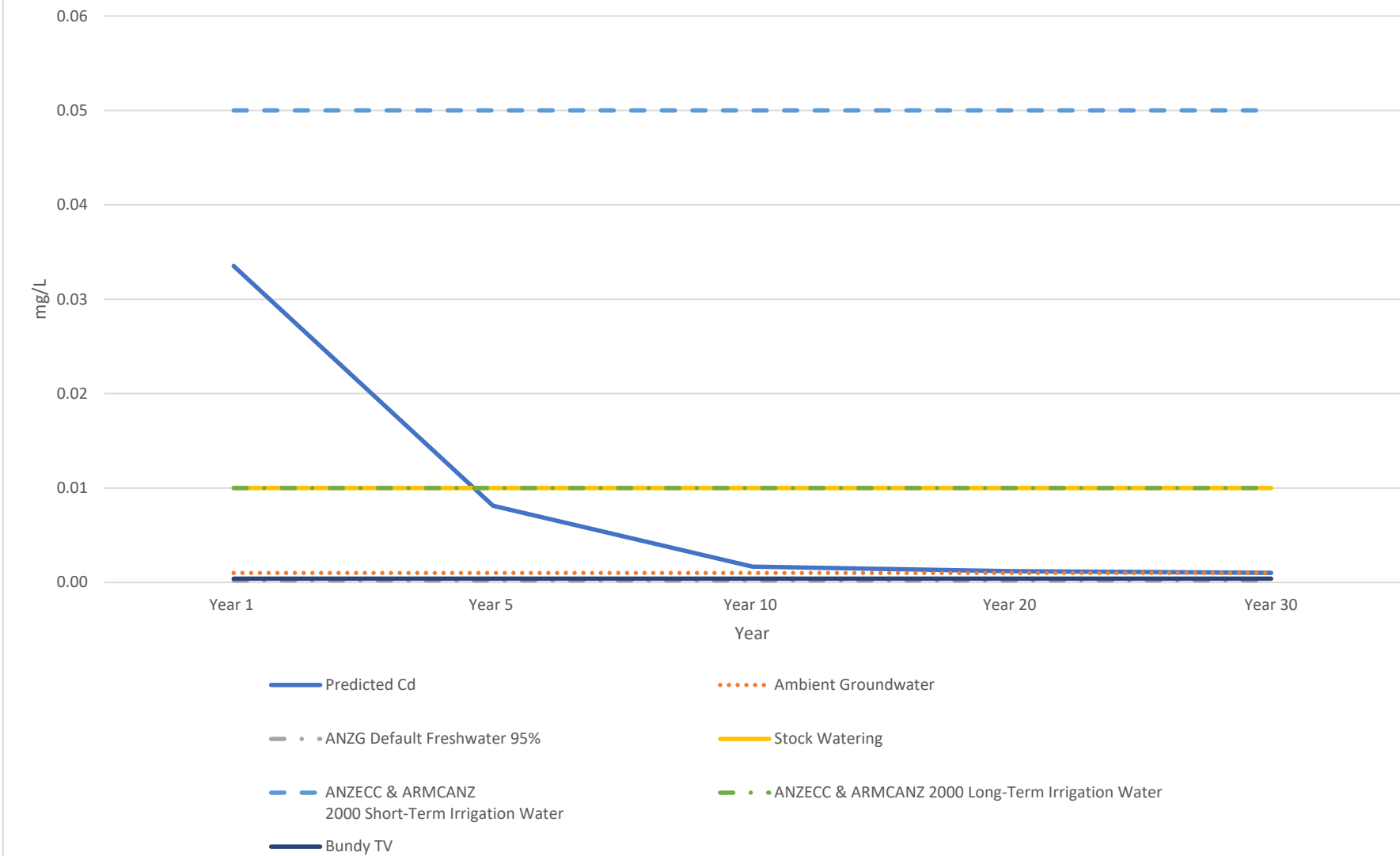
— — — ANZECC & ARMCANZ
2000 Short-Term Irrigation Water

• • • • Ambient Groundwater

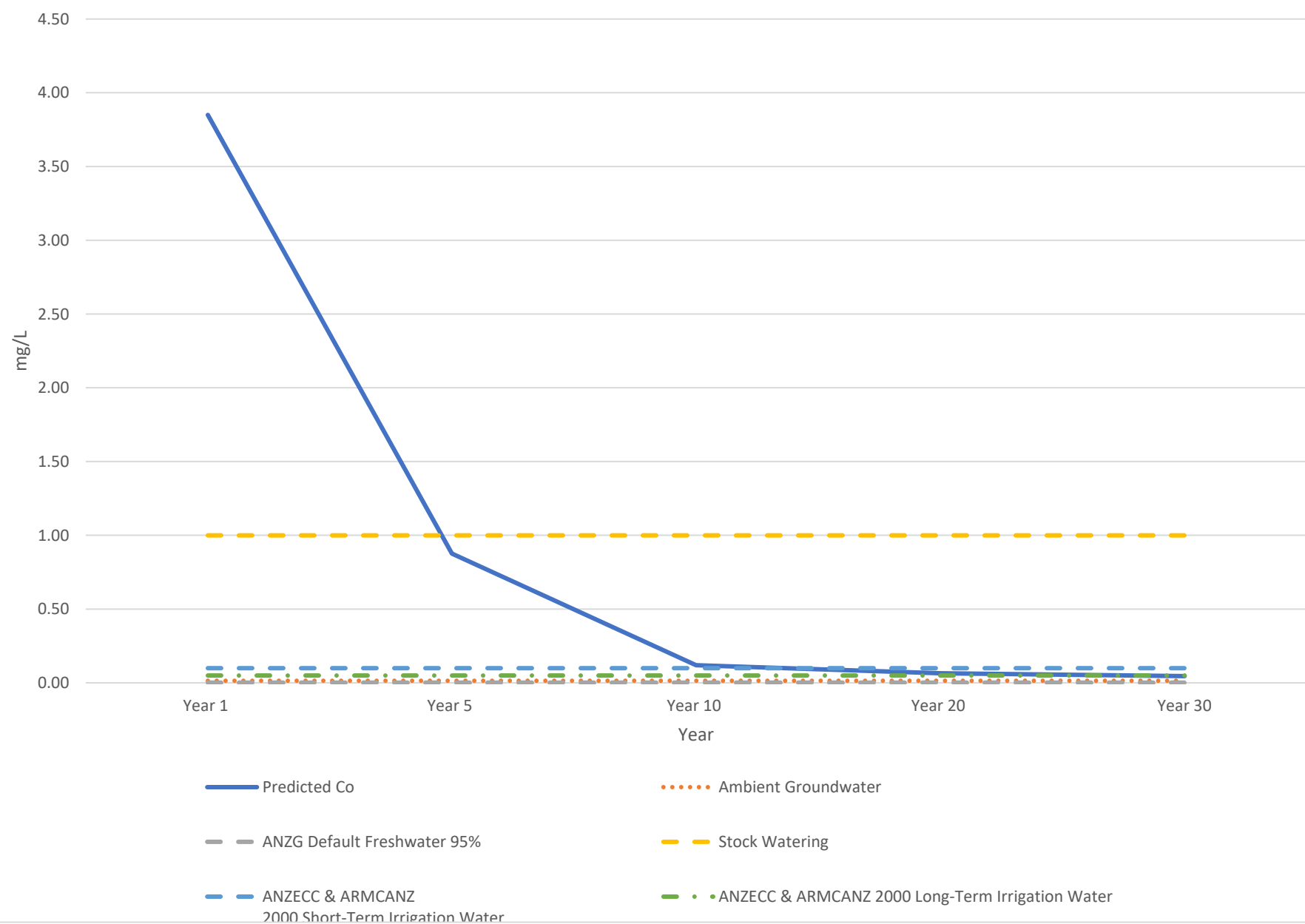
— — — Stock Watering

— — — ANZECC & ARMCANZ 2000 Long-Term Irrigation Water

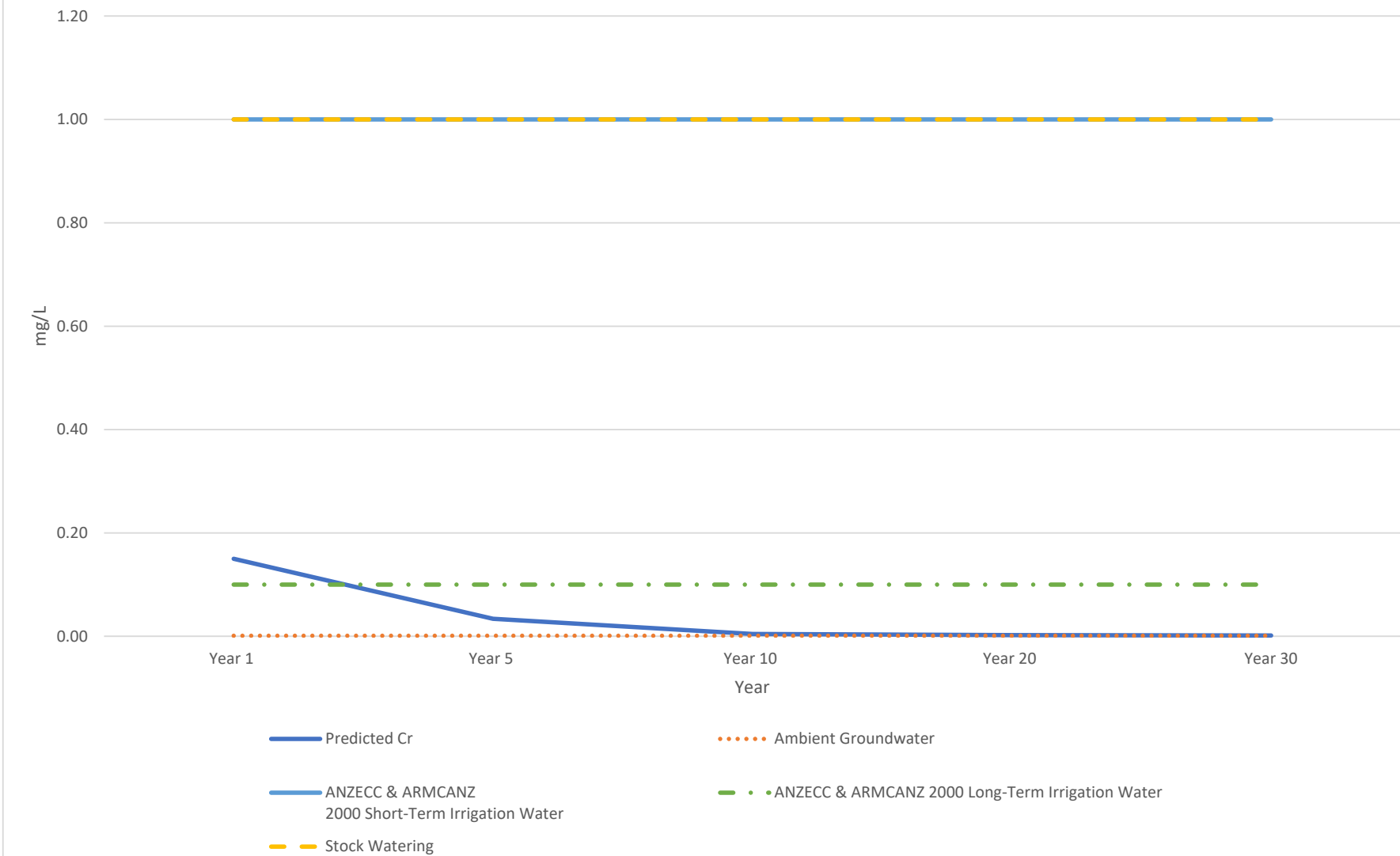
Predicted Cd in RR



Predicted Co in RR



Predicted Cr in RR



Predicted Cu in RR

35.00

30.00

25.00

20.00

mg/L

15.00

10.00

1

2

3

4

5

6

7

8

9

10

11

12

13

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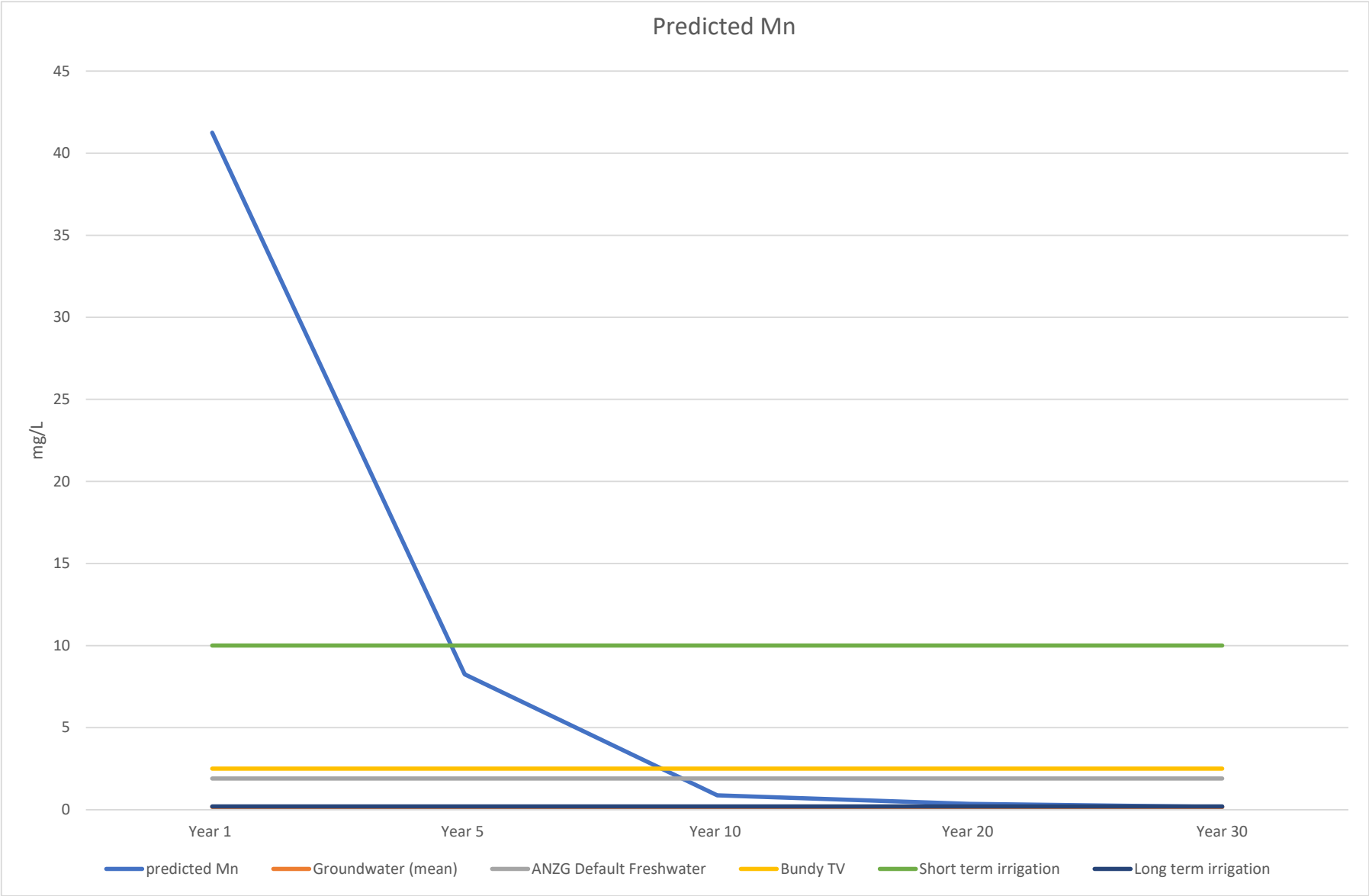
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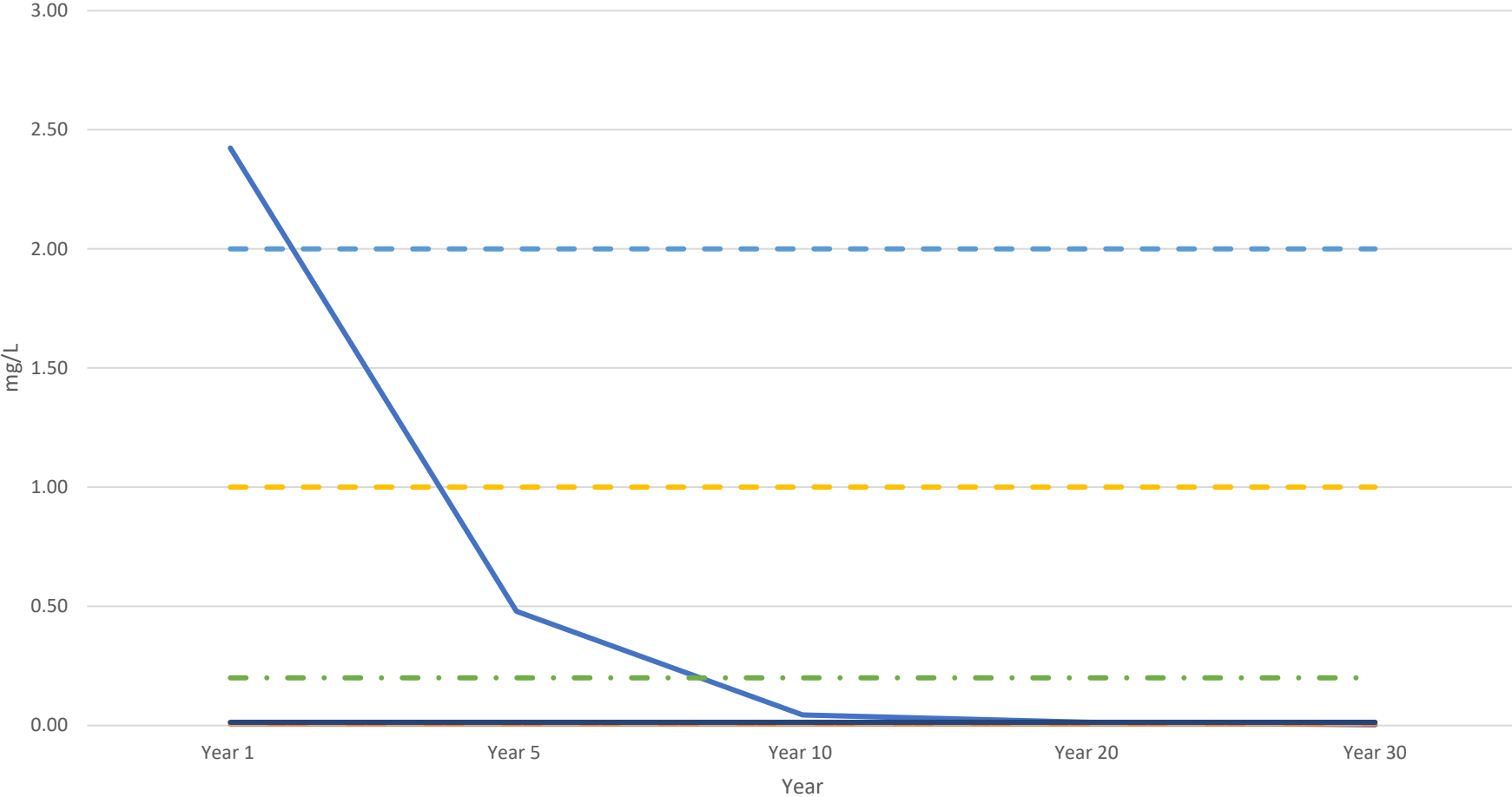
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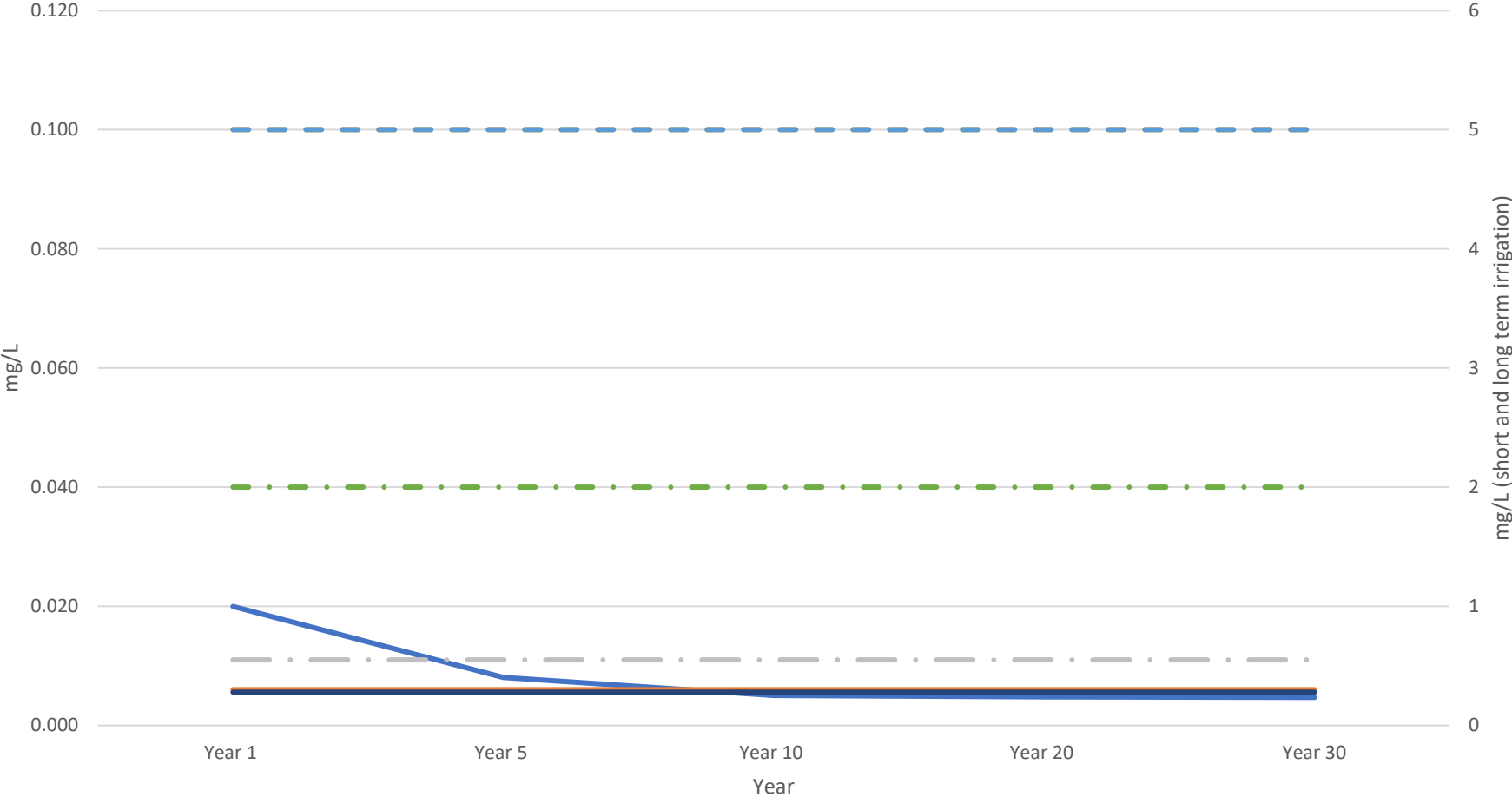


Predicted Ni in RR

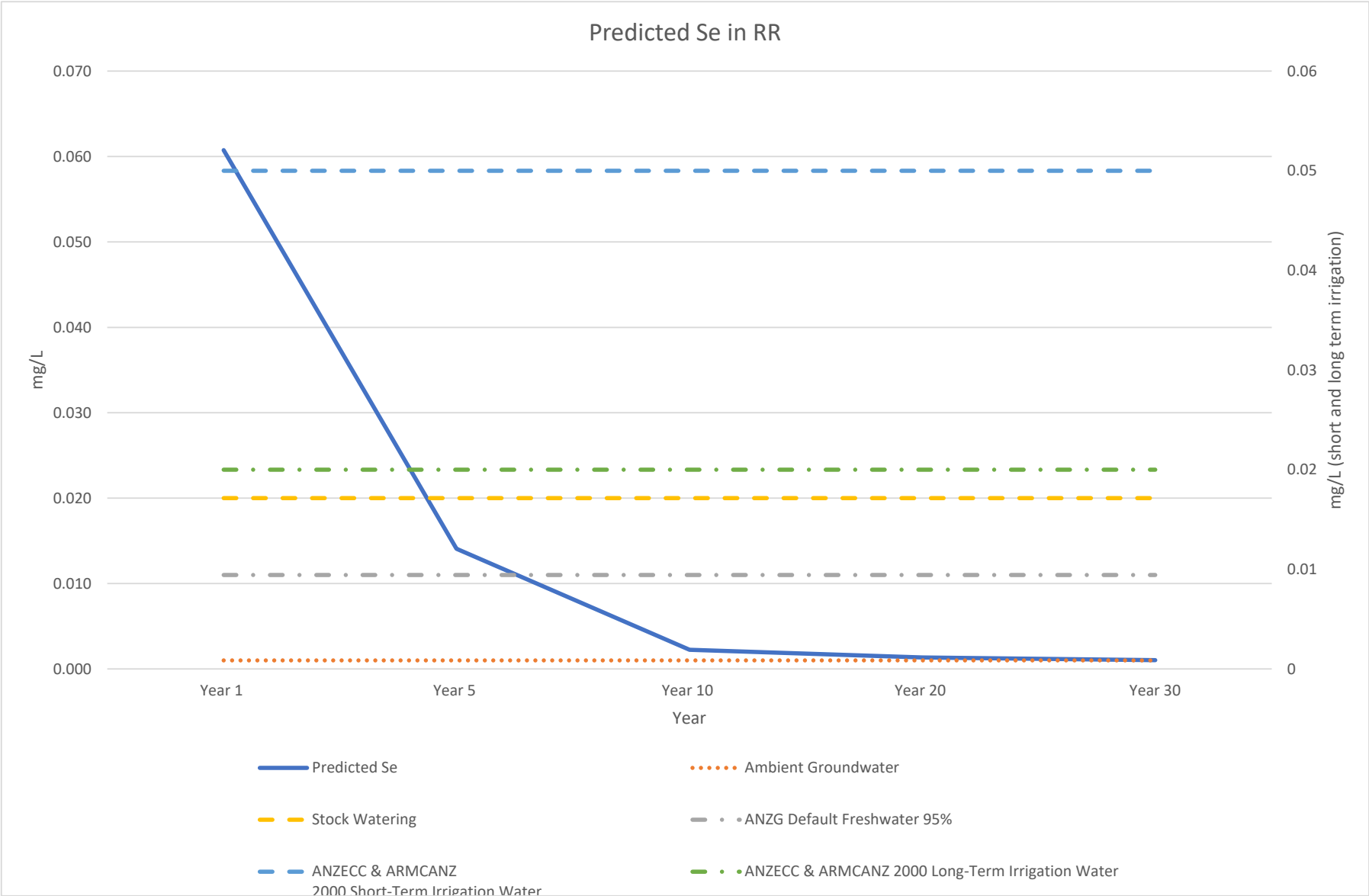


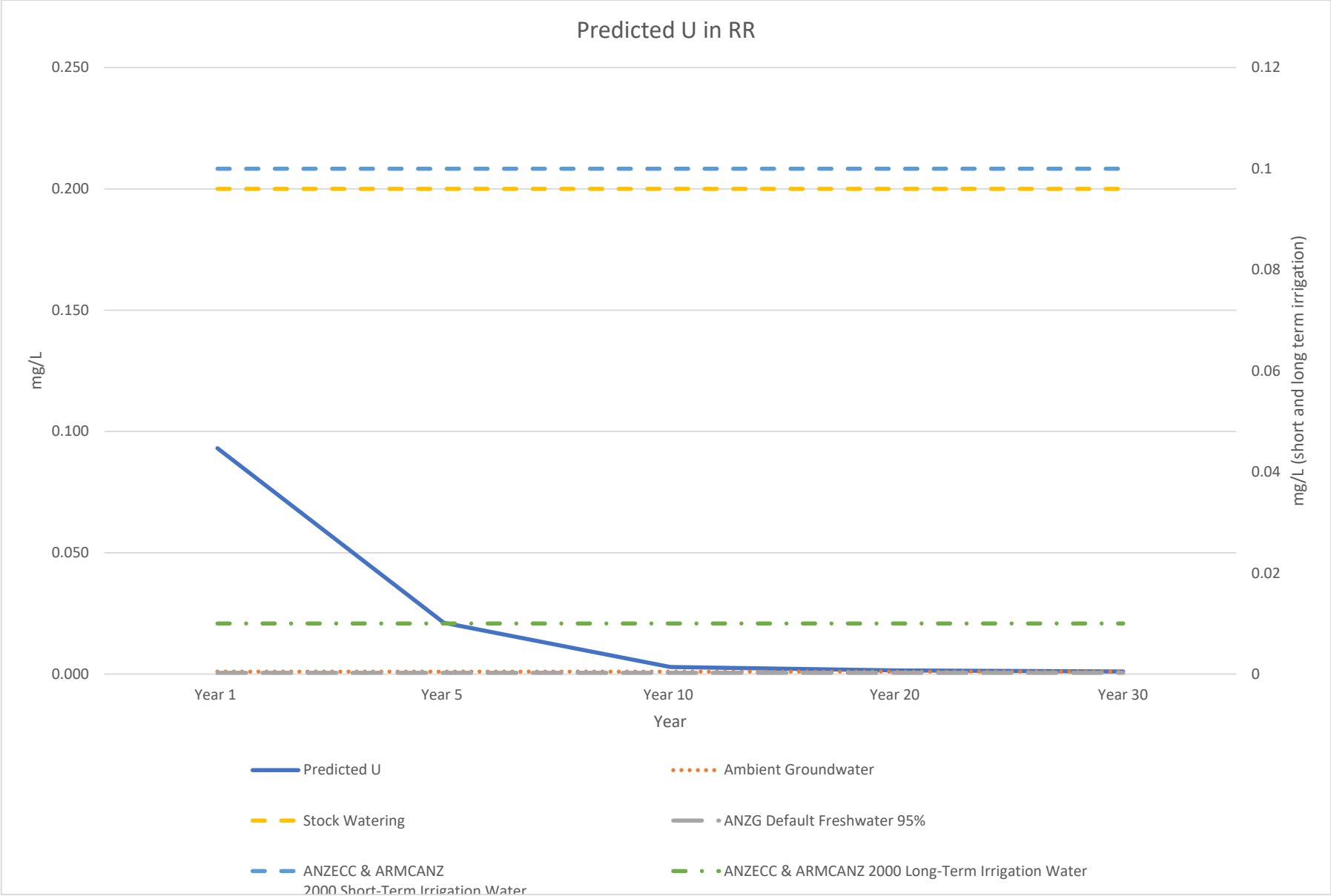
- Predicted Ni
- ANZECC & ARMCANZ 2000 Short-Term Irrigation Water
- Stock Watering
- Bundy TV
- Ambient Groundwater
- ANZECC & ARMCANZ 2000 Long-Term Irrigation Water
- ANZG Default Freshwater 95%

Predicted Pb in RR

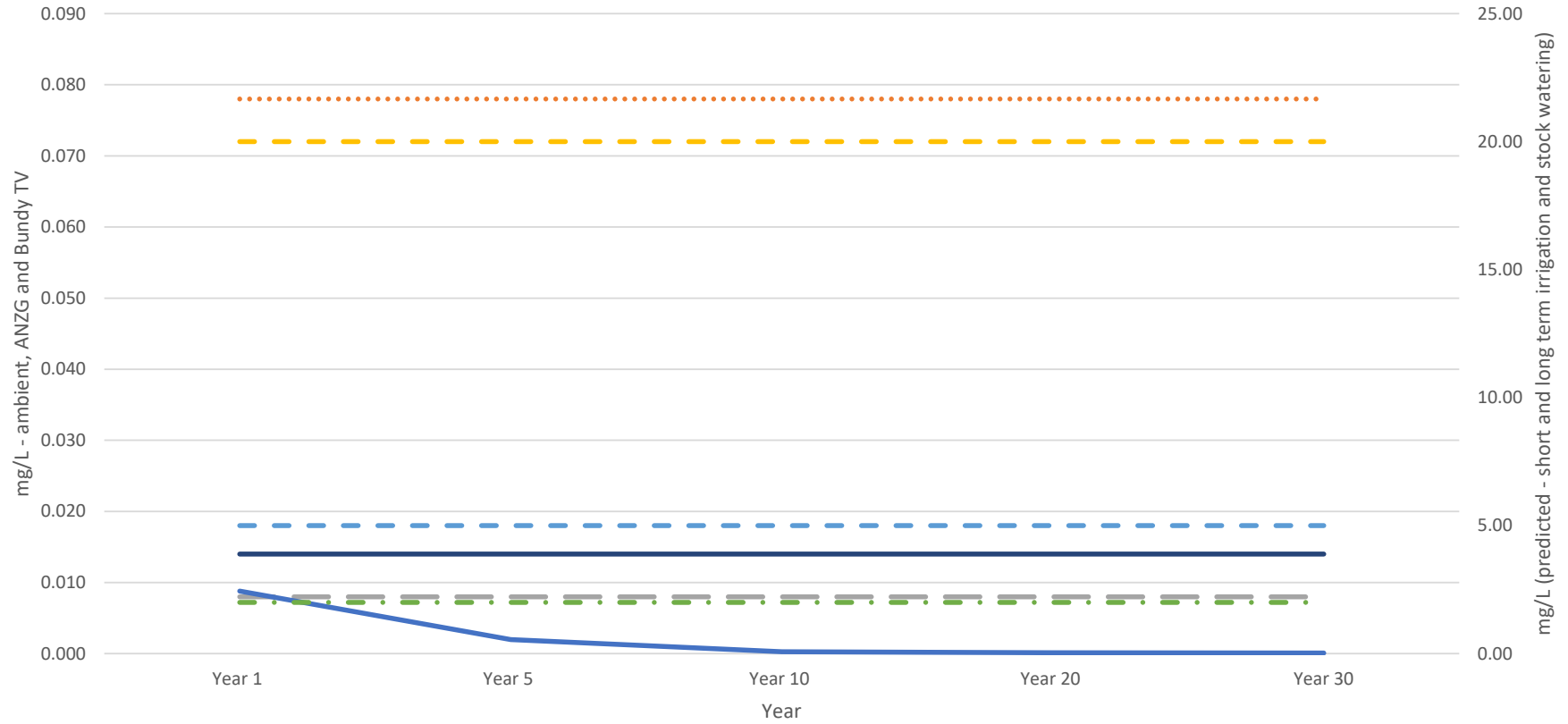


- Predicted Pb
- Stock Watering
- Bundy TV
- ANZECC & ARMCANZ 2000 Long-Term Irrigation Water
- Ambient Groundwater
- ANZG Default Freshwater 95%
- ANZECC & ARMCANZ 2000 Short-Term Irrigation Water





Predicted Zn in RR



..... Ambient Groundwater

———— Bundy TV

———— Stock Watering

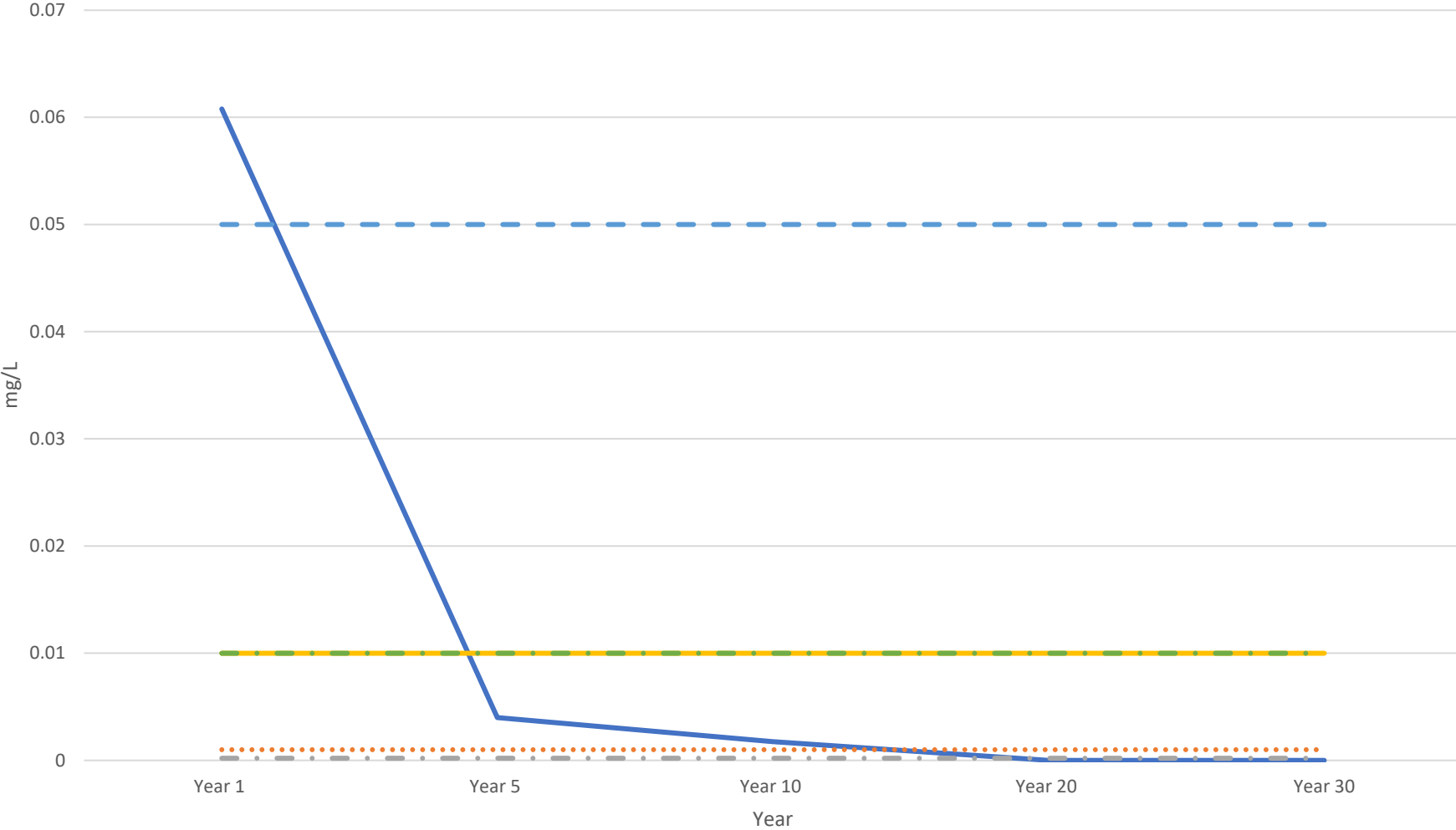
— • — ANZECC & ARMCANZ 2000 Long-Term Irrigation Water

— • — ANZG Default Freshwater 95%

———— Predicted Zn

— — — ANZECC & ARMCANZ
2000 Short-Term Irrigation Water

Predicted Cd in RR



Predicted Cd

Ambient Groundwater

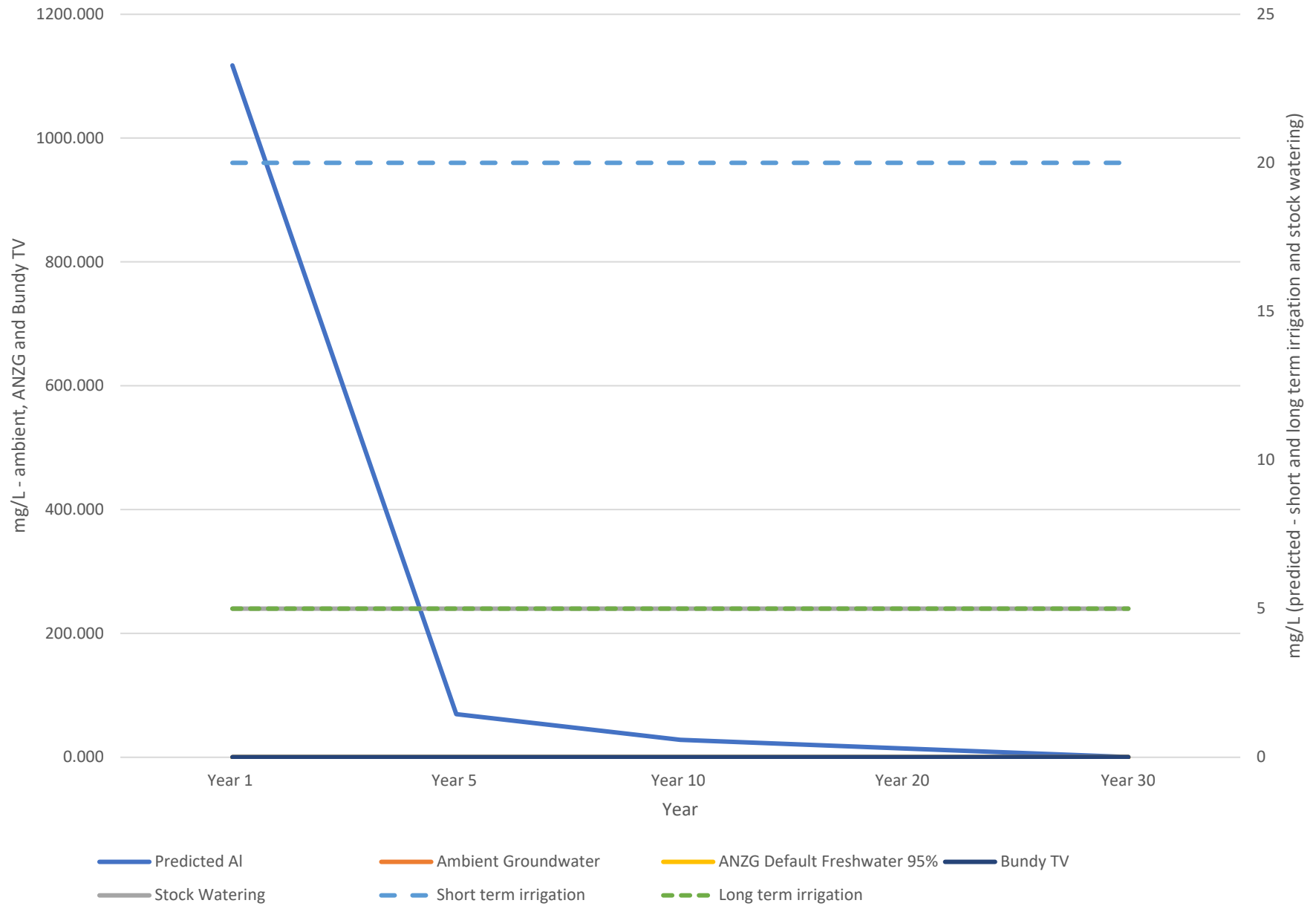
ANZG Default Freshwater 95%

Stock Watering

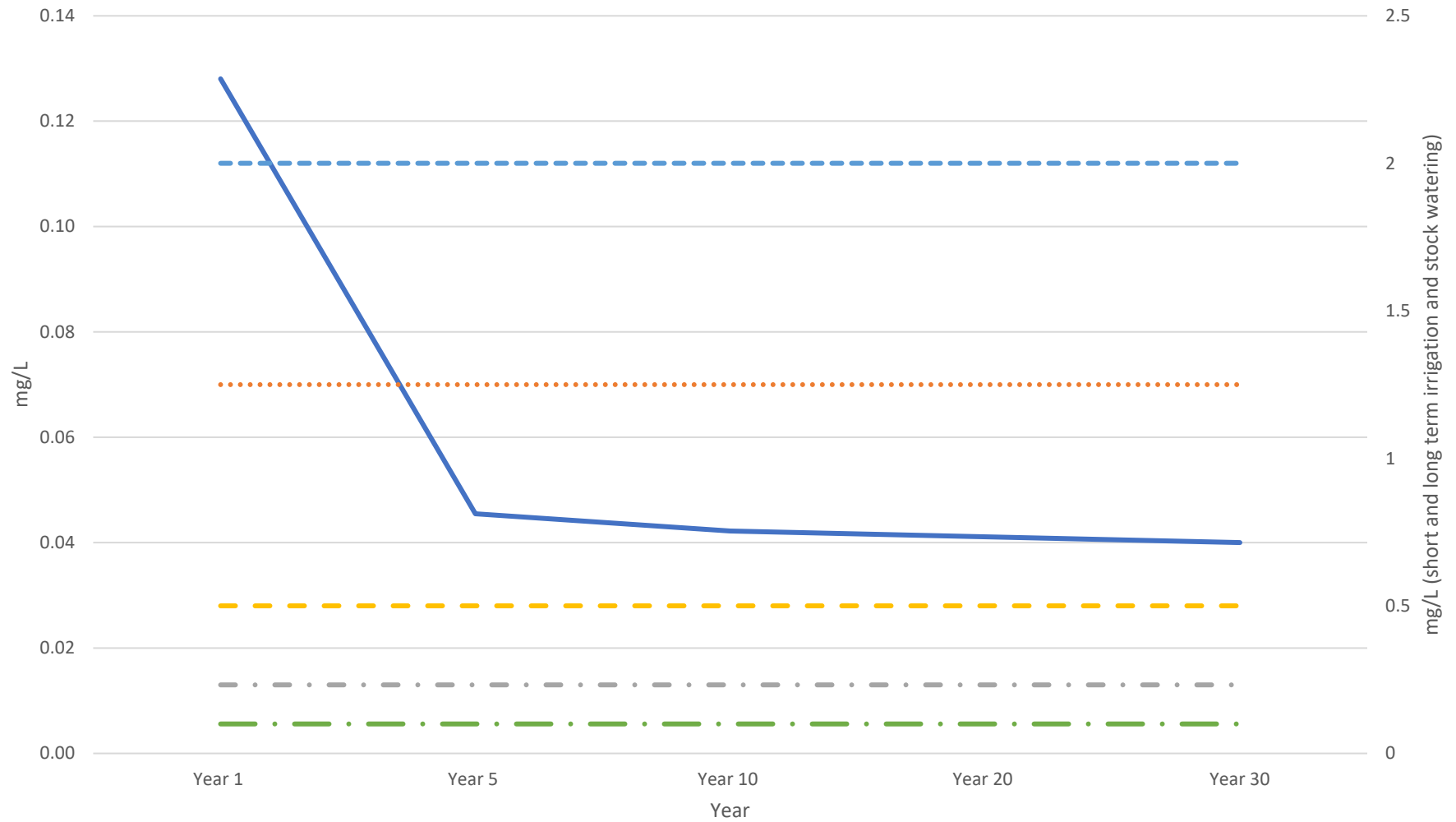
ANZECC & ARMCANZ
2000 Short-Term Irrigation Water

ANZECC & ARMCANZ 2000 Long-Term Irrigation Water

Predicted AI in Q29



Predicted As in Q29



Predicted As

Ambient Groundwater

ANZG Default Freshwater 95%

Stock Watering

ANZECC & ARMCANZ
2000 Short-Term Irrigation Water

ANZECC & ARMCANZ 2000 Long-Term Irrigation Water

Predicted Cd in RR

0.07

0.06

0.05

0.04

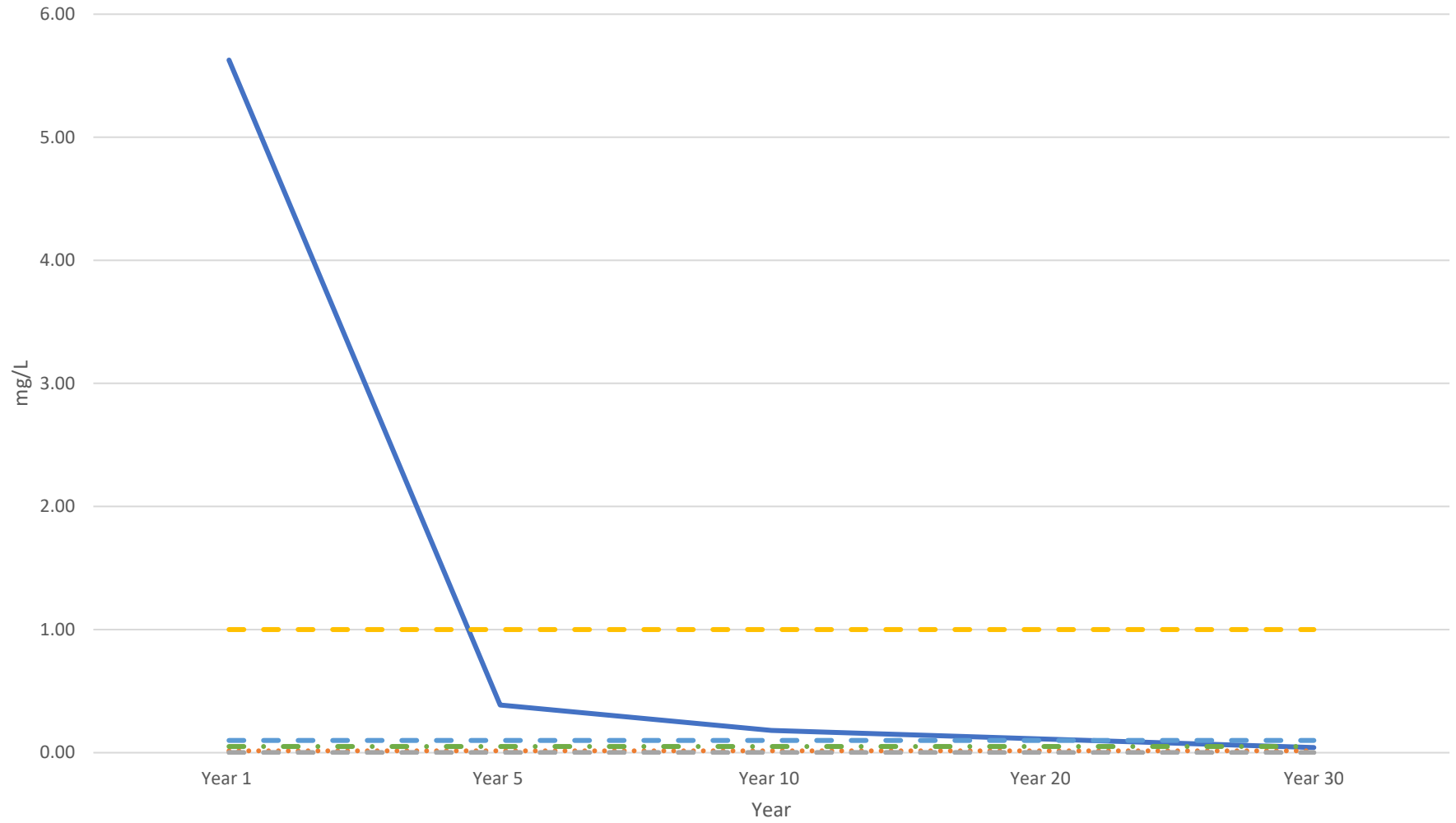
mg/L

0.03

0.02



Predicted Co in Q29



Predicted Co

Ambient Groundwater

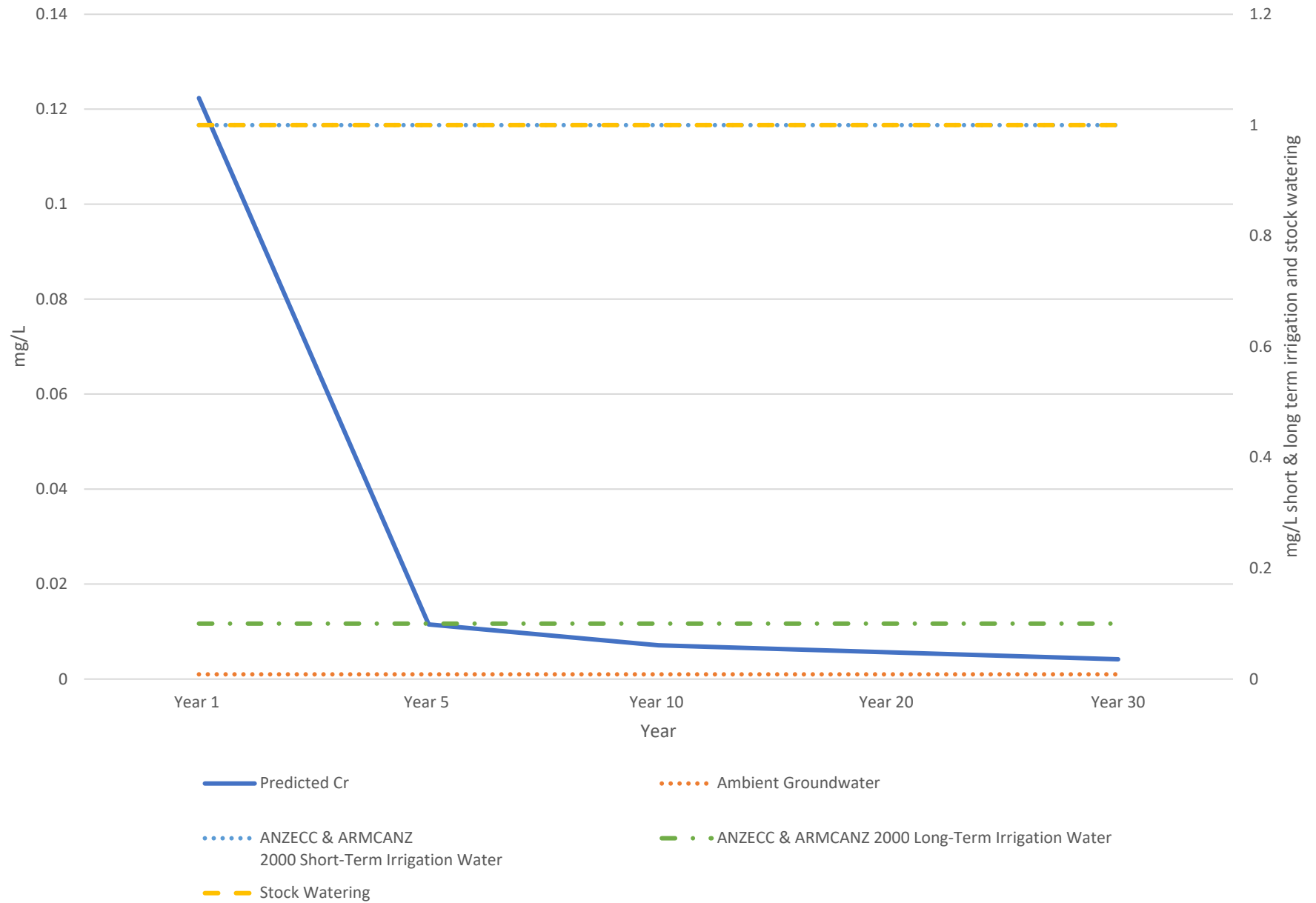
ANZG Default Freshwater 95%

Stock Watering

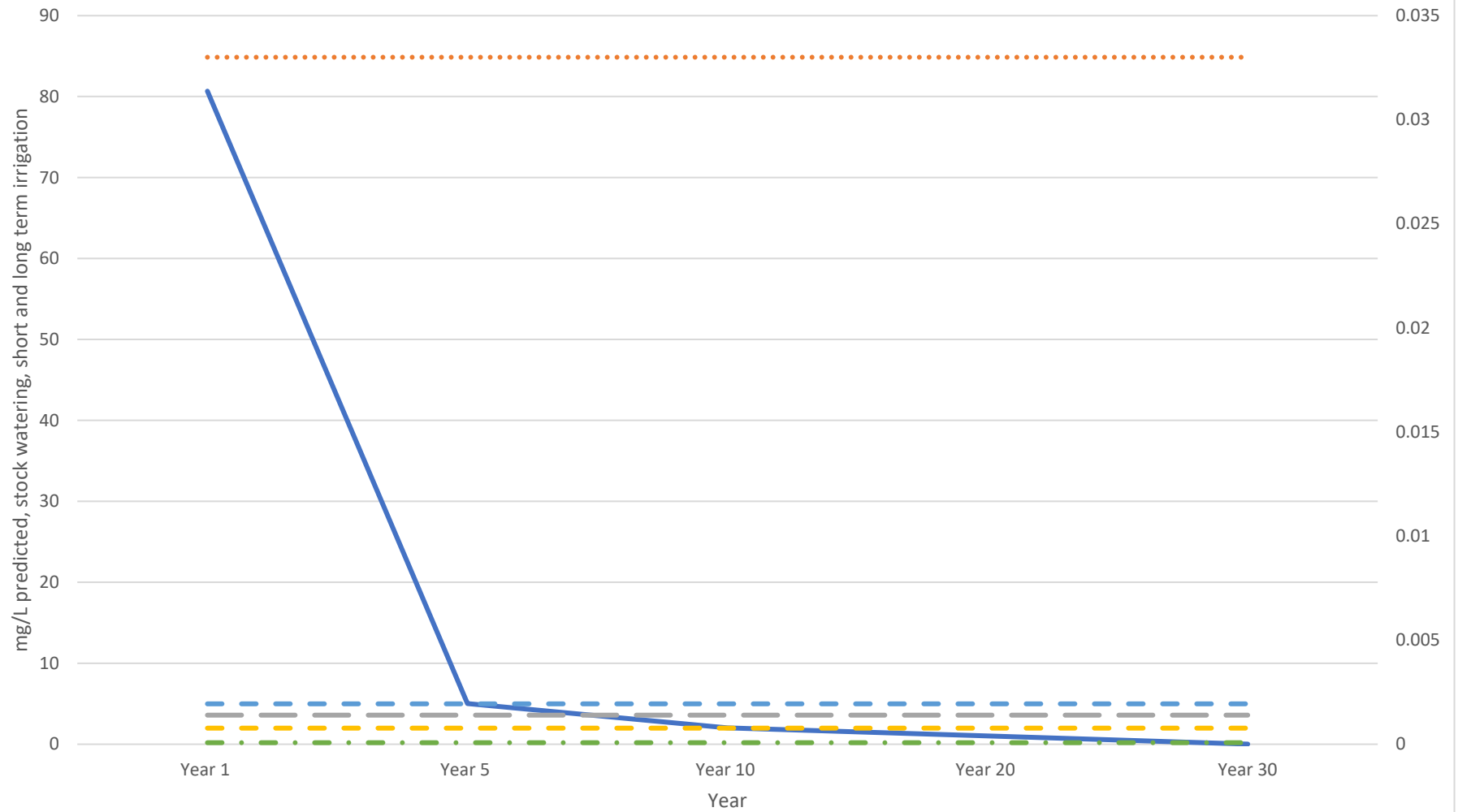
ANZECC & ARMCANZ
2000 Short-Term Irrigation Water

ANZECC & ARMCANZ 2000 Long-Term Irrigation Water

Predicted Cr in Q29



Predicted Cu in Q29



Predicted Cu

ANZECC & ARMCANZ
2000 Short-Term Irrigation Water

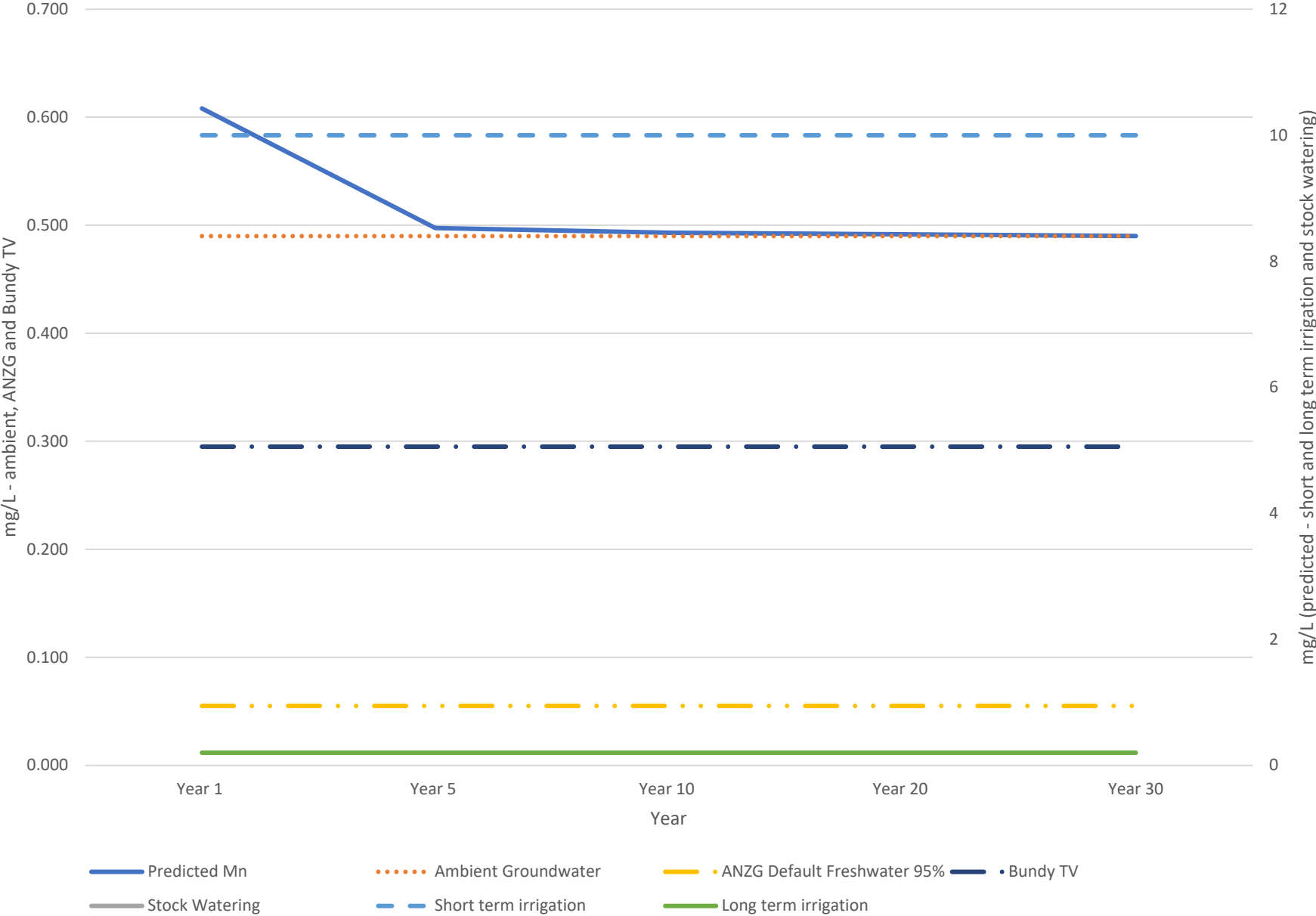
Ambient Groundwater

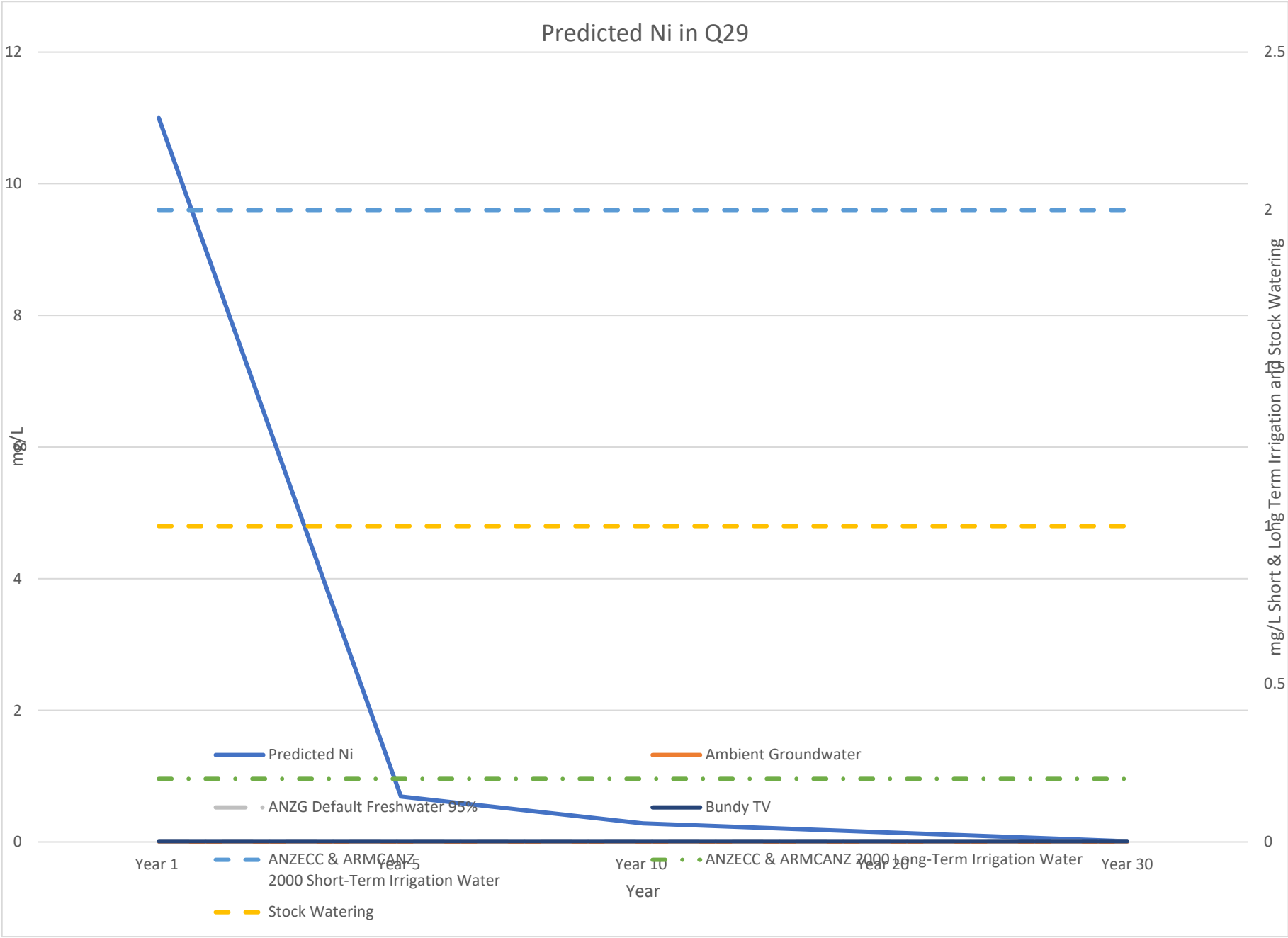
Stock Watering

ANZECC & ARMCANZ 2000 Long-Term Irrigation Water

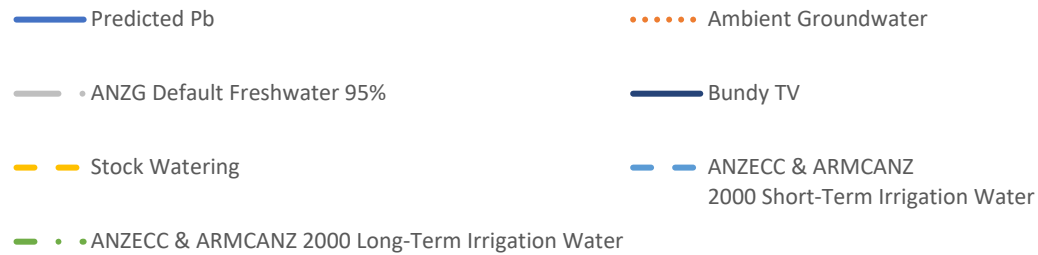
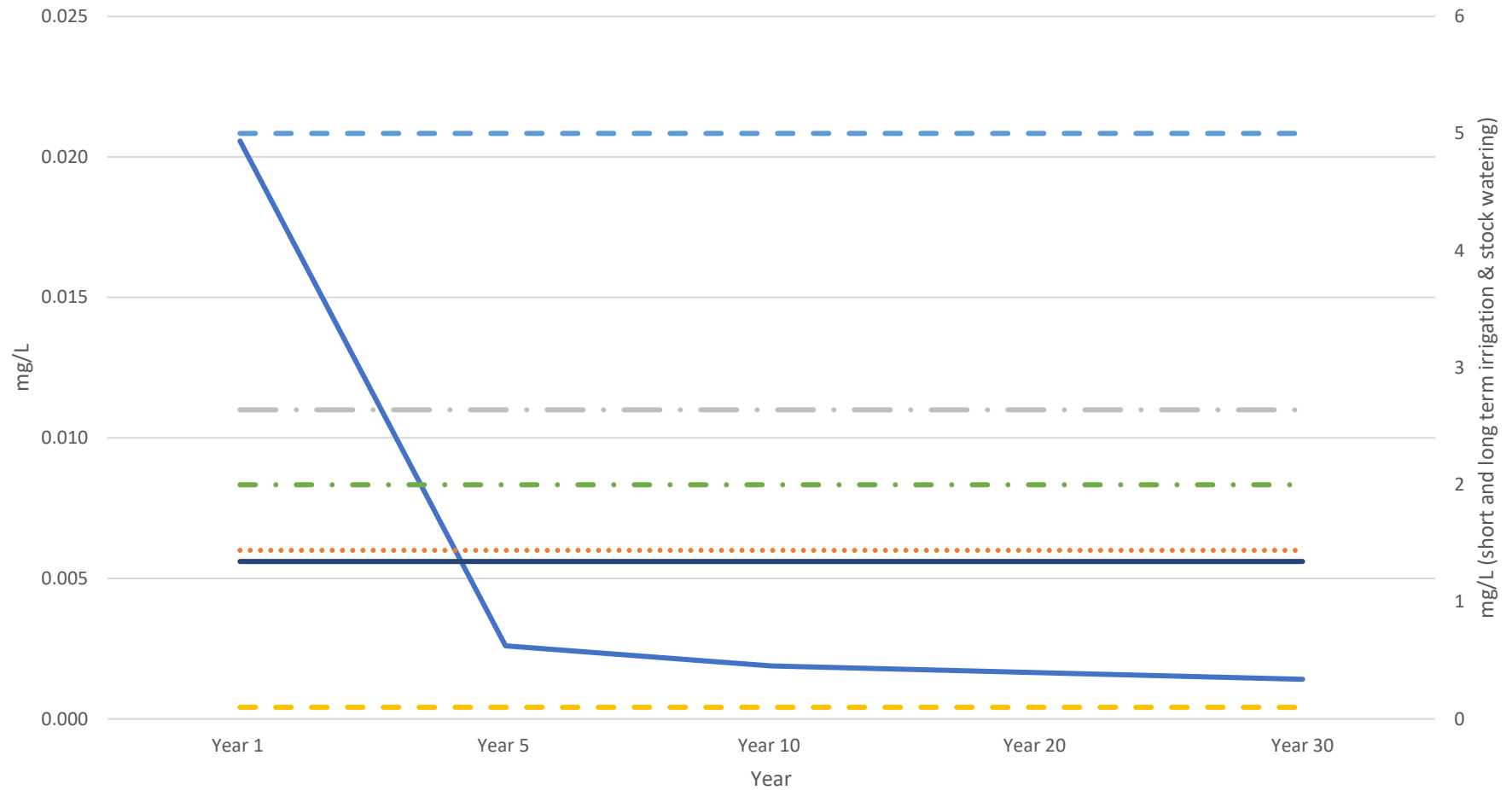
ANZG Default Freshwater 95%

Predicted Mn in Q29

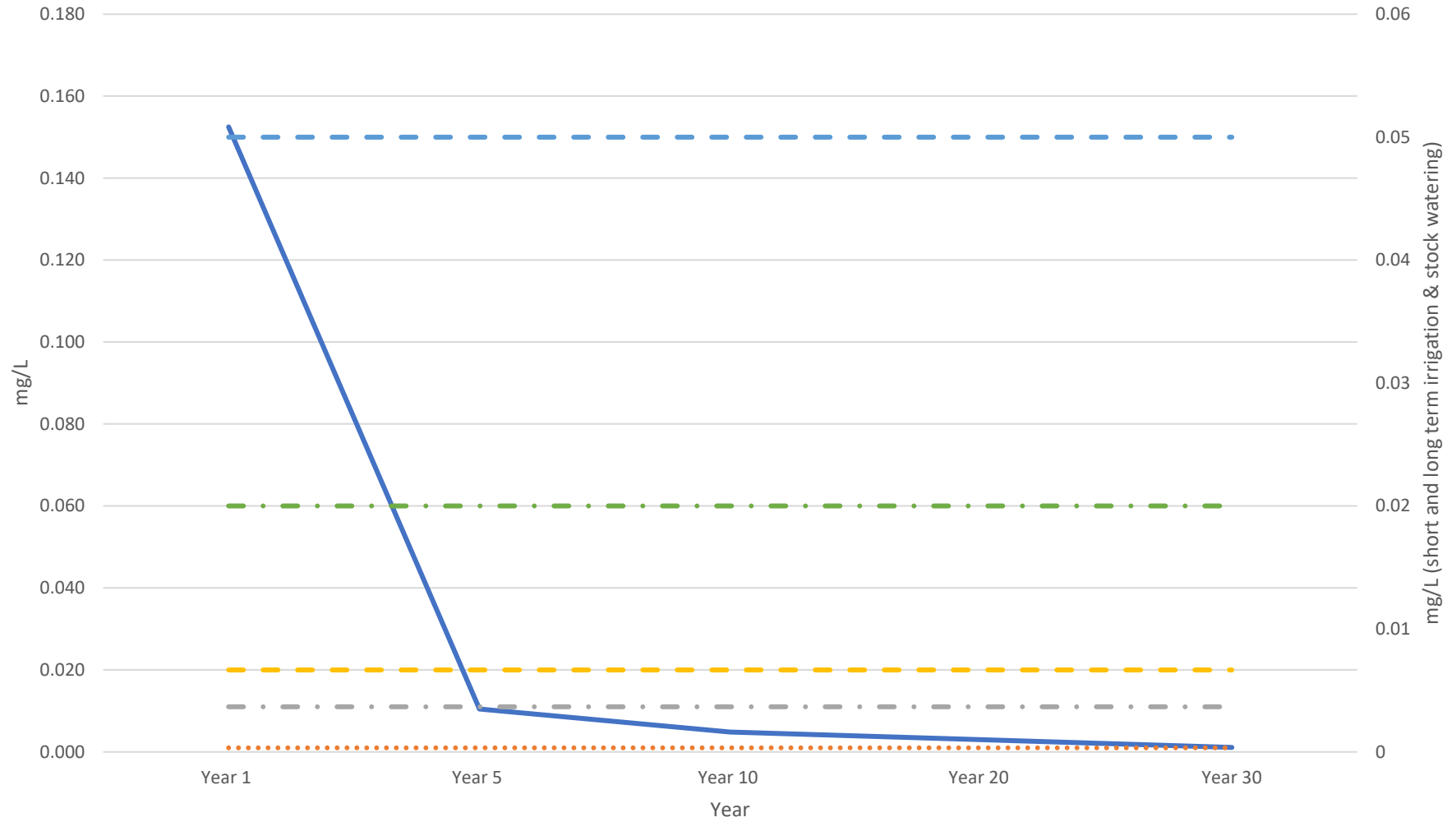




Predicted Pb in Q29



Predicted Se in Q29



Predicted Se

Stock Watering

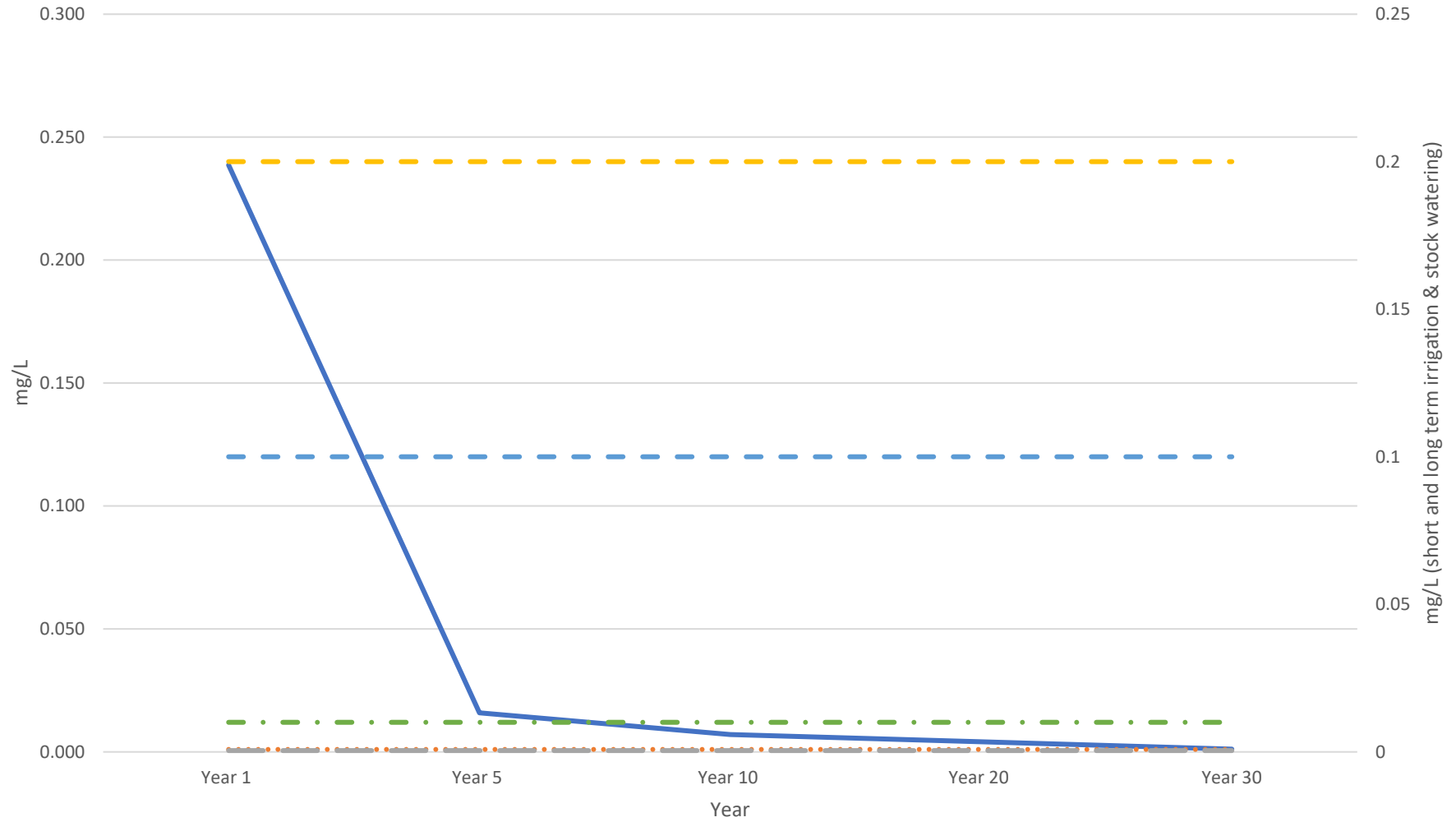
ANZECC & ARMCANZ
2000 Short-Term Irrigation Water

Ambient Groundwater

ANZG Default Freshwater 95%

ANZECC & ARMCANZ 2000 Long-Term Irrigation Water

Predicted U in Q29



Predicted U

Ambient Groundwater

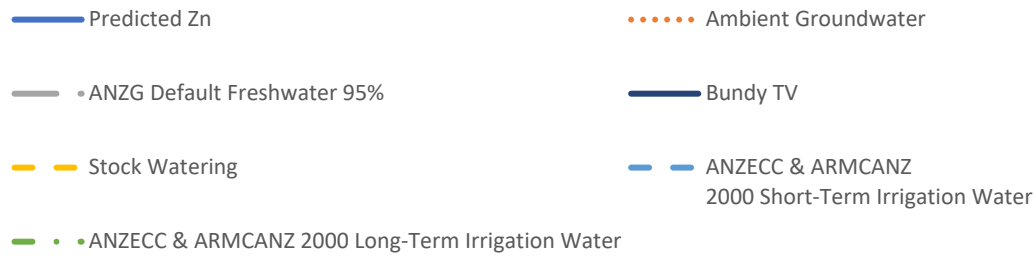
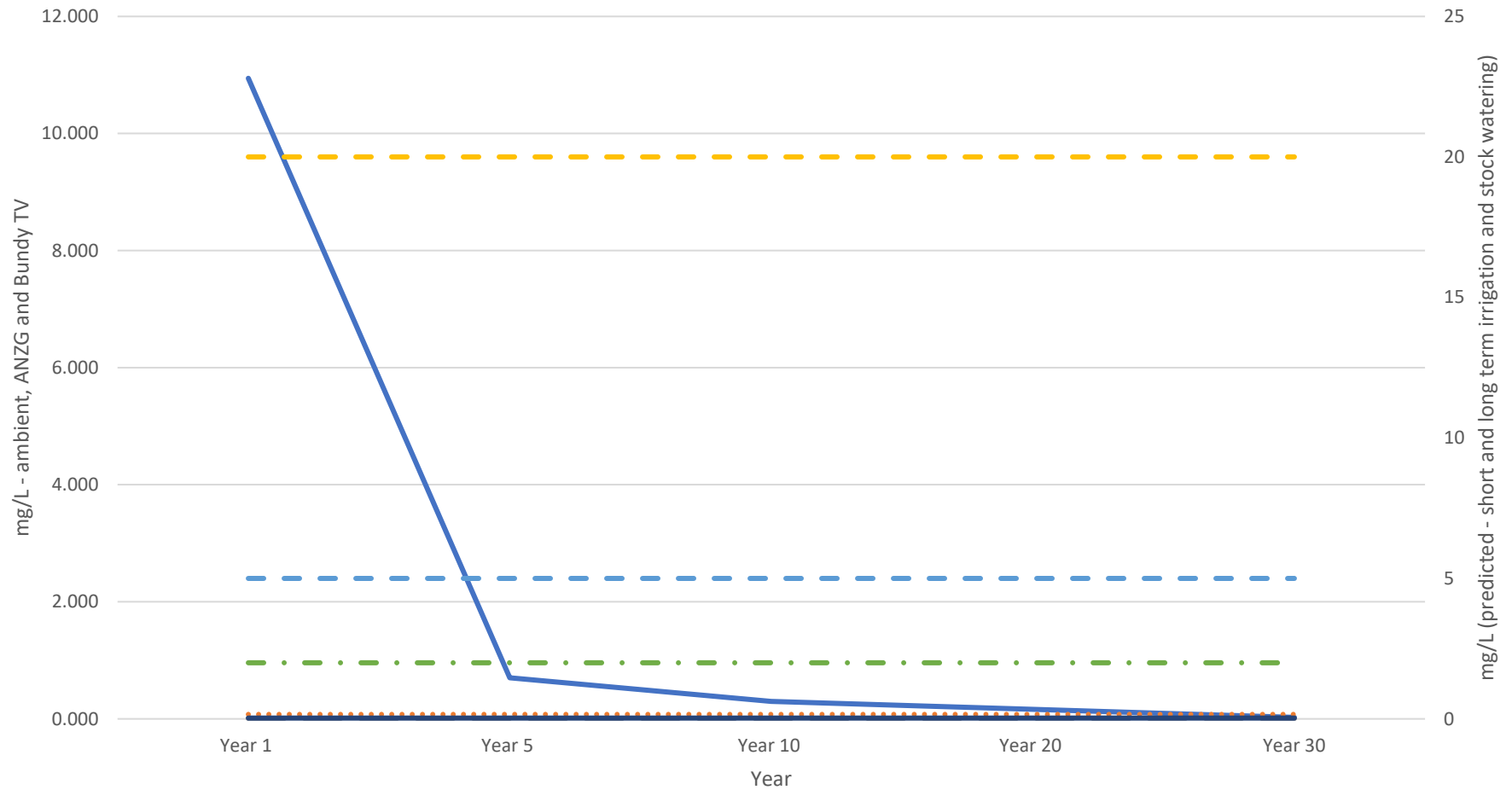
ANZG Default Freshwater 95%

Stock Watering

ANZECC & ARMCANZ
2000 Short-Term Irrigation Water

ANZECC & ARMCANZ 2000 Long-Term Irrigation Water

Predicted Zn in Q29



APPENDIX H – LIMITATIONS



STATEMENT OF LIMITATIONS & IMPORTANT INFORMATION REGARDING YOUR REPORT

INTRODUCTION

This report has been prepared by Land & Water Consulting for you, as Land & Water Consulting's client, in accordance with our agreed purpose, scope, schedule and budget.

The report has been prepared using accepted procedures and practices of the consulting profession at the time it was prepared, and the opinions, recommendations and conclusions set out in the report are made in accordance with generally accepted principles and practices of that profession.

The report is based on information gained from environmental conditions (including assessment of some or all of soil, groundwater, vapour and surface water) and supplemented by reported data of the local area and professional experience. Assessment has been scoped with consideration to industry standards, regulations, guidelines and your specific requirements, including budget and timing. The characterisation of site conditions is an interpretation of information collected during assessment, in accordance with industry practice.

This interpretation is not a complete description of all material on or in the vicinity of the site, due to the inherent variation in spatial and temporal patterns of contaminant presence and impact in the natural environment. Land & Water Consulting may have also relied on data and other information provided by you and other qualified individuals in preparing this report. Land & Water Consulting has not verified the accuracy or completeness of such data or information except as otherwise stated in the report. For these reasons the report must be regarded as interpretative, in accordance with industry standards and practice, rather than being a definitive record.

No warranty or guarantee of the site conditions is intended.

This report was prepared for the sole use of you, the Client and may not contain sufficient information for purposes of other parties or for other uses. Any reliance on this report by third parties shall be at such parties sole risk. This report shall only be presented in full and may not be used to support any other objectives than those set out in the report, except where written approval with comments are provided by Land & Water Consulting.

The report does not include the evaluation or assessment of potential geotechnical engineering constraints of the site.

LIMITATIONS OF THE REPORT

The scope of works undertaken and the report prepared to complete the assessment was in accordance with the information provided by the client and the specifications for works required under the contract. As such, works undertaken and statements made are based on those specifications (such as levels of risks and significance of any contamination) and should be considered and interpreted within this context. The analyses, evaluations, opinions and conclusions presented in this report are based on that purpose and scope, requirements, data or information, and they could change if such requirements or data are inaccurate or incomplete.

Your environmental report should not be used without reference to Land & Water Consulting in the first instance:

- When the nature of the proposed development is changed, for example if a residential development is proposed instead of a commercial one;
- When the size or configuration of the proposed development is altered;
- When the location or orientation of the proposed structures are modified;
- When there is a change in ownership;
- For application to an adjacent site.

In addition, advancements in professional practice regarding contaminated land and changes in applicable statutes and/or guidelines may affect the validity of this report. Consequently, the currency of conclusions and recommendations in this report should be verified if you propose to use this report more than 6 months after its date of issue.

ENVIRONMENTAL ASSESSMENT “FINDINGS” ARE PROFESSIONAL ESTIMATES

The information in this report is considered to be accurate with respect to conditions encountered at the site at the time of investigation and considering the inherent limitations associated with extrapolating information from a sample set. Note however that site assessment identifies actual subsurface conditions only at those specific points where samples are taken, when they are taken. Environmental data derived through sampling and analysis are interpreted by consultants who then render an opinion about overall subsurface conditions, the nature and extent of contamination and potential impacts on the use of the land. Actual conditions may differ from those inferred to exist as no professional and no subsurface assessment program can reveal every detail within the ground across a site. Subsurface conditions can vary across a particular site and no practical degree of sampling can ever eliminate the possibility that conditions may be present at a site that have not been represented through sampling.

SUBSURFACE CONDITIONS CAN CHANGE

This report is valid as of the date of preparation. The condition of the site (including subsurface conditions) and extent or nature of contamination or other environmental hazards can change over time, as a result of either natural processes or human influence. Land & Water Consulting should be kept apprised of any such events and should be consulted for further investigations if any changes are noted, particularly during construction activities where excavations often reveal subsurface conditions. Since subsurface conditions (including contamination concentrations) can change within a limited period of time and space, this inherent limitation to the representation of site conditions provided by this report should always be taken into consideration particularly if the report is used after a delay in time.

DATA SHOULD NOT BE SEPARATED FROM THE REPORT

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way. Logs, figures, laboratory data, drawings, etc. are customarily included in our reports and are developed by scientists or engineers based on their interpretation of field logs, field testing and laboratory evaluation of samples. This information should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

This report should be reproduced in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties.

RESPONSIBILITY

Environmental reporting relies on interpretation of factual information using professional judgement and opinion and has a level of uncertainty attached to it, which is much less exact than other design disciplines. As noted earlier, the recommendations and findings set out in this report should only be regarded as interpretive and should not be taken as accurate and complete information about all environmental media at all depths and locations across the site.