APPENDIX M - VOID HYDROGEOCHEMICAL MODELLING

TECHNICAL REPORT

Pit lake hydrogeochemical modelling

Isaac Downs Extension Project

Prepared for: Stanmore Resources

MINE WASTE AND
WATER MANAGEMENT

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TECHNICAL REPORT

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Table of Contents

List of Figures

List of Tables

Glossary of terms and acronyms

Acidity	A measurement of the amount of acidity in a water sample generally derived using a titration method to a set pH value (in units of mg/L $CaCO_3$ equivalent).
Alkalinity	A measurement of the amount of alkalinity in a water sample generally derived using a titration method to a set pH value (in units of mg/L $CaCO_3$ equivalent).
ABA	Acid Base Account. Evaluation of the balance between acid generation and acid neutralisation processes. Determines the maximum potential acidity (MPA) and the inherent acid neutralising capacity (ANC), as defined below.
ABCC	Acid buffering characteristic curve
AD	Acid drainage
AHD	Australian Height Datum used for altitude measurement in Australia.
AMD	Acid and metalliferous drainage from mine waste materials characterised by low pH, elevated metal concentrations, high sulfate concentrations and high salinity.
ANC	Acid Neutralising Capacity expressed as kg H_2SO_4 per tonne of sample. A measure of a sample's maximum potential ability to neutralise acid.
CCS	Consistent Climate Scenarios
CHPP	Coal handling and preparation plant
EA	Environmental Authority
EC	Electrical Conductivity, expressed as µS/cm.
Eh	Redox potential. A measure of the tendency of a chemical species to acquire or lose electrons to an electrode. Used to measure oxidising (+ve) or reducing (-ve) conditions in a saturated column.
EIS	Environmental Impact Statement.
FCCM	Fort Cooper Coal Measures
GAI	Geochemical Abundance Index
IDE	Isaac Downs Extension
IPM	Isacc Plains Mine
INAP	International Network on Acid Prevention
Interburden	The material found in between ore layers, and considered to be of low economic value (ie. a type of waste material).
IPC	Isaac Plains Complex
IPCC	Intergovernmental Panel on Climate Change
KLC	Kinetic Leach Column. Leaching setup that generates time-dependent data on the kinetics and rate of acid generation and acid neutralising reactions under laboratory controlled (or onsite conditions)
LC	Low capacity
LDWG	Livestock drinking water guidelines (ANZG, 2018)
LoR	Limit of Reporting. Laboratory detection limit for the reporting of results for a particular geochemical test.
MPA	Maximum Potential Acidity. Calculated by multiplying the total sulfur or sulfide-sulfur (CRS) content of a sample by 30.6 (stoichiometric factor) and expressed as kg H_2SO_4 per tonne.

NAF	Non-Acid Forming. Geochemical classification criterion for a sample that will not generate acid conditions.
NAG	Net acid generation
NAPP	Net Acid Producing Potential, expressed as kg H_2SO_4 per tonne. Calculated by subtracting the ANC from the MPA.
NMD	Neutral mine drainage typically caused by exposure of sulfide minerals in mine waste materials to oxygen and water and then neutralisation by gangue minerals. Typically characterised by neutral pH and elevated concentrations of salts, sulfate and metals.
Ore	Material that has been mined with sufficient value to warrant processing.
Overburden	The waste rock material found overlying the first ore horizon within the stratigraphic profile.
PAF	Potentially Acid Forming. Geochemical classification criterion for a sample that has the potential to generate acid conditions.
PMLU	Post mining land use
PRCP	Progressive rehabilitation and closure plan
pH	A measure of hydrogen ion (H^+) concentration.
QLD	Queensland
RCM	Rangal Coal Measures
S	Sulfur.
SCL	Stochastic Climate Library
SD	Saline Drainage. Water that is elevated in dissolved salts (e.g., Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, and SO_4^{2-}), but may have acidic, neutral, or alkaline pH.
SO_4^{2-}	Sulfate.
SR	Stanmore Resources Ltd
ST	Source term
Static test	Procedure for characterising the geochemical nature of a sample at a single point in time. Static tests may include measurements of mineral and chemical composition of a sample and the Acid Base Account.
TDS	Total dissolved solids is a measurement of the suspended solids concentration in a water sample.
TS	Total sulfur content of a sample generally measured using a 'LECO' analyser expressed as total sulfur%.
UC	Uncertain
WRD	Waste rock dump
w:v	Weight to volume ratio.

1 Introduction

RGS Environmental Consultants Pty Ltd (RGS) was commissioned by Stanmore Resources Ltd (Stanmore) to develop a hydrogeochemical (water quality) model for the final void/ pit lake at the Isaac Downs Extension (IDE) Project (the Project) located immediately south of the Isaac Downs Mine (IDM), and 17km south-east of Moranbah, a town in east-central Queensland (QLD).

This technical report presents the results of the hydrogeochemical modelling. The results discussed in this report are considered to be at an 'inferred' level of confidence.

An "inferred water quality model" is that part of an environmental and engineering assessment for which quantity and quality can be estimated on the basis of hydrogeological, hydrological, and geochemical 'evidence' and reasonably assumed, but not verified, from geological, geochemical and hydro-geological data. The model estimate is based on limited information and sampling gathered through appropriate standard industry practices for sampling and analysis methodology, and conformance to the Australian Groundwater Modelling Guideline.

The results of the inferred model provide an acceptable level of confidence and reliability to forecast likely future environmental outcomes. It is assumed to be suitable for environmental approval level of investigation and suitable for pre-feasibility engineering.

1.1 Purpose of report

Preparation of an environmental impact statement (EIS) is required prior to the approval of a new environmental authority (EA) and progressive rehabilitation and closure plan (PRCP) schedule for the Project. Development of an EIS includes the creation of a hydrogeochemical model of the final landform at closure of the mine (**Figure 1-1**). This is necessary to understand the water quality within the final void/ pit lake, which is intended to be used for beneficial purposes, primarily for livestock drinking supply.

The objective of this assessment is to produce a technical document estimating the chemistry of water in the IDE final void/ pit lake post closure. RGS understands this document will support the EIS for approval of the Project.

1.2 Scope of work

The general scope of work included:

- Stage 1 – Review existing water balance and hydrogeological models to see if fit for purpose and develop model specification;
- Stage 2 – Hydraulic modelling (use the existing void water balance model);
- Stage 3 – Geochemical modelling; and,
- Stage 4 – Assessment and reporting (i.e. this report).

Based on the above general scope, this report is laid out as follows:

- Section 1 – This introduction describing the Project layout, objectives of the work, and overview of the work conducted for this assessment.
- Section 2 – Describes background information relevant to the Project and this assessment.
- Section 3 – Describes the hydrogeochemical conceptual model which underpins the numerical water quality model.
- Section 4 – Describes the development of the hydrogeochemical model. For this assessment, one model was developed to estimate the water quality in the pit lake post closure.
- Section 5 – Describes the assessment criteria by which the estimated results are discussed.
- Section 6 – Discusses model assumptions and uncertainty. Considering the multiplicity of inputs the model results should be considered as order of magnitude approximations rather than deterministic characteristics of water quality.

- Section 7 – Presents the results of the hydrogeochemical model.
- Section 8 – Summarises the work, presents the key conclusions of the modelling and recommendations as required.

Supplementary information, including detailed model results, are presented in Attachments to this report.

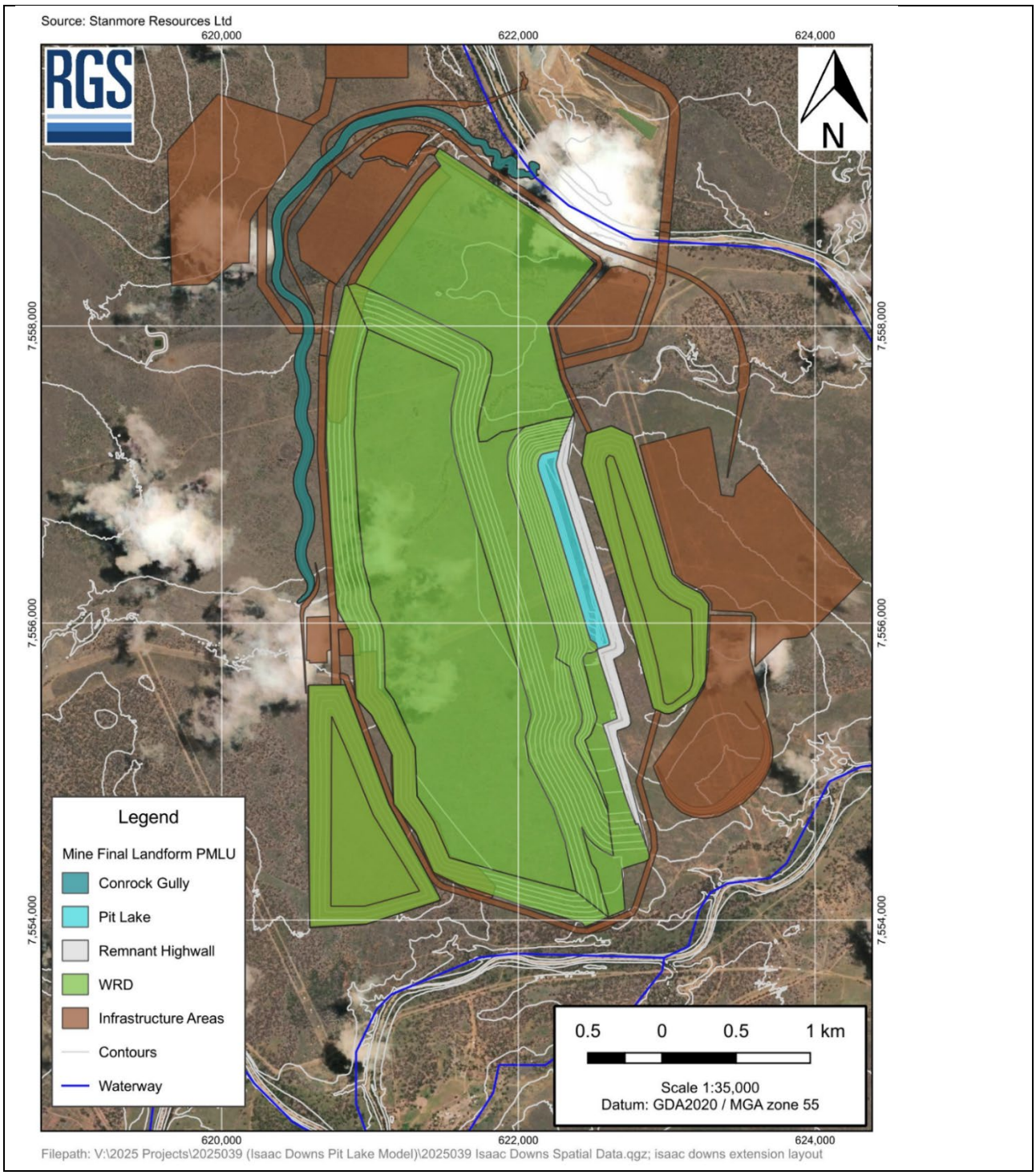


Figure 1-1: Isaac Downs Extension Project final landform PMLU

2 Project Background

2.1 Project description

The Project will be integrated into the existing Isaac Plains Complex (IPC), which comprises the Isaac Plains Mine (IPM) and Isaac Downs Mine (IDM). It will leverage established infrastructure within the IPC, including the coal handling and preparation plant (CHPP), train loading facility, rail loop, mine infrastructure area (MIA), internal haul road network, explosives magazine, and existing connections to raw water, power, and communications. Rejects and tailings generated by the Project will be managed in within existing mining dumps and voids in accordance with existing approvals for IPM (i.e. not associated with the Project landform presented in this report). Operations will be conducted within mining lease (ML) areas (the 'Project area') of 2,707 hectares, utilising the same mining methods and equipment currently employed across the IPC.

The Project will incorporate a comprehensive water management system consisting of mine water dams, sediment dams, and clean water storages to support operational and environmental requirements. Raw or external water supply will be sourced in accordance with the existing agreements with SunWater, with no requirement for additional raw water supply.

During operations, mined spoil (overburden and interburden, including minor volumes of waste coal) will be backfilled in the mined void and placed in waste rock dumps (WRDs) (**Figure 1-1**). Post-mining, the final landform will result in the formation of a final void and subsequent pit lake. The post-mining land use (PMLU) specified for the WRDs include grazing and woodland and the pit lake will be utilised for livestock drinking water. Other PMLUs being considered for the pit lake include an algae farm and pumped hydro project. The Project also includes the proposed permanent diversion of Conrock Gully and associated modifications to the local floodplain following completion of mining activities.

2.2 Geology

The Project is situated on the western limb of the northern Bowen Basin, close to the western margin of the Taroom Trough, a sedimentary basin that accumulated a substantial thickness of predominantly terrestrial sediments during the Permo –Triassic period (Terrenus, 2026).

Coal-bearing strata at the Project comprise the Late Permian Rangal Coal Measures (RCM) and the uppermost seam of the Fort Cooper Coal Measures (FCCM). These include the following seam groups, listed from youngest to oldest:

- Leichhardt Seam (RCM): L1 and L2 plies, which are collectively referred to as the Leichhardt (LHD) Seam.
- Upper Vermont Seam (RCM): V1 ply.
- Lower Vermont Seams (FCCM): V2, V31 and V32 plies (not mined).
- Girrah Seam (FCCM): G1, G2 and G3 plies (not mined).

Lithologies at the Project are typical of basin-fill sequences and include mudstone, claystone, siltstone, fine- to medium-grained sandstone, carbonaceous sediments, and coal seams. Some sandstone units contain interbedded or interlaminated siltstone. The stratigraphy also includes tuffaceous horizons, most commonly within the FCCM and to a lesser extent the RCM. The laterally extensive Yarrabee Tuff serves as a regional marker across the RCM and defines the upper boundary of the FCCM. Within the Project area, this tuff occurs between the V1 and V2 plies

The RCM is overlain by a thin cover of Quaternary- and Tertiary-aged sediments, which across the region are typically highly weathered, semi-consolidated, and composed mainly of sand, clay, and gravel.

Beneath the RCM lie the FCCM, which are lithologically similar to the RCM host rocks and consist predominantly of quartzose to lithic sandstone, siltstone, carbonaceous shale, and minor coal.

2.3 Geochemistry

In coal mining environments, fresh carbonaceous materials typically contain elevated sulfide concentrations relative to fresh non-carbonaceous units and therefore present a greater potential geochemical risk. In

contrast, non-carbonaceous lithologies generally contain little to no carbonaceous material and consequently have low or negligible sulfide content. An important exception occurs where non-carbonaceous units are located within, or immediately adjacent to (approximately within 0.5 m above or below), coal seams, as these materials commonly exhibit higher sulfide concentrations than overburden or interburden located further from coal horizons (Terrenus, 2026).

The Project will generate three main types of mineral waste:

- Spoil
- Tailings
- Rejects

However, only spoil (overburden and interburden, including minor volumes of waste coal) will be disposed at the Project. Spoil at the Project is expected to be composed of:

- 95% non-carbonaceous material, and
- 5% as carbonaceous material, with almost all the carbonaceous spoil being unweathered.

Coal is generally not considered mineral waste, except for small quantities of sub-economical seams that may report to the spoil dumps, and coal exposed on the pit highwalls of the residual void. Terrenus (2026) developed a geochemical assessment of potential spoil and coal samples with regard to their potential to generate acid and metalliferous drainage (AMD). AMD includes acid drainage (AD), neutral and metalliferous drainage (NMD), and/ or saline drainage (SD).

2.3.1 Static geochemistry

To characterise the spoil (266 samples) and coal's (38 samples) potential to generate AMD, static tests were undertaken by Terrenus (2026), including:

- Total sulfur (TS) and chromium reducible sulfur (S_{CR});
- Acid neutralising capacity (ANC) and acid buffering characterisation curve (ABCC);
- Net acid generation (NAG);
- Total metals and metalloids analysis; and,
- Soluble multielement analysis.

A summary of the geochemical characteristics of the spoil and coal from the Terrenus (2026) investigation is provided below:

Spoil:

- Expected to generate pH-alkaline to highly alkaline contact.
- Non-carbonaceous spoil has a very low potential to generate AMD.
- Carbonaceous spoil, has a slightly higher AMD source hazard potential than non-carbonaceous spoil.
- The TS concentration of the spoil is very low, with a 95th percentile TS concentration of 0.14%.
- ANC values were moderate to moderate-high with a median of 28 kilograms (kg) H_2SO_4/tonne (t). In contrast, the median maximum potential acidity (MPA) was 0.6 kg H_2SO_4/t.
- Approximately 98% of samples were classified as non-acid forming (NAF) or uncertain NAF (UC(NAF)). Less than two percent of samples were classified as potentially acid forming (PAF), PAF low capacity (PAF-LC) or uncertain PAF (UC PAF).
- ANC for the spoil is generally expected to be about 37% to 67% available (median of 48%), with ferrous dolomite being the main carbonate mineral likely contributing to the acid buffering potential of the spoil.
- Total metals and metalloid analysis suggest that no spoil samples were significantly enriched according to the geochemical abundance index (GAI).

- Soluble multi-element results indicate that spoil leachate is expected to contain generally low concentrations of soluble metals and metalloids. For many spoil samples, particularly weathered, the concentrations of most of the elements of potential environmental interest was below or marginally above the laboratory limit of reporting.

Coal:

- Expected to generate pH-alkaline to highly alkaline contact.
- Coal has a low-moderate potential to generate AMD.
- The TS concentration of the spoil is very low, with a 95th percentile TS concentration of 0.32%. Approximately 11% of TS is present as sulfide (S_{CR}), with the bulk of the TS likely present as organic sulfur, which does not contribute to acid drainage.
- ANC values were moderate to moderate-high with a median of 23 kg H_2SO_4/t. In contrast, the median MPA was 8.6 kg H_2SO_4/t.
- Approximately 79% of samples were classified as NAF or UC(NAF). The remaining 21% of coal samples were mostly classified as UC(PAF), with one coal sample classified as PAF-LC.
- Results suggest that sub-economical coal seems reporting to spoil dumps, mixed with non-coal spoil, would pose a low-moderate AMD risk.
- Total metals and metalloid analysis suggest that no coal samples were significantly enriched according to the GAI.
- Soluble multi-element results indicate that coal leachate is expected to contain low concentrations of soluble metals and metalloids. For most coal samples, the concentrations of most of the elements of potential environmental interest was below or marginally above the laboratory limit of reporting.

2.3.2 Kinetic geochemical testing

The kinetic leach column (KLC) composite samples were created based on the site location and material type of the samples (**Table 2-1**). The KLC tests were operated under both saturated and unsaturated (free leaching) conditions (**Figure 2-1**). The primary objectives of the KLC test program were to quantify the concentration and rate at which weathering products (acid, soluble salts and metals and metalloids) are leached from the solid phase materials (carbonaceous and non-carbonaceous spoil) over time, under free leaching unsaturated ('wet-dry') versus saturated conditions. The columns were leached weekly for the first five leaches (to remove readily soluble weathering products) and then monthly thereafter. Filtered leachates were analysed for key parameters and metals and metalloids according to **Table 2-2**. The KLC program will run for at least 6-months and is up to week 16 at the time of reporting.

Table 2-1: Summary of KLC sample materials, leach types, material sources, and material classifications

KLC ID	Material	Leach Type	Material Source	Material Classification	Number weeks operated*
KLC 1	Non-carbonaceous Spoil	Saturated	Mixed lithologies	NAF	16
KLC 2	Non-Carbonaceous Spoil	Free leach	Mixed lithologies	NAF	16
KLC 3	Carbonaceous Spoil	Free leach	Mixed lithologies	NAF/ Uncertain	16

*Note: only results up to week 12 were available at the time of modelling and used in the assessment.

Table 2-2: Kinetic testing leachate analysis suite-

Analytes	Laboratory Analysis
Key parameters	pH/ EC and acidity/ alkalinity
Major Ions	Calcium (Ca), Potassium (K), Magnesium (Mg), Sodium (Na), Chloride (Cl), Fluoride (F), Sulfate (SO_4^{2-})
Metals/ metalloids	Aluminium (Al), Arsenic (As), Boron (B), Barium (Ba), Beryllium (Be), Bismuth (Bi), Cadmium (Cd), Cerium (Ce), Caesium (Cs), Cobalt (Co), Chromium (Cr), Copper (Cu), Dysprosium (Dy), Erbium (Er), Europium (Eu), Gadolinium (Gd), Gallium (Ga), Hafnium (Hf), Holmium (Ho), Indium (In), Lanthanum (La), Lithium (Li), Lutetium (Lu), Iron (Fe), Mercury (Hg), Manganese (Mn), Molybdenum (Mo), Neodymium (Nd), Nickel (Ni), Praseodymium (Pr), Lead (Pb), Antimony (Sb), Rubidium (Rb), Samarium (Sm), Selenium (Se), Silver (Ag), Strontium (Sr), Tellurium (Te), Terbium (Tb), Thallium (Tl), Thorium (Th), Thulium (Tm), Titanium (Ti), Tin (Sn), Uranium (U), Vanadium (V), Ytterbium (Yb), Yttrium (Y), Zinc (Zn), Zirconium (Zr).

Figure 2-1: Kinetic leach column (KLC) tests for IDE at RGS Laboratory.

The pH values of the leachate in all KLCs appears to be relatively stable, increasing slightly over time (**Figure 2-2**). KLC 3 (free leach, carbonaceous) generally has the highest pH values at any given leach, followed by KLC 2 (free leach, non-carbonaceous) and KLC 1 (saturated, non-carbonaceous).

The electrical conductivity (EC) values of the leachate in all KLCs appears to be increasing, following an initial decline related to the 'first flush' (**Figure 2-2**). KLC 2 (free leach, non-carbonaceous) generally has the highest pH values at any given leach, followed by KLC 3 (free leach, carbonaceous) and KLC 1 (saturated, non-carbonaceous).

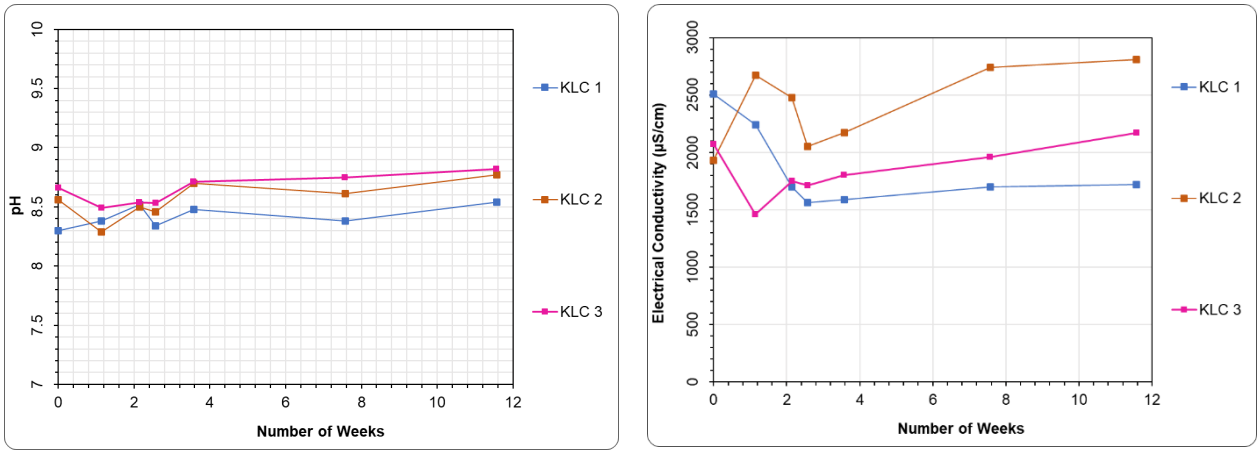


Figure 2-2: KLC pH and EC versus time (weeks) plot

The key findings from the KLC testing are summarised below:

- Saturated sample materials transitioned from oxidising to reducing conditions over time.
- Across all materials, initial high salinity values and major ion concentrations and high loading rates seen in the leachates are likely due to the initial first flush of readily solubilised reaction products resulting in elevated dissolved concentrations.
- Consistent with the static geochemical testing undertaken by Terrenus (2025), most materials are expected to generate alkaline drainage.
- The pH of drainage from mine materials is expected to increase as the pit lake fills, materials become saturated, and the oxidation of materials slows or stops. With an increase in pH, leached metals and metalloids typically decrease.
- Drainage from most materials is expected to have low dissolved acidity and relatively high alkalinity.
- Initial drainage from spoil materials may contain concentrations of soluble molybdenum, selenium and fluorine, that are elevated relative to the Livestock Drinking Water guideline values (ANZG, 2018) (see discussion in Section 7.3 and **Figure 2-3**); however, concentrations of these elements in solution are expected to decrease over time.
- Leached selenium under oxidising (free-leach) conditions (KLC 2 and KLC 3) is more elevated than for the saturated column (KLC 1) since selenium is relatively immobile under reducing conditions.
- Increase in sulfate, calcium, magnesium, sodium, relatively constant pH, and decreasing chloride concentration suggest there is long-term dissolution of sulfate salts.

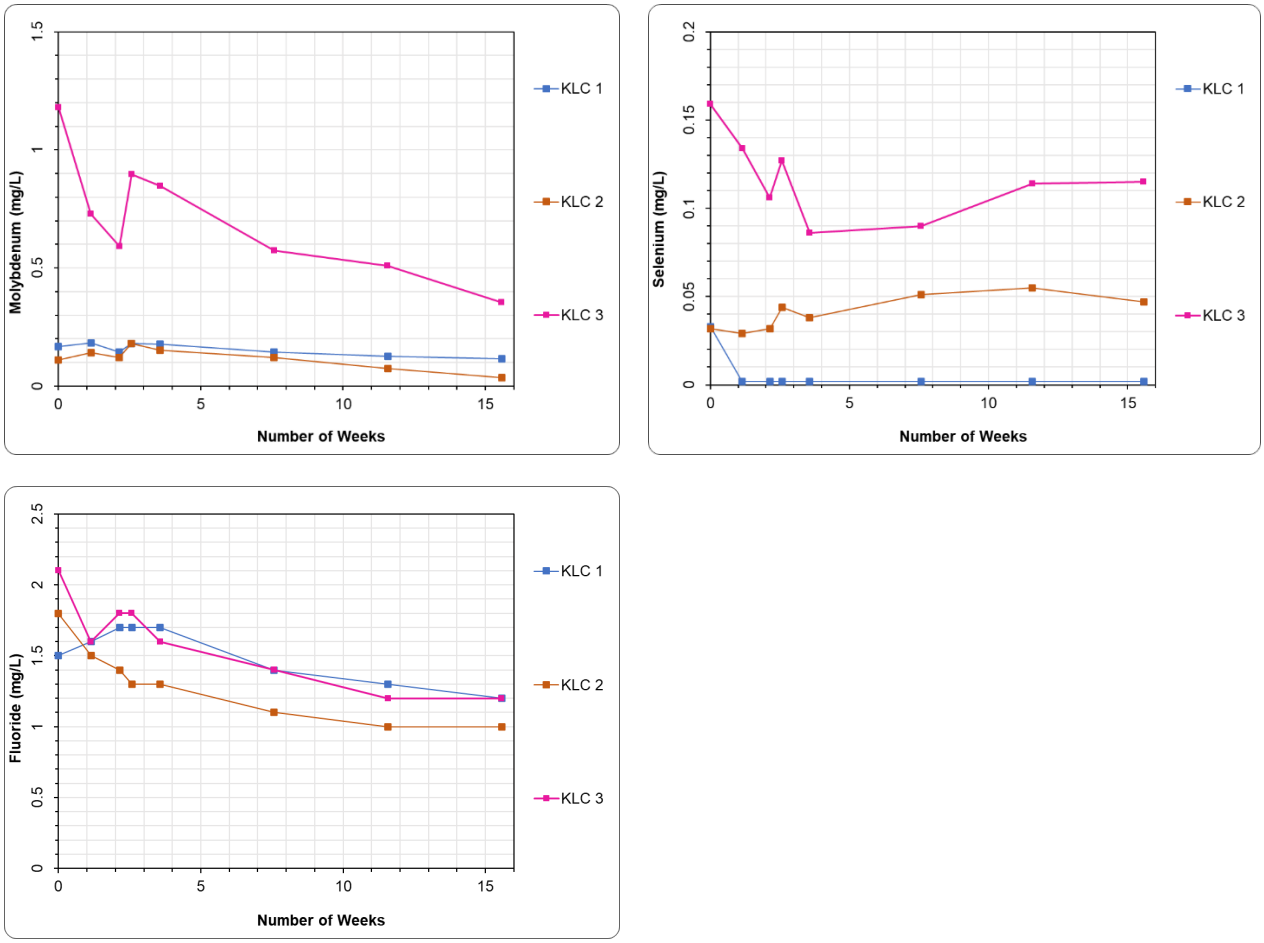


Figure 2-3: KLC Mo and Se concertation (mg/L) versus time (weeks) plot

3 Hydrogeochemical conceptual model

Conceptual models are the foundation for numerical models by providing a simplified representation of the key physical and chemical processes governing a real-world system. Conceptual models integrate available data, expert knowledge, and assumptions to define system boundaries, key variables, and interactions. This section describes the conceptual framework for the hydrogeochemical model of the post-closure Project mined void/ pit lake.

A summary of the key components of the conceptual model is provided below and in **Figure 3-1**.

- Runoff into the pit lake/ void from:
  - the backfilled spoil surfaces (A),
  - rehabilitated surfaces on the waste rock dumps (L), and,
  - natural runoff (M).
- Infiltration and seepage from:
  - the spoil baseflow above the water table (B),
  - spoil to pit lake/ void (C)
  - spoil to groundwater (D) and groundwater to spoil (E),
  - pit lake/ void to spoil (I),
  - groundwater to pit lake/void (J),
  - pit lake/ void to groundwater (K).
- Direct rainfall (G)
- Evaporation (F)
- Water extraction for beneficial use (H)

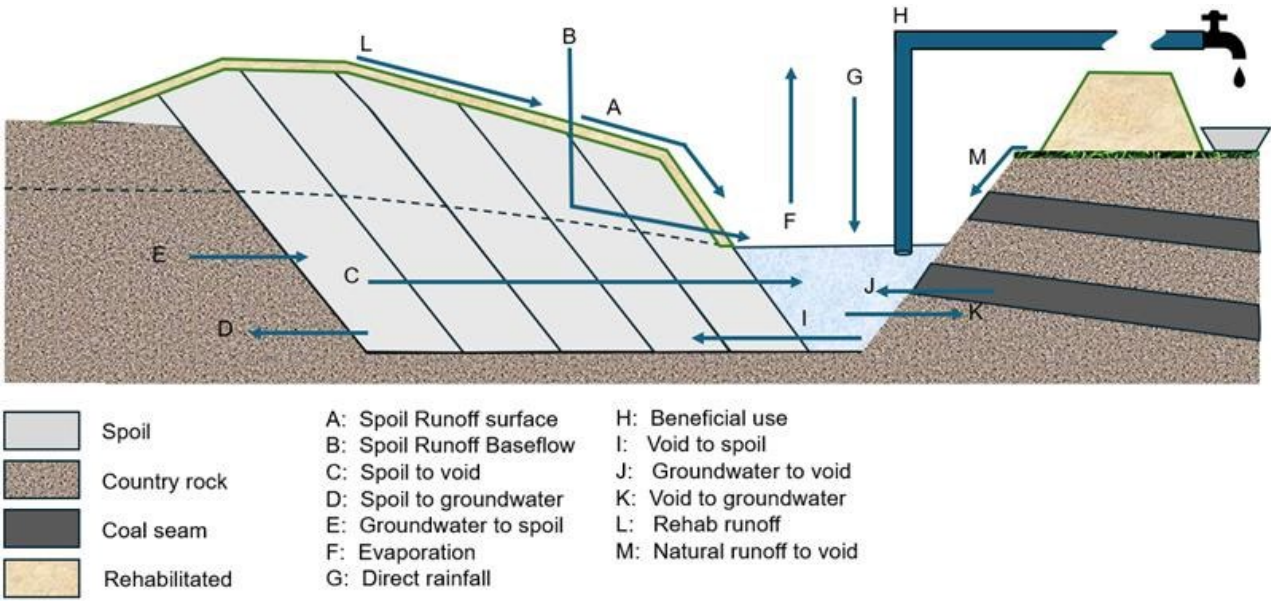


Figure 3-1: Conceptual diagram of the post-closure phase of the Project hydrogeochemical model

3.1 Hydrological impact on pit lake quality

The water quality of the pit lake is a result of many factors including but not limited to geology and minerology of the host formations, surface water and groundwater quality entering the mined void/ pit lake, concentrating effects of evaporation (evapoconcentration), geochemical, biological, and limnological processes with the pit lake and anthropogenic impacts. The key water quality inputs to the final void/ pit lake are summarised in **Figure 3-1**.

The hydrology of the pit lake affects the water quality of the pit lake by changing the chemical mass balance associated with the pit lake.

General statements regarding the impacts of hydrological processes on water quality can be made and these are applicable to Project:

- Groundwater inflows carry dissolved constituents at background concentrations into the lake. Natural, upgradient groundwater will have a certain water quality and will contribute to the lake quality. Inflowing groundwater can also pick-up constituents from weathered coal immediately surrounding the mine void or from recharging meteoric water passing through the dewatered zone.
- Surface water runoff from pit walls and local catchment may transport constituents and sediments that will affect the chemistry of the lake.
- Backfilled spoil seepage (and throughflow) and runoff may carry dissolved constituents into the pit lake.
- Direct precipitation generally is a diluting factor on pit lake water quality.
- Since evaporation removes water and leaves behind any dissolved constituents, evaporation tends to have a concentrating effect on pit lake water quality.
- Groundwater outflows from the pit lake typically have the effect of removing constituents from the pit lake, noting that the pit lake is predicted to be a groundwater sink (SLR, 2026). Given the shallow nature of the pit lake, density stratification is not expected to occur.
- Removal of 30 ML/year of water from the pit lake for beneficial use (stock drinking water) is likely to results in an overall improvement of water quality over time.

3.2 Lake – groundwater interaction

Mining will lower the standing groundwater table through dewatering thereby increasing the extent of the unsaturated (vadose) zone, moving (generally) laterally down through the coal seams in a broad cone of depression. As the groundwater table dropped in response to dewatering air maybe drawn into the coal and this may lead to the (partial) oxidation of the coal, including oxidation of sulfide minerals that may be present within the coal seam (refer to **Section 2.3**). The extent of oxidation and weathering of coal in the cone of depression is uncertain and it is possible that the pore voids in the vadose zone may be dominated by either oxygen or nitrogen.

The mining process will result in removal and placement of spoil (overburden and interburden, including minor volumes of waste coal) within the mined void and WRDs. When the dewatering ceases and the groundwater level rebounds, the rebound could occur ahead, in equilibrium, or lag behind the pit lake level. In each of these situations the soluble weathering products in the pore voids in the vadose zone and backfilled spoil may be leached out and mobilised to the pit lake or to groundwater.

Groundwater will seep to pit lakes through permeable units exposed in the pit walls (referred to herein as upgradient ‘Country Rock’ (non-coal) and highwall inflows (combined coal and non-coal)). A groundwater quality database is available for each of the aquifer systems (provided by SLR Consulting) potentially contributing groundwater flux into the mined void (or backfilled spoil)/ pit lake and impacting pit lake water quality composition; this has been used to develop geochemical source terms for groundwater inflow.

The conceptual groundwater model extends beyond the extent of the pit shell and this has been developed by other consultants (SRL, 2026).

3.3 Surface water inflows

After closure, there will be various potential surface water inflows to the mined void that will create a pit lake. Each inflow will need to be accounted for within the numerical model. The conceptual model identified the key surface water flows into the mined void as:

- Runoff from rehabilitated surfaces (e.g. rehabilitated WRD).
- Runoff and seepage from backfilled spoil.

- Direct rainfall onto the mined void/ pit lake surface.
- Highly localised runoff from catchment within the high wall bund (various land use types).
- Potential contribution from external sources (e.g. Eungella Burdekin pipeline).

3.4 Backfilled spoil contact water

During rainfall events, runoff will occur from the backfilled spoil and enter the mined void/ pit lake. A proportion of the direct rainfall (on the backfilled spoil surface) will infiltrate into and percolate through the backfilled spoil, mix with spoil porewater/ groundwater, eventually entering the pit lake as a potentially saline seep, or potentially containing elevated metals/ metalloids. The amount of runoff versus seepage will be dependent on the closure strategy for the final landform (e.g. rehabilitation, compaction, etc.)..

The following conditions would be expected once a pit lake is formed;

- A portion of the backfilled spoil dumps will be submerged (saturated); however, the majority will remain unsaturated.
- Runoff and seepage will be the predominant hydrogeological processes affecting the pit lakes (as opposed to diffusion).
- Groundwater flow towards the mined void would be expected with aquifer rebound (SRL, 2026).
- Oxidation of sulfides and the mobility of some metals/ metalloids within the saturated base of the backfilled spoil would be constrained by water saturation and reduced oxygen availability.

3.5 Biological processes

Biogeochemical reactions can affect pit lake water quality. Microbial processes can influence the redox conditions present in the pit lake. Concentrations of dissolved metals/ metalloids can be impacted by the precipitation of sulfide minerals and uptake of dissolved metals/ metalloids by microorganisms. Microbial processes can also be responsible for the removal of organic carbon from the pit lake water.

Biological reactions such as photosynthesis and respiration can alter the concentration of dissolved CO_2 and O_2 in the pit lake waters. Stratification in the pit lake can result in the depletion of O_2 at the base of the pit lake, which will affect any organisms present.

Studying the microbial communities in pit lakes is an important part of understanding element cycling. Element cycling occurs from chemical, geological, and biological factors. Microbes can increase chemical reaction rates and water-rock interactions by metabolising both organic and inorganic components in a system. In effect, these interactions affect the speciation of elements in an environment, which can lead to either an increase or reduction of dissolved metals in water. In mine waters, microbes can act as catalysts in redox reactions, alter mineral compositions, sequester or release toxic metals, and change net pH as a product of their metabolism.

The chemical, physical and biological processes that contribute to the production and neutralisation of acid and the presence of salts and metals/metalloids particularly in anoxic and reducing water in the pit lake are extremely complex and not included in this investigation.

4 Model Development

A numerical hydrogeochemical model of the Project's pit system was developed to assess the potential water quality of the pit lake post closure.

4.1 Model objectives

The modelling objective is to estimate the pit lake water quality over a 500-year period post closure.

4.2 Model software

These models were ensemble models, that is models composed of several separate models. These separate models included water balance and water quality components developed using GoldSim (HydroBalance, 2026), Excel and PHREEQC (Parkhurst & Appelo, 2013) software. Furthermore, the groundwater inflows contributing to the water balance was modelled by others and provided to HydroBalance for inclusion in the water balance model (HydroBalance, 2026 and SLR, 2026).

The post closure hydrogeochemical model consisted of:

- A GoldSim model was used to simulate the generation, movement, and loss of water on a daily time-step within the final void, over a 500-year period. The volume of water in the void was calculated at each time step as the sum of direct rainfall to the void surface, catchment runoff, and groundwater flux, less evaporation losses. The model also tracks the quantity of salt captured and stored within the system. The water balance component of the modelling was undertaken by others (HydroBalance, 2026) and used as received in the RGS water quality model.
- An Excel spreadsheet to calculate the post-closure water balance. Noting the HydroBalance water balance was annualised (from daily time steps) so that it could be use in the RGS water quality model.
- A PHREEQC mixing model to simulate geochemical processes and estimate the water quality leaving the backfilled void. PHREEQC COM module (Version 3.8.6.17100, 2 January 2025) was used to conduct the geochemical modelling applying the minteq.v4.dat thermodynamic database (included in the installation).

4.3 Modelling scenario

The base case modelling scenario assumes the mined void is empty (near empty) at the start of the modelling period (post closure) and fills as a result of natural processes and the final landform shape (i.e. direct precipitation, rainfall runoff directed to the mined void and rebounding groundwater inflows).

4.4 Water balance

As mentioned above, the water balance component of the modelling was undertaken by HydroBalance (2026) and provided to RGS.

The GoldSim software platform was used to:

- Simulate the long-term water level behaviour for the void. Water levels in the residual void would vary over time, depending on the prevailing climatic conditions, and the balance between evaporation losses and inflows from rainfall, surface runoff, and groundwater.
- Simulate the generation, movement, and loss of water on a daily time-step within the final void, over a 500-year period. The volume of water in the voids was calculated at each time step as the sum of direct rainfall to the void surface, catchment runoff, and groundwater flux, less evaporation losses. The model also tracks the quantity of salt captured and stored within the system.
- Develop a dynamic water balance model to simulate the long-term behaviour of water levels within the mined void/ pit lake. The modelling considered a 500-year period with a daily time step, allowing for detailed representation of temporal variability. Water levels within the void are influenced by climatic conditions, particularly the balance between inflows and evaporation, making the system highly sensitive to changes in weather patterns over time (refer to **Section 4.4.1**).

The model represents the void as a control volume in which water storage is updated at each time step based on key hydrological fluxes. Inflows to the system include direct rainfall onto the void surface, surface runoff from the surrounding catchment, and groundwater exchange (i.e. from the highwall and through the backfilled spoil). These inputs are offset by evaporation losses, which form the primary outflow from the system. As a result, water levels fluctuate dynamically depending on the net water balance at any given time.

At each daily time step, the model calculates the total volume of water in the void by summing all inflows and subtracting evaporation losses. This iterative approach enables simulation of long-term trends and variability in water storage under changing climatic conditions.

In addition to water balance processes, the model also tracks salt mass within the system. This allows for assessment of salt accumulation and storage in the void over time, providing a 'cross check' for modelled water qualities estimated from the water quality model.

Key components of the model are described in HydroBalance (2026).

4.4.1 Climate change and variability

The water balance model adopted the approach to addressing climate change and climate variability as follows.

Climate-adjusted rainfall and evaporation data were generated using the Australian Government's Consistent Climate Scenarios (CCS) project. This approach involved transforming historical climate records spanning 1960 to 2024 (64 years) into future climate projections. The CCS dataset provides daily time series outputs across Australia on a 0.05-degree spatial grid, with the grid cell nearest to the project centroid selected for this assessment.

The climate projections were based on the Shared Socioeconomic Pathway SSP2-8.5, aligned with the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). A baseline global warming sensitivity for the year 2050 was adopted, as this timeframe is considered representative of the anticipated commencement of the final void/ pit lake.

SSP2-8.5 reflects a "middle-of-the-road" socio-economic development trajectory combined with very high greenhouse gas emissions, corresponding to a high radiative forcing scenario of 8.5 W/m² by 2100. Although it is not regarded as the most likely future pathway, it represents a high-end climate risk scenario and is useful for evaluating system sensitivity under extreme warming conditions and assessing potential upper-bound impacts.

The climate inputs applied in the water balance model were selected based on defined climate sensitivity and model ensemble criteria. A medium climate warming sensitivity was adopted, and the representative future climate grouping was defined as HP, corresponding to a high global warming scenario.

Using the 64-year record of climate-adjusted rainfall and evaporation, a stochastic dataset extending over 500 years was developed with the Stochastic Climate Library (SCL), part of the eWater CRC catchment modelling suite. The SCL was used to generate 500 independent replicates of 500-year rainfall and evaporation sequences for input into the model. This approach produces 500 realisations of model outputs, capturing the variability inherent in the historical climate record from 1960 to 2024. RGS utilised a single realisation (R#39) for the water quality assessment.

To better represent evapotranspiration processes, pan evaporation data were converted to Morton's Lake (mLake) and Morton's Wet (mWet) evaporation estimates. A conversion factor of 0.894 was applied to represent evaporation from the pit lake surface (mLake), while a factor of 0.850 was used to estimate evapotranspiration losses from the surrounding catchment (mWet).

4.5 Water quality components of model

4.5.1 Assessment period

The water quality model was developed on an annual time-step to run for a period of 500 years, starting post closure. i.e. the water quality model is based on annualised outputs derived from the daily time-step water balance model.

It should be noted that the longer the model simulation period, the greater the bounds of uncertainty in the modelled water balance and water quality results that are likely to be observed. For example:

- the inherent uncertainty of some of the key input parameters such as climate, hydrology and chemistry. When the model run time is extended, these uncertainties are magnified.
- the uncertainty in groundwater inflows especially as related to changes to climate and recharge rates and possible climate induced changes to local and regional water use, as well as possible changes to demand are not currently known.
- uncertainty in chemistry and reactions e.g. precipitation of materials as concentration increases which may be compounded with modelled time.
- uncertainty in micro(biological) processes.

Water quality inputs use a conservative approach, and the limitations and uncertainty are provided in **Section 6**.

4.5.2 Model structure and process

The model simulates water quality as the mined void fills and forms a pit lake. Each contributing input to the void is assigned a water quality source term (ST) based on available monitoring or laboratory data (**Section 4.5.3**). Each input volume is calculated for each (yearly) timestep from the water-balance. These volumes are then converted to proportions of overall contributions and the resulting mixture modelled for 500-years using PHREEQC.

The mined void/ pit lake and water retained within the backfilled spoil material are considered two connected "reservoirs" for the purpose of modelling (**Figure 4-2**). This means that water quality is modelled for each reservoir for each annual timestep. The water quality evolves in these reservoirs as water moves between them and other interactions occur (e.g, rainfall infiltration).

PHREEQC is used to calculate equilibrated solutions including total dissolved constituents, pH, and alkalinity via mixing. Evaporation and charge balance as well as mineralogical controls are incorporated. The model outputs water quality for the pit lake at each time step.

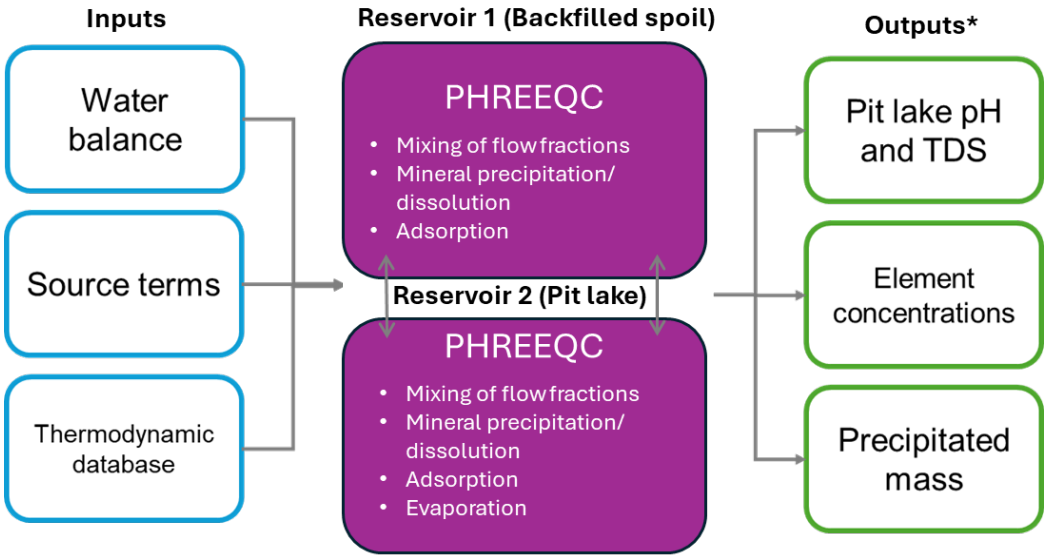


Figure 4-1: Geochemical model workflow (left to right). *Note: backfilled spoil water quality evolution can also be output if required.

For each year of the simulation period the model calculated:

- Cumulative mixing of relevant water balance inflows (**Section 4.4**), as represented by their respective source terms (**Section 4.5.3**), for both the backfilled spoil (Reservoir 1) and pit lake (Reservoir 2).

- Concentration of pit lake water by removal of pure water, representing evapoconcentration according to the relevant water balance.
- Geochemical speciation modelling of the mixed, evapoconcentrated water to account for geochemical processes including:
  - Equilibration with atmospheric CO_2 (and to a limited extent O_2).
  - Precipitation of secondary minerals, principally iron and aluminium (oxy)hydroxides (represented by Ferrihydrite and Gibbsite).
  - Adsorption of dissolved metals and metalloids on precipitated iron (oxy)hydroxides.

Model results (after mixture of source terms, mineral precipitation/dilution, and addition of backfill solute mass) had charge balance error less than 10%, which was considered acceptable for this first-order approximation of water quality.

The *minteq.v4.dat* database was used for thermodynamic calculations. This database includes most trace elements of potential environmental concern and is widely used in environmental modelling. The database is suitable for solutions with an ionic strength up to about 0.5 molal (sea water is about 0.7 molal).

The model included calculation of mineral saturation indices (SI). SI > 0 indicates that precipitation of the mineral from solution is thermodynamically possible. Published literature (e.g. Eary 1999) indicates that a range of mineral phases are known or likely to form under near-surface environmental conditions. These were designated as “equilibrium phases” in the PHREEQC model, indicating that the solutes making up these minerals would be removed from the pit void solution (precipitated) or added (dissolved, if present) as determined from calculated SIs. Initial conditions were set with no mineral mass present in the system.

Adsorption of aqueous chemical species to hydrous ferric oxides (as represented by the mineral ferrihydrite) was modelled using a diffuse double layer surface complexation model (Dzombak & Morel, 1990) included with PHREEQC.

Carbon dioxide partial pressure (pCO2) was set as -3.5 corresponding to a standard used value. Gaseous oxygen was allowed to interact with the pit lake system to assign redox potentials relevant to the conditions (pe[1] = 7 for pit lakes and pe = 0 for backfill pore water). These redox potentials are generally aligned with empirical measurements of aqueous environmental systems (Baas Becking et al., 1960).

The model was built in a Microsoft Excel spreadsheet. PHREEQC requires a text file for model inputs which are defined using keywords and associated parameters (called a “keyword block”). The keyword blocks required for the model were combined as text in the spreadsheet. VBA code was used to develop a PHREEQC input file from combined text, run the file by accessing the iPhreeqcCOM module, and save the output into a separate tab of the same spreadsheet. The output data were processed using a combination of Excel formulas and Python code. An example of the process is shown schematically in **Figure 4-3**.

[1] The redox potential stands for the negative log of electron activity (pe = -log{e-}).

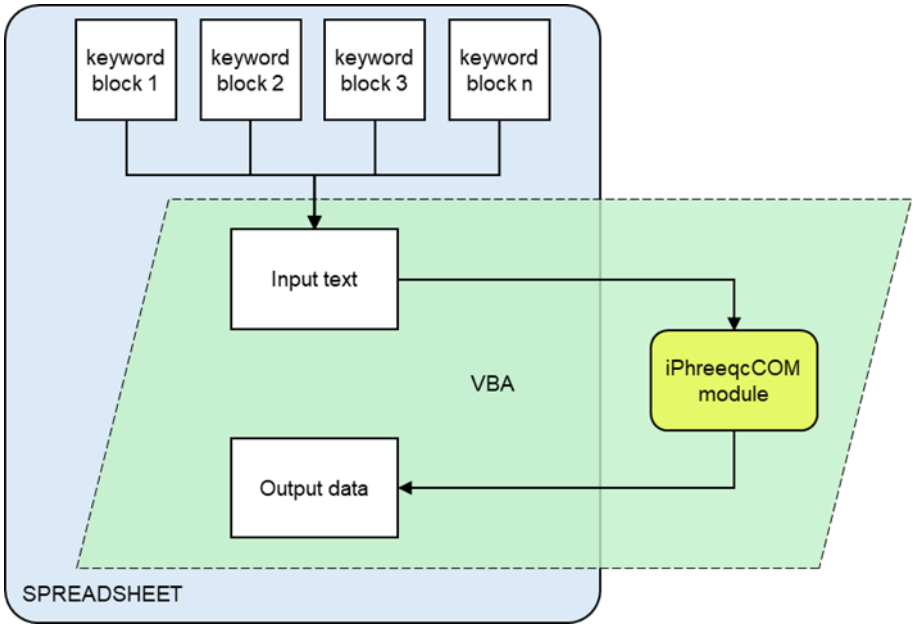


Figure 4-2: Geochemical model structure

4.5.3 Geochemical source terms

Source terms (ST) represent the concentrations of chemical substances in contact water from spoil and dissolved in groundwater and runoff. Source terms were derived from a combination of monitoring data, reference data and laboratory tests. **Table 4-1** lists the source terms, with reference to the data used to derive them.

Groundwater quality source terms were developed from historical site monitoring data provided by SLR (from groundwater quality data from SLR, 2026). The data was arranged according to aquifer (i.e. Leichhardt and Vermont Seams versus “Country rock”).

Spoil seepage water quality was inferred using results of laboratory KLC testing (**Section 2.3.2**). The most recent available leach data from the three KLC tests (i.e. leach 5) was used to calculate the median spoil leachate quality. This data likely represents the lower limit of the ‘first flush’ of readily soluble salts as opposed to a ‘steady-state’ which would typically be used to infer long-term leachate quality. Using crushed samples provides a very high surface area to solution ratio, which encourages mineral reaction and dissolution of the solid phase. Also, dehydration of samples (in storage) may lead to the concentration and precipitation of salts which effect the ‘first-flush’ results. As such, using the ‘first-flush’ results to infer spoil runoff/ seepage water quality is considered conservative (i.e. likely to overestimate the concentration of salts).

Scaling factors were applied to the calculated leach results to scale the laboratory derived release rates to field conditions at the Project. The scaling factors account for (amongst other things): particle size effects, water-rock contact and oxygen availability (e.g. saturated versus un-saturated) and are consistent with reported values elsewhere (Kempton, 2012; Linklater et al., 2017). The combined scaling factor applied to the data was 0.25.

Table 4-1: Geochemical data to derive source terms

Source term name	Input data
Starting lake water quality	For the base case scenario, there is no starting lake water volume
Groundwater inflow	Coal seam groundwater quality data provided by SLR, 2026.
	Country rock groundwater quality data provided by SLR, 2026.

Source term name	Input data
Natural catchment rainfall runoff	Surface water (creek) monitoring data from monitoring locations: IR1, RIA and W8.
Direct rainfall	Townsville rain water data (Crosbie et al., 2012) excluding trace elements. The limits of reporting (LOR) were significantly higher than LOR for other samples and had a disproportionate impact on model results.
Backfilled spoil (contact water: runoff and seepage)	Inferred input. Median of last available leach from three KLC tests. Median scaled to field conditions.
Evaporation	Pure water with zero solutes

The median hydro-chemistry values of the key water inputs are provided in **Table 4-2** against the assessment criteria (i.e. the revised Australian and New Zealand Guidelines for fresh and marine water quality guidelines livestock drinking water guidelines (ANZG, 2018), as the primary intended beneficial use of void lake water (refer to assessment criteria in **Section 5**). The water qualities were equilibrated and charge balanced using PHREEQC.

Comparison of the key water quality inputs against the assessment criteria highlight that several of the parameters are close to the livestock drinking water guidelines (namely median Se and Mo associated with spoil contact water); however, none exceed.

Table 4-2: Key water quality inputs against assessment criteria

Input water quality Parameter	Units	LDWG (ANZG, 2018)	Rain	Groundwater[1]	Groundwater[2]	Spoil runoff/ seepage	Surface water runoff
TDS	mg/L	4,000- 5,000	0.89	2,234	7,178	264	238
EC	µS/cm	-	1.4	3,492	11,216	414	373
pH	-	-	5.60	6.85	7.41	8.63	7.99
Aluminium	mg/L	5	0	0.005	0.005	0.038	0
Arsenic	mg/L	0.5	0	0.002	0.002	0.010	0
Boron	mg/L	5	0	0.40	0.54	0.06	0
Cadmium	mg/L	0.01	0	0.00005	0.00005	0.00003	0
Calcium	mg/L	1,000	1	148	186	2	15
Chloride	mg/L	-	9	814	3,700	67	39
Chromium	mg/L	1	0	0.0005	0.0005	0.0001	0
Cobalt	mg/L	1	0	0.0005	0.0005	0.00012	0
Copper	mg/L	1	0.028	0.001	0.001	0.000	0
Fluoride	mg/L	2	0.03	0.30	0.20	0.38	0
Iron	mg/L	-	0	0.14	0.24	0.01	0
Lead	mg/L	0.1	0	0.0005	0.0005	0.0001	0
Molybdenum	mg/L	0.15	0	0.002	0.004	0.1	0
Magnesium	mg/L	-	1	91	100	1	10
Manganese	mg/L	-	0.03	0.30	0.21	0.00	0
Nickel	mg/L	1	0	0.006	0.006	0.0003	0
Potassium	mg/L	-	1.0	10	12	1	6.7
Selenium	mg/L	0.02	0	0.005	0.005	0.01	0
Silver	mg/L	-	0	0.0005	0	0	0
Sodium	mg/L	-	4.5	572	1990	95	34
Sulfate	mg/L	1000	0	290	35	31	8
Zinc	mg/L	20	0.23	0.01	0.01	0.001	0
Total Alkalinity	mg/L	-	3	547	318	109	99

Notes: [1]groundwater from the country rock surrounding the spoil. [2]groundwater from the coal seems surrounding the void.

5 Assessment criteria

Assessment criteria are used to assess the significance of an impact. For the lake water quality assessment, the key impact of concern is reduced water quality. The specified PMLU for the pit lake is stock drinking water (specifically for cattle) (**Section 2.1**). Accordingly, levels of various parameters estimated using hydrogeochemical modelling will be evaluated against criteria specified in relevant legislation and guidelines.

The applicable guidelines for stock drinking water are the revised Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018), which provide essential, risk-based default guideline values (DGVs) for livestock drinking water to ensure animal health and productivity. These guidelines replaced the previous Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) guidelines (ANZECC and ARMCANZ, 2000).

There is a more recent version of stock drinking water guidelines in draft format (ANZG, 2023); however, these guidelines stipulate that the current guidelines (ANZG, 2018) should be referred to until the updated guidance have been published (i.e. out of draft format).

The livestock drinking water guidelines (LDWG) provide recommended values for biological, chemical and radiological substances that may occur in livestock drinking water. If levels of the substance in drinking water are below these values, there should be little risk of harmful effects on animal health (ANZG, 2018).

These water quality guidelines are used as the assessment criteria for the lake water quality assessment and presented in **Table 5-1**.

Table 5-1: **Summary of key water quality trigger levels for livestock drinking water guidelines**

Parameter	Unit	Livestock Drinking Water Guideline
Total dissolved solids	mg/L	4,000-5,000*
Sulfate	mg/L	1,000
pH	-	-
Fluoride	mg/L	2
TDS	mg/L	2,400
Aluminium	mg/L	5
Arsenic	mg/L	0.5
Boron	mg/L	5
Cadmium	mg/L	0.01
Calcium	mg/L	1,000
Chromium (III+VI)	mg/L	1
Cobalt	mg/L	1
Copper	mg/L	1
Mercury	mg/L	0.002
Molybdenum	mg/L	0.15
Lead	mg/L	0.1
Nickel	mg/L	1
Selenium	mg/L	0.02
Zinc	mg/L	20

*TDS between 4,000-5,000 mg/L (6,250-7,800 µS/cm based on 0.64 EC:TDS conversion factor): Beef cattle (animals may have initial reluctance to drink or there may be some scouring, but stock should adapt without loss of production).

6 Model assumptions and uncertainty

Key assumptions relating to the geochemistry and conceptual model aspects of the hydrogeochemical models are outlined in this section.

6.1 Water balance

The key assumptions used in the water balance model are described in HydroBalance (2026).

6.2 Geochemistry

The following assumptions were made:

- Complete instantaneous mixing of source terms. This is considered appropriate since the mixing process is likely to be rapid relative to the time periods considered in the model.
- A pCO2 of -3.5 was assumed for water exposed to the atmosphere.
- Mineral reactions were modelled in equilibrium. If conditions were met, precipitation and dissolution occurred instantly until mineral equilibrium was attained.
- Kinetically limited reactions were not accounted for. This is considered appropriate since most environmentally significant mineral reactions occur rapidly relative to the time periods considered in the model.
- Biochemical processes were not considered in the model (e.g., nitrate degradation). This is considered appropriate because: (i) the rates of biochemical processes are site specific and vary over time, (ii) the information regarding these rates was not available for this modelling, and (iii) the inclusion of a kinetic biochemical source term in PHREEQC is a model feature not consistent with the initial-level objective of this work.

6.3 Uncertainty

All models estimate future conditions (e.g., physicochemical parameters) by reducing complex systems to a limited number of significant, often simplified, processes. Predicting the water qualities of complex systems requires many assumptions. Even a rigorous sampling and analysis programme cannot precisely determine all the physical, chemical, and geological characteristics of the system. Nor can they precisely indicate how these characteristics might change over time. Even though assumptions are informed by data they include an inherent level of uncertainty. As geochemical models become more sophisticated, the most important thing that gets lost is an understanding of the uncertainties associated with the predictions (Drever, 2011). While these uncertainties are generally hard to quantify, they can be recognised. **Table 6-1** summarises key uncertainties associated with the IDE hydrogeochemical models.

Table 6-1: Key uncertainties of the VCMP hydrogeochemical models

Uncertainty source	Limitation	Uncertainty estimate
Predicting field-scale water quality from lab scale test results is an approximation	Leaching of salts and metals at the field scale is variable in time and controlled by factors not fully applied at the lab scale. Amongst others, these factors include temperature, nature of the leaching solution, the solution to solid ratio, solution-solid contact time, particle size of the solid. This indicates that the quality of water due to interaction with material such spoil as presented in this report, are informed estimates	Laboratory solute release rates may differ from field rates by a factor of one to 100
The compositions of input waters	The quality of water sources, such as groundwater, surface water, and rainwater, are the results of other complex systems (aquifer, catchment, atmosphere). While water composition can be determined in the laboratory with some accuracy, it requires a statistically relevant number of samples to establish inherent variability due to factors such	Concentrations within 50% of “real world value”

Uncertainty source	Limitation	Uncertainty estimate
	as seasons, sediment movement, changes in gradient, etc. The required number of samples is only rarely obtained in practice	
Source terms are constant	There is rarely sufficient data to identify how source terms may vary over time and whether the variation is systematic or random. This limitation is managed by assuming most source terms are constant. For declining source terms, this is a conservative assumption.	Solute releases may be overestimated by a factor of 1 to 100
The geochemical database is relevant to the system being modelled	Hydrogeochemical modelling uses the inherently uncertain laboratory results and water qualities as inputs. These are processed using thermodynamic data determined in the laboratory on ideal materials and solutions. The laboratory determined constants may not be directly applicable to the materials, solutions, and chemical context of the system being modelled	The impact of changes in thermodynamic parameters on model results are difficult to quantify
The modelling assumes thermodynamic equilibrium in the model system	In the field, all chemical components are subject to kinetic variation and the system might, at best, be in a state of quasi equilibrium	Published research shows that this assumption produces results that align with the general chemistry in the field
Groundwater inflow rates, groundwater levels, hydrogeological parameters	The numerical groundwater used to develop the water balance incorporates limitations and assumptions that are propagated, at least in part, to the hydrogeochemical model.	Mixing proportions of source terms may be in error by 10% to 50%

The uncertainties outlined above may suggest that attempts to simulate or predict the state of these complex systems have questionable value. However, geochemical evaluations over the last few decades have shown that modelling, particularly the equilibrium assumption, is a powerful tool that in many circumstances produces results that accurately describe the general chemistry of natural and mine waters.

Considering the above, the available information is considered sufficient to provide “qualitatively correct” estimates of water chemistry, as presented in this report. However, even though this report presents deterministic concentrations, these should be viewed as first-order approximations. The emphasis should be on the modelled trends in chemistry, rather than the precise concentrations. The model results are an informed estimate of future conditions and a prudent starting point for policy decisions. Implicit in the results is the acknowledgement that there is no such thing as absolute certainty about the future.

7 Results

This section presents the results of the hydrogeochemical model.

7.1 Water balance results

The mined void fills rapidly, and the pit lake elevation reaches a quasi-steady state after approximately 30 years of modelled time (**Figure 7-1)**. From this point the pit lake elevation shows minor seasonal variation at around RL 146 mAHD and remains a terminal sink for groundwater (noting the overflow RL is 202 mAHD) (SLR, 2026). Realisation 39 (R#39) of 500, used for the water quality model, represents the median water level according to water balance modelling (**Figure 7-1**).

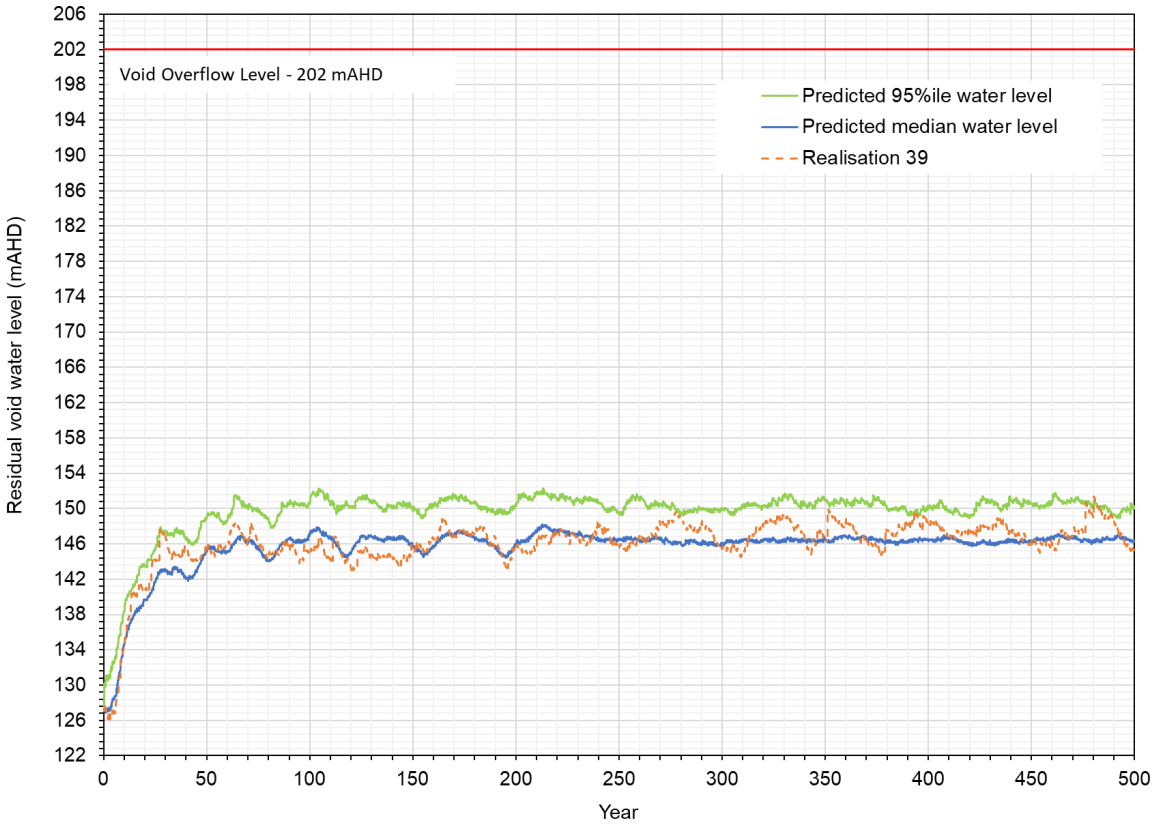


Figure 7-1: Pit lake water level (m AHD) versus time

Daily water balance results were cumulated into annual volumes for input into PHREEQC for geochemical modelling. **Table 7-1** presents the annualised volumes of pit inflows and outflows for the respective water balance components.

Figure 7-2 presents the relative proportions of all the combined outflows and inflows derived from the water balance results in **Table 7-1**. Each staked bar represents the year closest to the median for every 25-year interval. The 50% dotted line shows how the outflows and inflows compare. Generally, the outflows exceed the inflows into the IDE pit lake. A further breakdown of the proportions of outflows and inflows are shown in **Figure 7-3** and **Figure 7-4**, respectively.

The water balance inflows are dominated by spoil-lake seepage (i.e. spoil impacted water) with approximately 55-60% contribution to inflows over the 500-year modelling period (**Figure 7-4**). The outflows from the lake are dominated by evaporation (thus evapoconcentration) with approximately 85% contribution to outflows over the 500-year modelling period. There are generally no significant changes to the water balance over the modelling period.

Table 7-1. Annualised model outputs

Period	Cumulative Inflows (ML/100 years)						Cumulative Outflows (ML/100 years)			
	R_N	R_S	R_R	Dir. Rain	Spoil to Void	Rock to Void	Evap.	Ben. Use	Void to Spoil	Void to Rock
1-100 years	154	485	5,484	6,578	15,542	41	22,317	2,922	1,242	3
101-200 years	127	420	5,189	7,471	16,055	16	24,655	2,922	1,626	2
201-300 years	116	392	5,003	7,690	16,839	15	25,050	2,922	1,892	2
301-400 years	151	452	5,731	8,034	16,475	15	35,050	2,922	1,936	3
401-500 years	119	391	5,181	8,010	16,488	15	45,050	2,922	1,935	3

Note: Runoff (Natural) = R_N; Runoff (Spoil) = R_S; Runoff (Rehab) = R_R; Direct rainfall = Dir. Rain; Evaporation = Evap.; Beneficial Use = Ben.Use.

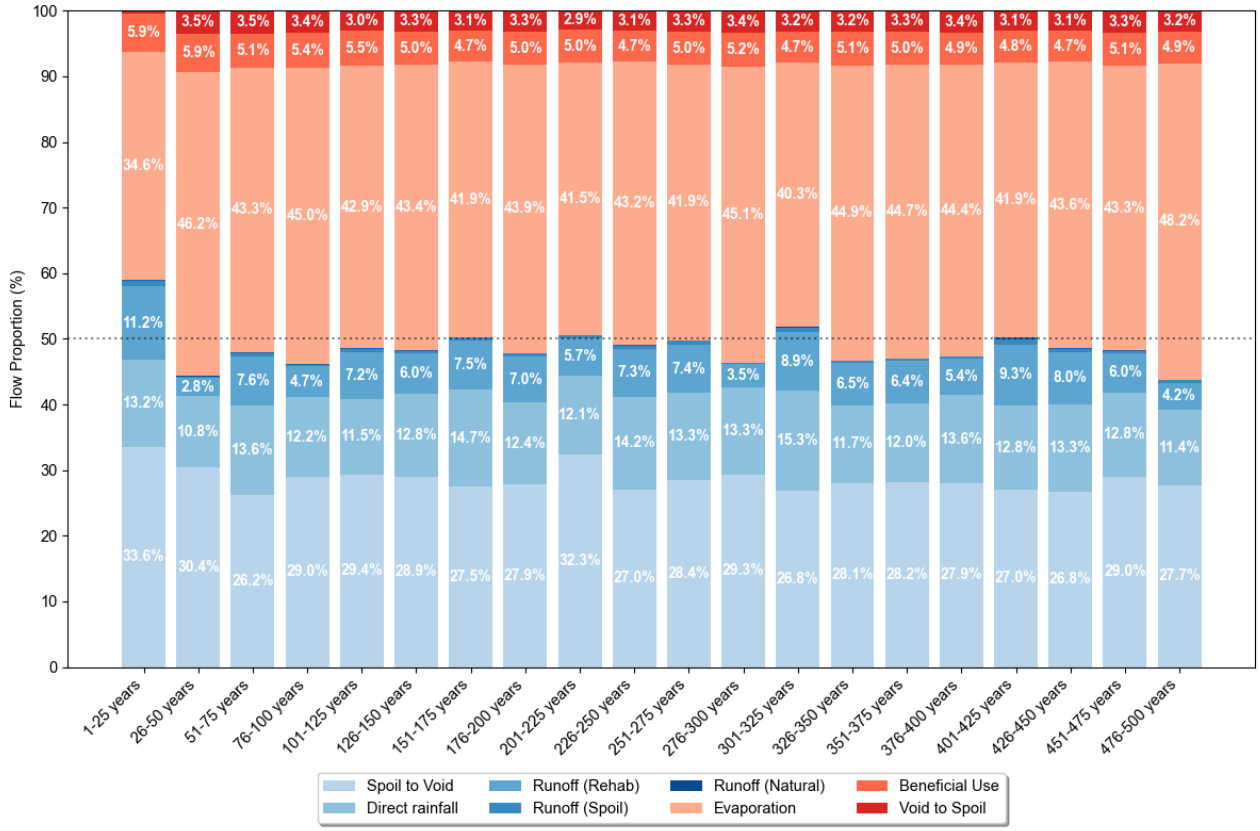


Figure 7-2: Relative proportions of inflows and outflows of the IDE pit lake

Note: The runoff (natural) inflow and void to rock (outflow) are not shown in the legend for their negligible contributions.

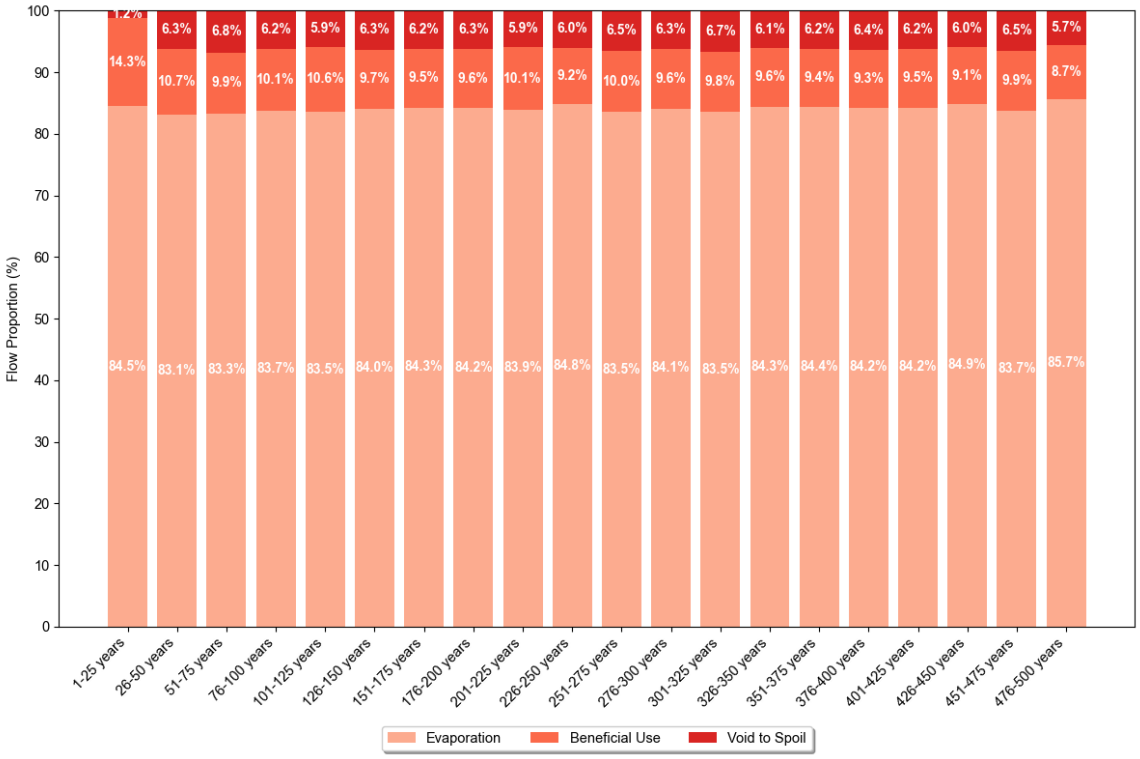


Figure 7-3: Relative proportions of outflows from the IDE pit lake

Note: The void to rock outflow is not shown in the legend due to its negligible contribution.

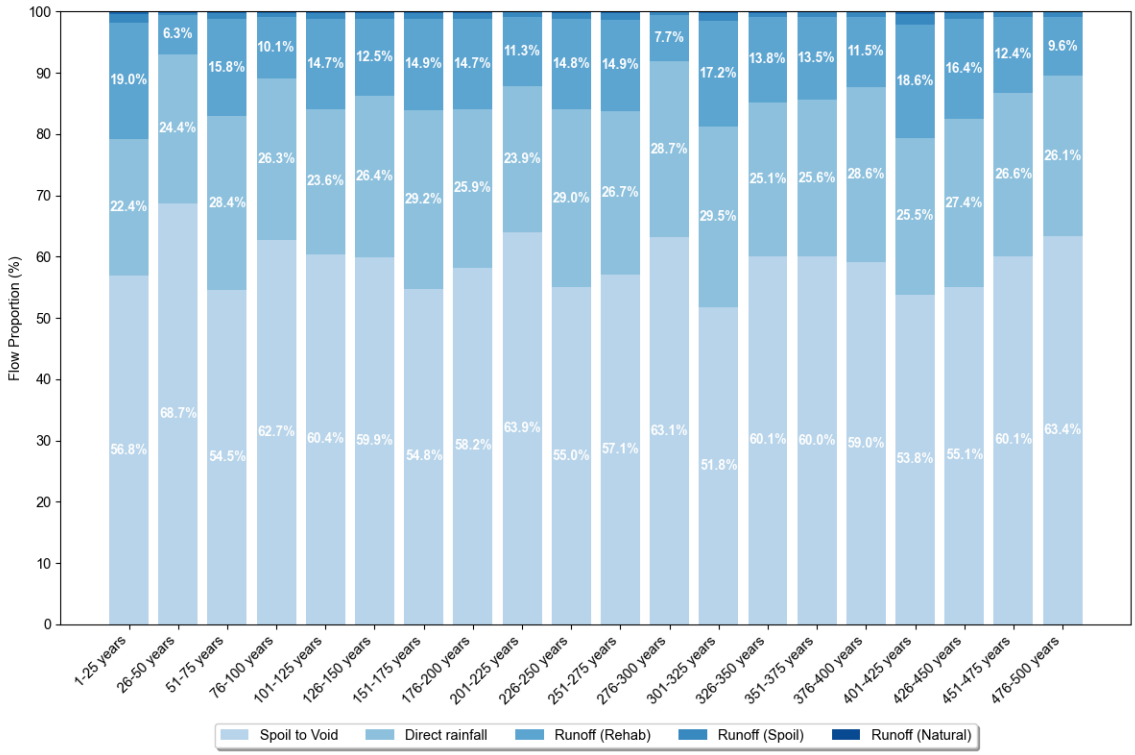


Figure 7-4: Relative proportions of inflows from the IDE pit lake

Note: The void to rock outflow is not shown in the legend due to its negligible contribution.

7.2 Water quality results

The water balance results (**Section 7.1**) provided criteria for mixing:

- Relative proportions of each source term by year.
- Normalised water balance evaporation volume (expressed as number of moles of H_2O).

The source terms were mixed in the relative proportions in PHREEQC, and water was removed to simulate evapoconcentration. Tabulated water quality results are presented in **Attachment A**, while concentration versus time graphs are presented in **Attachment B**.

Figure 7-5 presents the modelled pH, salinity (expressed as EC), sulfate (SO_4) and calcium (Ca) for each simulated year for 500-years post closure, as well as showing the LDWG where applicable.

Key points from the modelling include:

- All modelled parameters generally show an increasing concentration trend for the first 110 years (**Figure 7-5**). After this period the values reach a quasi-steady state.
- Modelled pH in the quasi-steady state (after 110 years) ranges between 8.92 and 9.07 (slightly alkaline), with a median value of 9.00. The corresponding total alkalinity ranges between 282 mg $CaCO_3$/L to 440 mg $CaCO_3$/L with a median of 358 mg $CaCO_3$/L indicating there is an excess of acid buffering capacity of the lake water.
- Modelled EC (salinity) in the quasi-steady state varies from ~2,275 µS/cm to ~3,450 µS/cm, with a median of ~2,825 µS/cm.
- The major ion (represented by sulfate and chloride in **Figure 7-5**) and metal/ metalloid concentrations (represented by arsenic (As), manganese (Mn), lead (Pb), and zinc (Zn) in **Figure 7-5**) generally follow the same trend as EC.
- The dominant major ions (other than bicarbonate alkalinity) are sodium and chloride with lesser sulfate, magnesium, potassium and calcium.
- The majority of modelled metal/ metalloid concentrations are very low in the lake, except fluorine (F), molybdenum (Mo) and selenium (Se) which, at some point in the 500-year modelling period, exceed LDWG (ANZG, 2018) (refer to **Section 7.3**)
- The spikes in salinity, major ions and metals/ metalloids, once a quasi-steady state is reached, tend to be associated with lower rainfall years when runoff volumes (and direct rainfall) are lower relative to ‘groundwater inflow’ (inclusive of spoil to lake flow) and thus dilution effects (from runoff and direct rainfall) are reduced while evapoconcentration of accumulated water in the void is relatively higher.

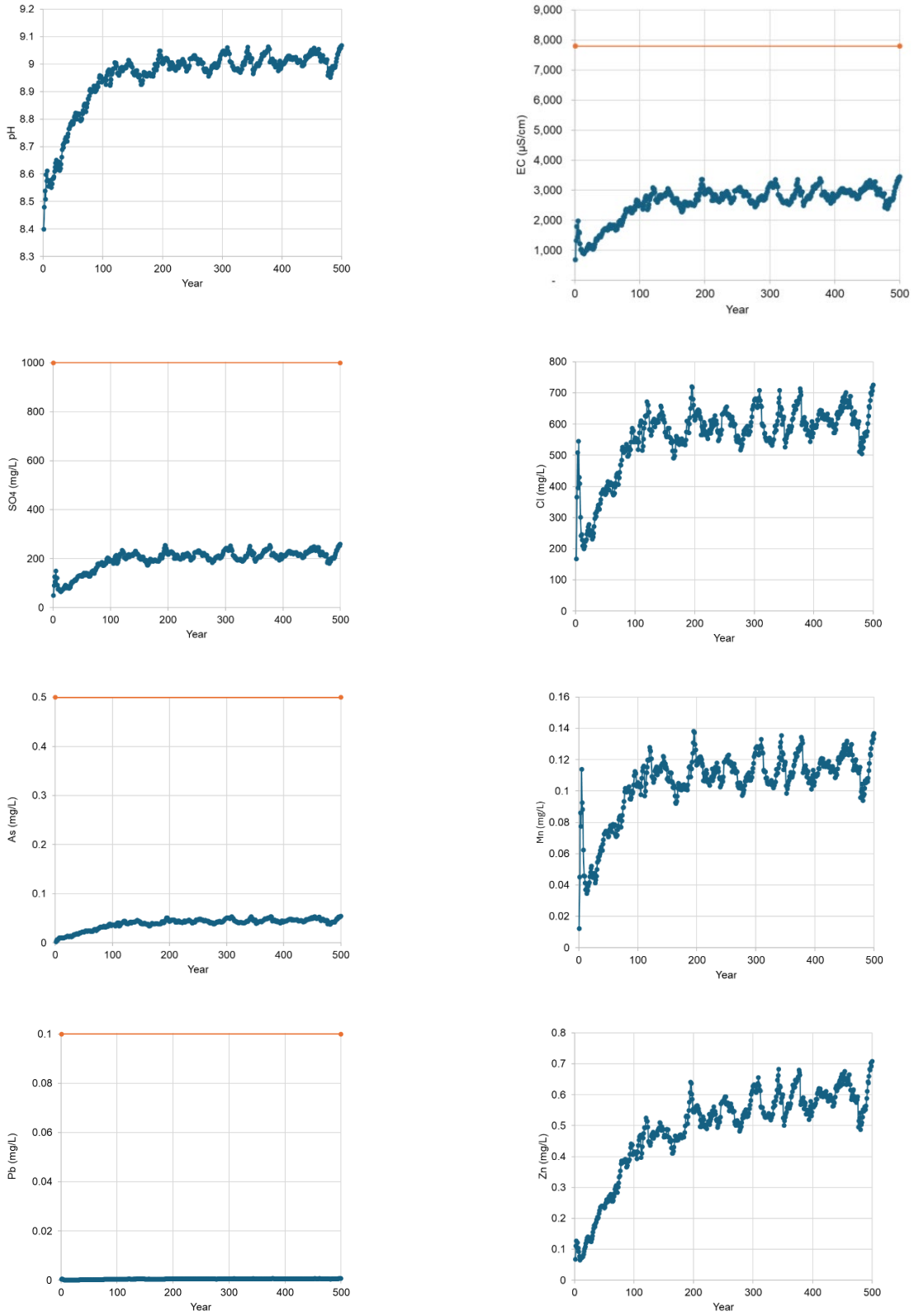


Figure 7-5: Modelled pH, salinity (EC), and other constituents of concern of the pit lake post closure.

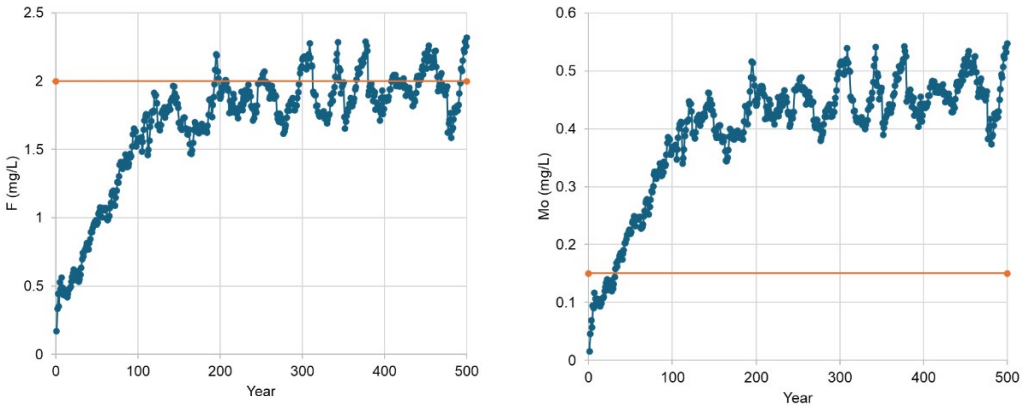
Note: Orange lines are the trigger value for Livestock drinking water guidelines (ANZG, 2018)

7.3 Modelled water quality compared to guidelines

As an indicator of potential environmental risk, model results tabulated in **Attachment A** have been compared to the assessment criteria; LDWG (ANZG, 2018) (refer to **Section 5**).

Comparison of the modelled post-closure pit lake water quality results to LDWG indicates:

- Modelled lake pH is within the proposed guideline range.
- Salinity (as indicated by EC) is well below the LDWG concertation of 7,800 µS/cm over the 500-year modelling period.
- Calcium (Ca) and sulfate (SO_4) are below the LDWG concentrations (LDWG for Ca and SO_4 is 1,000 mg/L).
- The vast majority of modelled dissolved metal/ metalloid concentrations in the pit lake are within the LDWG values except for the following (with further discussion on interpreting these result provided in **Section 8.3**):
  - Fluorine (F) first exceeds the LDWG (2 mg/L) at ~200 years (before decreasing back below the LDWG) and occasionally exceeds the LDWG when quasi-steady state is reached (**Figure 7-6**). The spikes in fluorine reflect lower rainfall years.
  - Molybdenum (Mo) exceeds LDWG at the start of the modelling period and is consistently above the guideline value (**Figure 7-6**). The maximum modelled molybdenum concertation is approximately five times the LDWG value (i.e. 0.01 mg/L).
  - Selenium (Se) first exceeds the LDWG at ~35 years and stays above the guideline value (**Figure 7-6**). The maximum modelled selenium concertation is approximately three times the LDWG value (i.e. 0.02 mg/L).



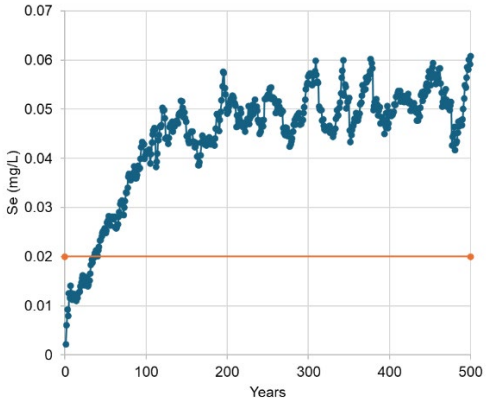


Figure 7-6: Constituents of concern above Livestock drinking water guidelines (ANZG, 2018)

Note: Orange line is the Livestock drinking water guideline (ANZG, 2018).

8 Conclusions

RGS has developed a hydrogeochemical model to estimate water quality of the Project's final mined void/ pit lake for 500-years post closure. The modelling uncertainty, key findings, discussion, and recommendations are summarised in this section.

8.1 Uncertainty

Uncertainty is inherent in all models and part of the value of modelling is identifying the key areas of uncertainty to target future work. Another useful outcome is in increased understanding of the system being modelled. The benefit of this modelling lies in identifying the aspects expected to control water quality and the contributions of the various identified contributors to the evolving pit lake. It is important to recognise the limitations however, and particularly with such a long modelled period (500-years) the uncertainty is significant.

The modelling shows the seepage from spoil (spoil to lake) is the largest contributor by volume of water to the pit lake, as well as for certain metal/ metalloid solute loads. Improving the data quality for the spoil-lake quality interactions would address a recognised significant area of uncertainty. The modelling undertaken has therefore used conservative inputs to account for this level of uncertainty.

The model inputs and therefore the model reliability can be improved with additional testing and calibration/verification steps with future site monitoring. Backfilled spoil behaviour is difficult to determine due to many factors being difficult to determine using laboratory methods, e.g. reactive surface area.

8.2 Key findings

The water quality modelling has indicated that after closure, the pit lake water may be described as follows:

- The pit lake generally shows an increasing concertation trend for the first 110 years post closure and then reaches a quasi-steady state for the remaining 390 years (post-closure).
- Modelled pit lake pH is slightly alkaline and ranges between 8.92 and 9.07, with a median value of 9.00.
- Modelled pit lake salinity (represented as EC) in the quasi-steady state varies from ~2,275 µS/cm and ~3,450 µS/cm, with a median of ~2,825 µS/cm, which is well below the LDWG concertation of ~7,800 µS/cm. The salinity is present mainly as sodium-chloride salts as opposed to sulfate salts.
- The majority of modelled metal/ metalloid concentrations are very low in the pit lake, except fluorine, molybdenum and selenium which, at some point in the 500-year modelling period, exceed LDWG (ANZG, 2018).

8.3 Summary discussion

Spikes in concentrations of salinity, major ions and metals/ metalloids are correlated with periods of reduced rainfall (and thus rainfall runoff to the mined void). Under these conditions, there is a relative decrease in direct precipitation and surface water inflows compared to groundwater contributions. Concurrently, increased evaporation during drier years leads to the concentration of dissolved constituents within the void, thereby amplifying salinity and associated chemical parameters.

The modelled concentrations of fluoride (F), selenium (Se), and molybdenum (Mo), which exceed the LDWG and are inferred to be mobilised from backfilled spoil, are considered conservative estimates (i.e. likely to overestimate concentrations). This conservatism arises from methodological assumptions and testing conditions that likely overstate constituent mobilisation under long-term field conditions.

Firstly, the KLC test results used to estimate spoil porewater quality are representative of early-stage "first flush" conditions rather than long-term equilibrium behaviour. The columns have only been operated for a limited duration (12 weeks), meaning steady-state geochemical conditions have not yet been achieved. Additionally, KLC tests are conducted on crushed rock, which significantly increases the surface area available for water–rock interaction, thereby enhancing mineral dissolution rates. Sample dehydration during storage may also concentrate salts, influencing initial leachate chemistry. Consequently, extrapolating these first-flush results to predict long-term runoff or seepage quality likely overestimates contaminant concentrations.

Secondly, the long-term infiltration dynamics of the backfilled spoil are expected to reduce constituent mobilisation. Over time, spoil material will undergo consolidation, resulting in decreased permeability and reduced infiltration rates. This shift will favour increased surface runoff relative to percolation. Surface runoff generally exhibits more dilute concentrations compared to groundwater/ surface water that has interacted extensively with spoil material before discharging into the lake. Therefore, long-term water quality impacts are expected to be less pronounced than those predicted by current model assumptions.

Furthermore, the LDWG thresholds themselves are considered conservative in this context. For instance, modelled fluoride concentrations at or near LDWG values remain below the South African guideline limit of 4 mg/L (DWAF, 1996). Similarly, molybdenum concentrations are approximately aligned with the Canadian guideline (CCME, 1999) value of 0.5 mg/L and may be further mitigated through copper supplementation. Selenium concentrations are also comparable to both Canadian and South African guideline limits of 0.05 mg/L (CCME, 1999; DWAF, 1996). Collectively, these comparisons suggest that modelled exceedances relative to LDWG may not necessarily indicate unacceptable risk when evaluated against alternative international standards.

8.4 Recommendations

The following recommendations are derived from the findings of the water quality modelling.

- Additional scenario-based modelling could be undertaken to assess a broader range of environmental conditions and their influence on pit lake water quality. This could include sensitivity analyses incorporating both climate variability and projected climate change scenarios (including pCO_2 scenarios) to better constrain the potential range of evolved water quality outcomes.
- Refining the characterisation of key source terms that exert the greatest influence on water quality in terms of both load and volume. Improved definition of these inputs will reduce model uncertainty and increase confidence in predictive outcomes. Priority areas include spoil water quality (e.g. updating source terms using long-term kinetic leach column results) and backfilled spoil hydrology (e.g. incorporating temporal consolidation effects and associated changes in permeability and lake water balance).
- An iterative approach to model refinement is recommended throughout the life of the mine. This should involve ongoing site monitoring, with particular emphasis on parameters and inputs that most strongly influence the water balance and water quality, followed by periodic updates to the modelling framework to reflect improved understanding and newly acquired data.
- Inconsistencies in monitoring datasets should be addressed to ensure comprehensive parameter coverage across all sampling locations. For example, parameters such as calcium should be consistently measured across all relevant inputs. The implication for the modelling is that there may be significant underestimation of parameters which are not included in all contributing flows (and are therefore assigned a zero value).

9 References

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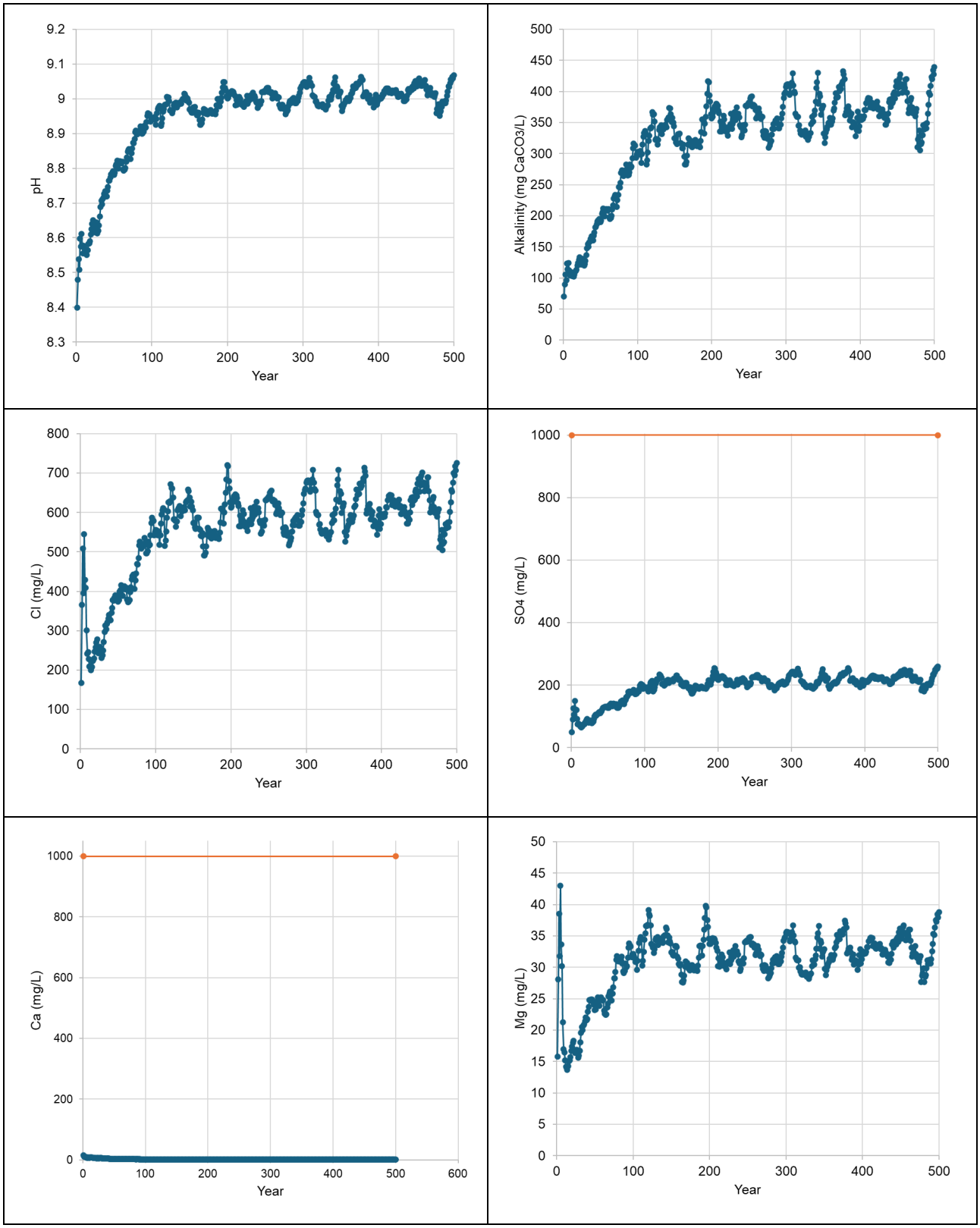
10 Attachments

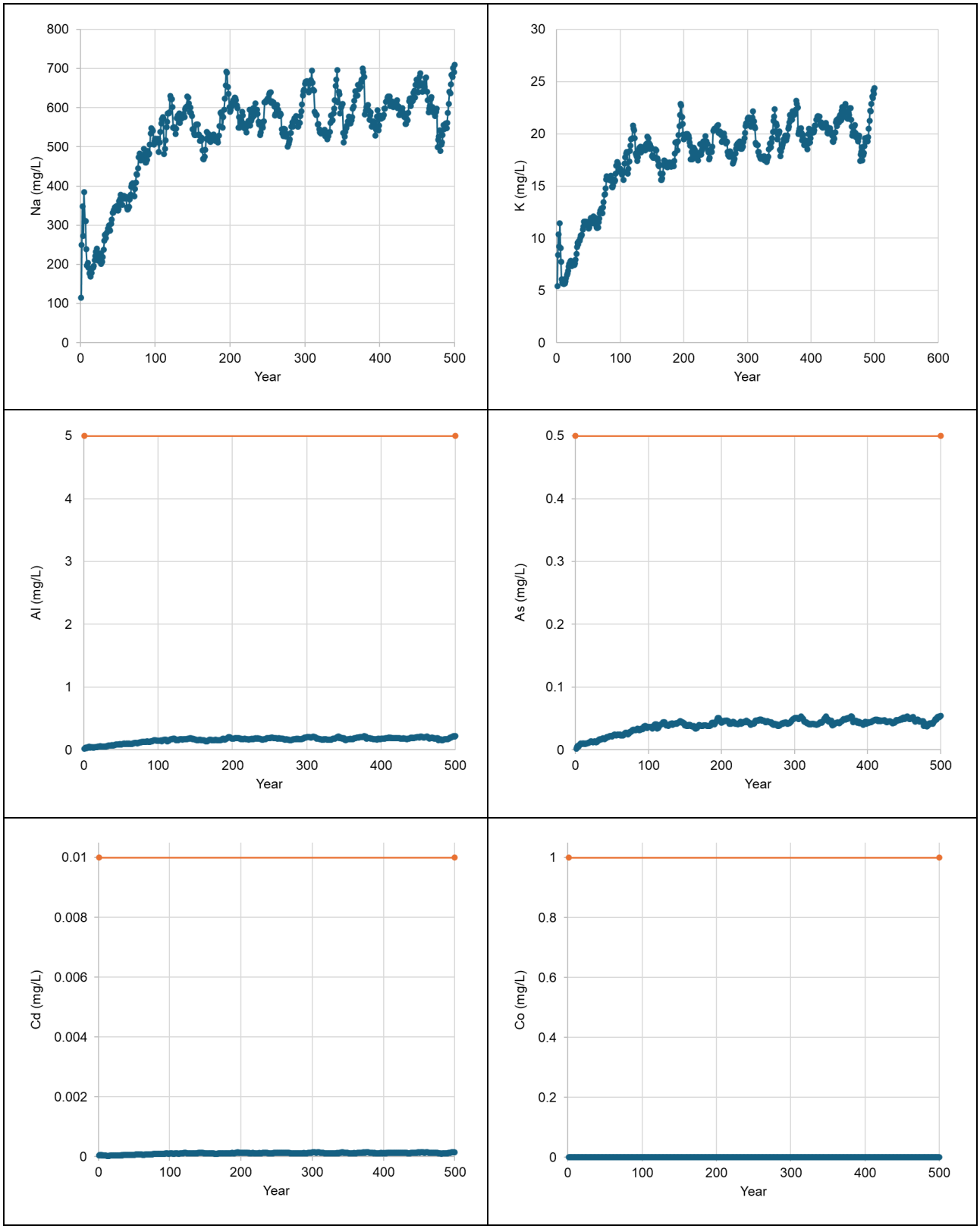
Attachment A: Modelled lake water qualities – summary table

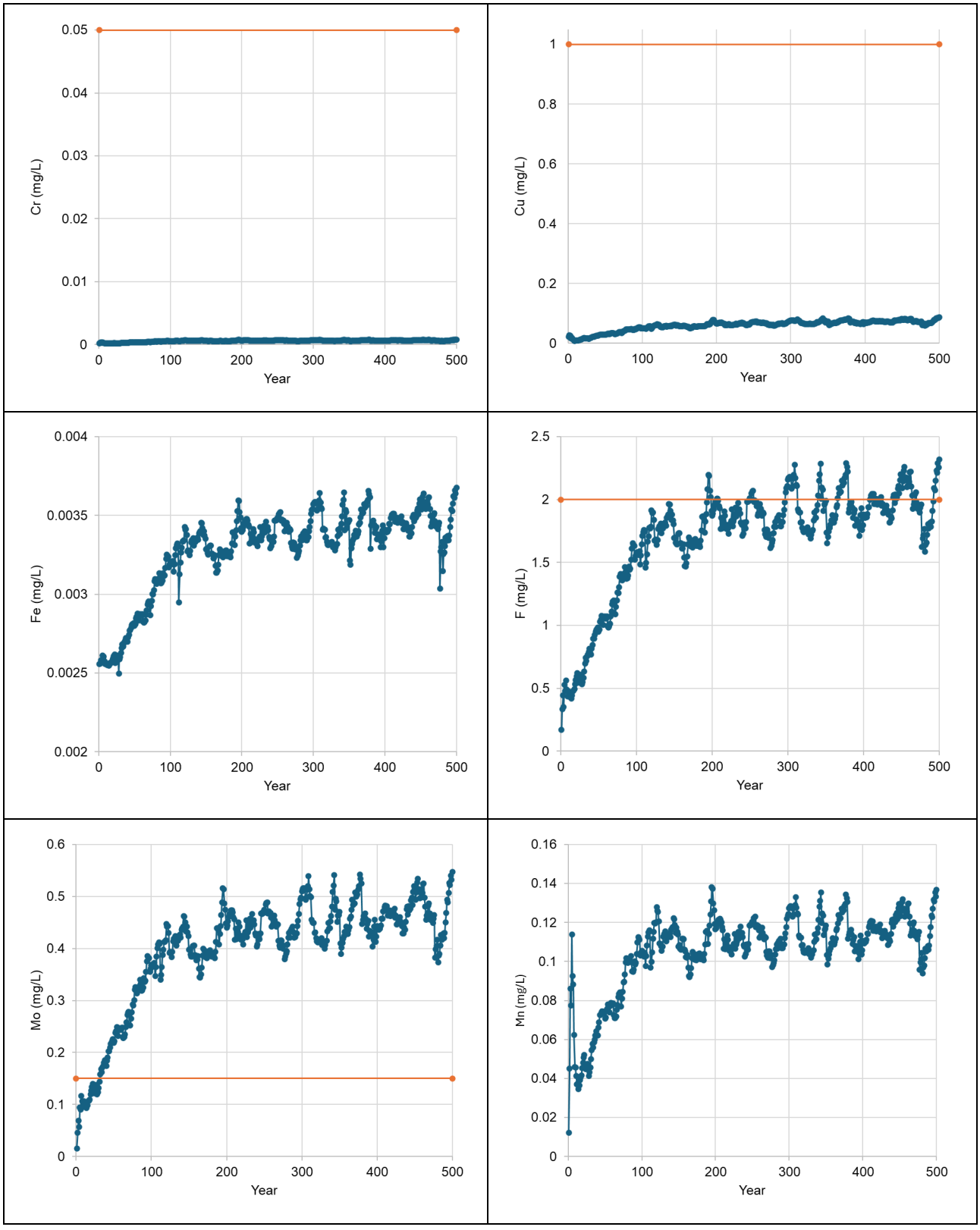
Table A-10-1: Simulation results summary

Parameter	LDWG (ANZG, 2018)	Year 1	Year 5	Year 10	Year 25	Year 50	Year 100	Year 250	Year 500
pH	-	8.40	8.60	8.58	8.63	8.78	8.94	9.02	9.07
EC (µS/cm)	-	687	1,976	1,042	1,108	1,666	2,541	3,021	3,443
TDS (mg/L)	5,000	439	1,265	667	709	1,066	1,626	1,933	2,204
Total Alkalinity (mg $CaCO_3$/L)	-	71	123	110	126	189	302	382	440
Ca (mg/L)	1,000	15	8	7	6	3	2	1	1
Mg (mg/L)	-	16	43	16	17	23	32	34	39
Na (mg/L)	-	115	385	204	218	337	521	623	710
K (mg/L)	-	5	11	6	7	11	17	21	24
Cl (mg/L)	-	167	544	245	251	374	556	640	726
F (mg/L)	2	0.2	0.5	0.5	0.6	0.9	1.6	2.0	2.3
SO_4 (mg/L)	1,000	50	149	77	83	127	193	228	259
Al (mg/L)	5	0.02	0.04	0.04	0.05	0.09	0.15	0.19	0.22
As (mg/L)	0.5	0.002	0.008	0.010	0.013	0.022	0.036	0.047	0.054
B (mg/L)	5	0.06	0.21	0.12	0.12	0.19	0.30	0.35	0.40
Cd (mg/L)	0.01	<0.0001	0.0001	<0.0001	<0.0001	0.0001	0.0001	0.0001	0.0001
Co (mg/L)	1	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001
Cr (mg/L)	1	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001
Cu (mg/L)	1	0.021	0.018	0.009	0.016	0.029	0.051	0.071	0.087
Fe (mg/L)	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mn (mg/L)	-	0.012	0.114	0.046	0.046	0.071	0.105	0.120	0.137
Mo (mg/L)	0.15	0.016	0.094	0.107	0.129	0.218	0.368	0.475	0.547
Ni (mg/L)	1	0.001	0.002	0.001	0.001	0.001	0.002	0.002	0.002
Pb (mg/L)	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001
Se (mg/L)	0.02	0.002	0.013	0.012	0.015	0.025	0.041	0.053	0.061
Zn (mg/L)	-	0.067	0.122	0.071	0.130	0.234	0.416	0.582	0.708

Attachment B: Modelled lake water qualities – graphs


pH
Year
Alkalinity (mg CaCO3/L)
Year
Cl (mg/L)
Year
SO4 (mg/L)
Year
Ca (mg/L)
Year
Mg (mg/L)
Year


Na (mg/L)
Year
K (mg/L)
Year
Al (mg/L)
Year
As (mg/L)
Year
Cd (mg/L)
Year
Co (mg/L)
Year


Cr (mg/L)
0.05
0.04
0.03
0.02
0.01
0
0
100
200
300
400
500
Year
Cu (mg/L)
1
0.8
0.6
0.4
0.2
0
0
100
200
300
400
500
Year
Fe (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0
100
200
300
400
500
Year
F (mg/L)
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
Year
Mo (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
500
Year
Mn (mg/L)
0.16
0.14
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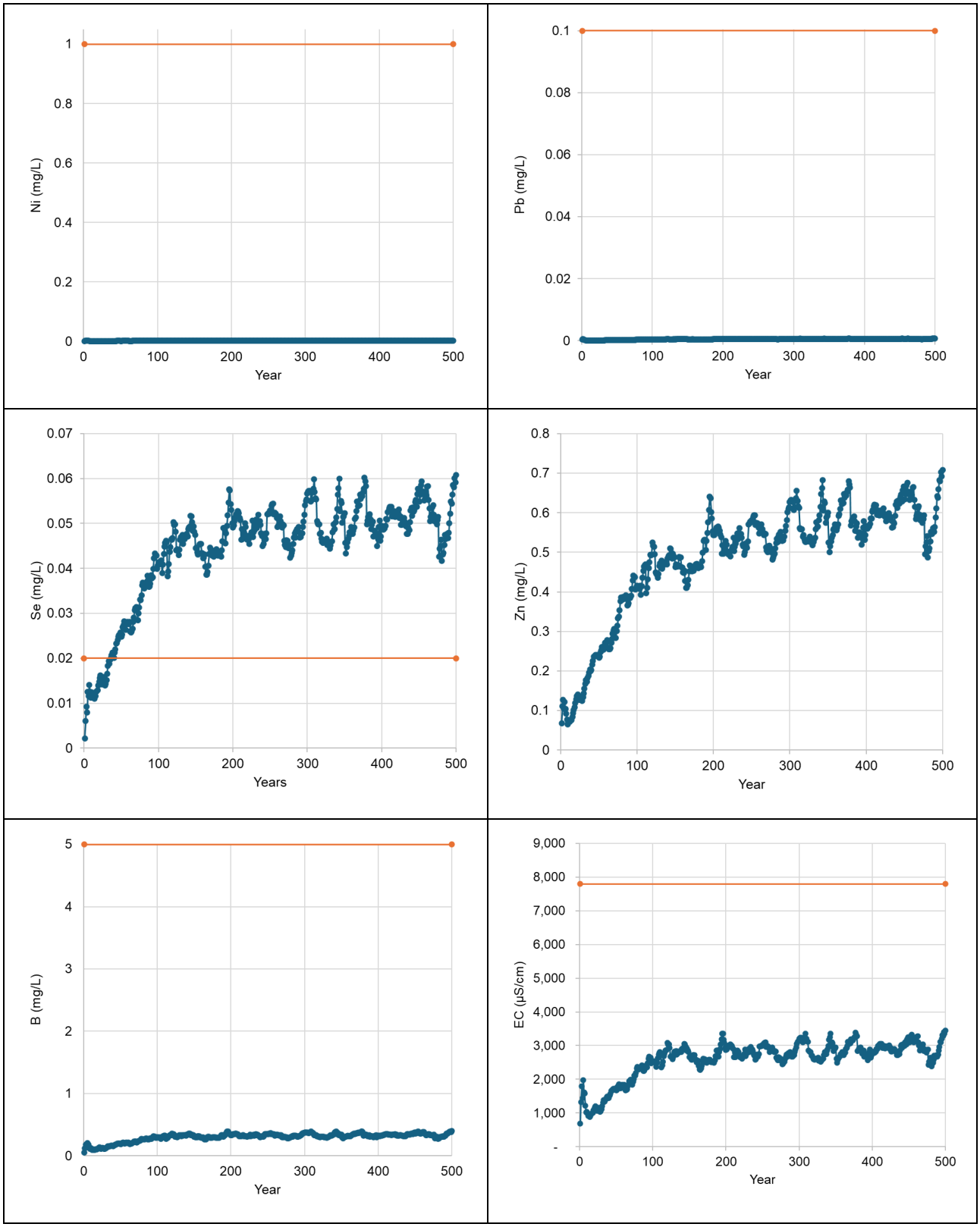
0.08
0.06
0.04
0.02
0
0
100
200
300
400
500
Year


Ni (mg/L)
Year
Pb (mg/L)
Year
Se (mg/L)
Years
Zn (mg/L)
Year
B (mg/L)
Year
EC (µS/cm)
Year

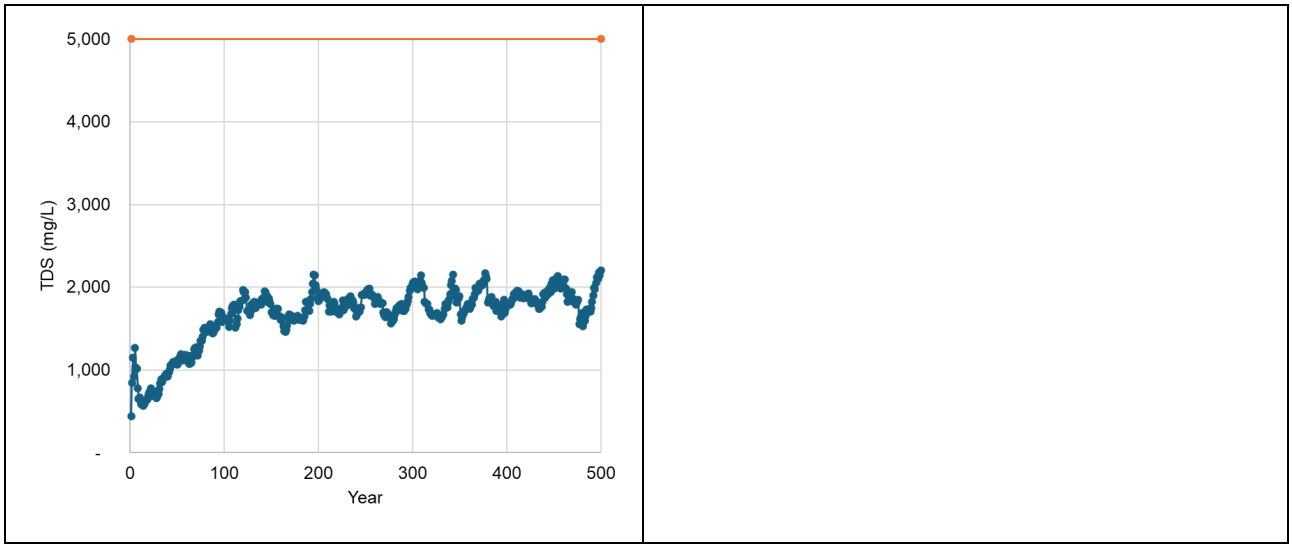


Figure C-1: Constituents below guideline values.

Note: Livestock drinking water guidelines are shown with an orange line in the corresponding constituents.

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