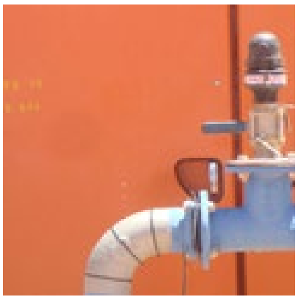

ERIAS Group

# Fountain Head Gold Project – Supplementary EIS Response: Pit Lake Water Quality

12 July 2022

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# Section 1 Introduction

## 1.1 Background

CDM Smith Australia Pty Ltd (CDM Smith) with support from Land Water Consulting have been engaged by ERIAS Group Pty Ltd (ERIAS) to undertake water-related assessments to support environmental approvals for the proposed Fountain Head Gold Project (FHGP) operated by PNX Metals Limited (PNX). The Project is located approximately 170 km south of Darwin within the Pine Creek region of the Northern Territory.

The FHGP proposes brownfield development of the Fountain Head deposit, where gold mining and exploration dates back to the late-1800's. Mining at Fountain Head was most recently undertaken from 2007 to 2009 by GBS Gold. PNX acquired the tenements in 2018, following further exploration and a mining scoping study completed in 2019. Recent exploration drilling intersected notable gold mineralisation in the vicinity of the existing open (but flooded) pit, prompting a renewed focus on the Fountain Head site. PNX proposes to use open pit mining methods and a carbon in pulp plant (CIP) at the Project site including the following activities:

- Dewatering of the existing Pit Lake and expansion of the existing open pit.
- Expansion of the waste rock storage (WRS) as an integrated waste landform (IWL).
- Construction of processing related areas, crushing facility and gold processing plant.
- Construction of supporting infrastructure and expansion of the existing Evaporation Dam to an Evaporation Pond (EP) for water storage.

To enable management of potentially acid forming (PAF) material during and following operations. PNX are proposing sub-aqueous disposal of up to around 0.15 Mt of PAF material within the Fountain Head pit. CDM Smith previously completed water quality modelling (Doc No. ERIAS-1001007-RPT-005-2) for the FHGP which provided predictions of the concentration for the key parameter of concern (arsenic) within the site water storages (i.e. Fountain Head pit and Evaporation pond, refer Figure 1-1). These predictions assumed 2 Mt of potentially acid forming (PAF) material would be stored within the Fountain Head pit during and following mining. Following the submission of the FHGP supplementary environmental impact statement (SEIS) in November 2021, it was recognised the PAF material quantity used in the water quality modelling was incorrect and reflected the total in-pit storage capacity (2 Mt) rather than the proposed quantity of PAF material to be stored within the pit (0.15 Mt). This error resulted in gross overestimations of the leachate generated (and concomitant water quality) as a result of the proposed in-pit storage of the PAF material.

Since this time, additional kinetic test data from the column leach tests have become available. These data have been included in updating the previous water quality modelling for the correct PAF material quantities for the FHGP. The updated modelling is provided in this report.

## 1.2 Project Status

On 6 January 2022, PNX were issued a direction (the Direction) to provide additional information for the draft EIS (clause 14(2)(a) of the Environmental Assessment Administrative Procedures 1984). The direction follows the preparation and submission of a SEIS (mentioned above) in November 2021 from which further comments relating to the FHGP were raised. The comments relating to water quality are listed in Table 1-1, while the following summarises the key concerns made by the Northern Territory Environmental Protection Agency (NT EPA) in the Direction:

- Water quality
  - Elevated contaminant concentrations within the EP and pit during and post mining.
  - Potential impacts to the downstream environment as a result of storing potentially acid forming (PAF) material within the Fountain Head pit.

  - Passive or uncontrolled discharge of contaminants and impacts from the sources of contamination (EP and Fountain Head Pit).
  - Lack of broader predictions of contaminants relating to water quality evolution post mining.

## 1.3 Objective and Scope

The objective of this report is to update the current water quality modelling to reflect the correct PAF material quantities proposed for storage within the Fountain Head pit (i.e. 0.15 Mt) using the latest kinetic test data. To achieve this objective the following tasks are scoped:

- Address comments from the Department of Industry, Tourism and Trade (DITT) regarding pit lake water quality (Table 1-1).
- Gather information on the PAF rock deposit schedule and information from the geochemical characterisation of the PAF waste rock to be disposed of in the Fountain Head pit.
- Conceptualise the processes of acid generation, acid neutralisation and soluble minerals that would contribute to the water quality of the pit lake.
- Study and understand the long-term water quality of the Fountain Head pit lake and the EP.
- Complete a geochemical analysis of kinetic test data and expand the source term by screening the kinetic data against background data and relevant criteria to define the source term.
- Comment on the level of risk posed from the PAF oxidation regarding the source term constituents.
- Provide predictions of the Fountain Head pit lake water quality that reflect the updated PAF material quantity proposed for in-pit storage.

**Table 1-1 Regulatory comments relating to water quality modelling**

| Relevant section | Comment | Additional information required |
|---|---|---|
| Evaporation pond, seepage and groundwater modelling:<br>Section 3.3<br>Appendix 4 and Appendix 5 | The draft EIS indicated the potential for impacts to groundwater due to seepage from the evaporation pond stating that the impact would be negligible. However, there was considerable uncertainty in the modelling, and values of the receiving environment that could be impacted, such as the presence of groundwater dependent ecosystems (GDEs) close to the proposal site, were not identified.<br>The NT EPA's Direction to prepare the Supplement<br>required the proponent to demonstrate that the evaporation pond would be constructed and operated with a high degree of certainty that contaminated water would not enter groundwater and the downstream environment.<br>Modelling undertaken for the Supplement confirmed that seepage through the evaporation pond floor would result in groundwater mounding that has the potential to impact beyond the footprint of the site.<br>The seepage is predicted to be contaminated, with dissolved arsenic concentrations in the evaporation pond predicted to increase from current levels to over 40,000 µg/L from mid-2023, and then to around 80,000 µg/L by 2024.<br>While the Supplement indicated that predicted mounding would not express to surface except within the evaporation pond itself, there is the potential for long term (post closure) groundwater quality impacts from seepage down-gradient of the site including adverse impacts to nearby GDEs (Figure 1). The significance of this potential impact cannot be predicted from the information provided.<br>The proponent should note that unauthorised discharge (active or passive) of polluted water (diluted or non-diluted) to a waterway is considered an offence under the Water Act 1992 and the Waste Management and Pollution Control Act 1998. | Additional information is required to demonstrate, with certainty, that the operation and subsequent decommissioning of the proposed evaporation dam would not have an unacceptable impact on sensitive receptors and values in the downstream environment, particularly the recorded sacred site and relevant GDEs identified in Figure 1.<br>Detailed measures must be proposed that are likely to avoid and/or mitigate:<br>Potential impacts to the downstream environment from pit dewatering activities.<br>Passive or uncontrolled discharge of contaminants and impacts from the sources of contamination (evaporation pond and Fountain Head Pit).<br>Information must be provided to clearly define the extent, magnitude and duration of impacts and demonstrate that impacts to the environment, including from mitigation measures such as discharge, do not have significant residual impacts.<br>Demonstrate/explain how the mitigation measures proposed are achievable and will result in the best environmental outcome |
| In-pit storage of potentially acid-forming (PAF) material:<br>Section 2.4<br>Appendix 5, Appendix 6, Appendix 8 and Appendix 10 | The predicted volume of PAF material is 280,000 m3 and the Supplement indicates approximately 957,700 loose cubic metres (LCM)equivalent to 2 million tonnes) of PAF waste may be stored within Fountain Head pit, and encapsulated in three separate pods. This storage capacity is three times the estimated volume of PAF material to be stored.<br>Pod 1 has capacity to contain the highest amount of PAF material at 470,300 LCM and would be located above the pit lake water table.<br>• There are concerns that Pod 1 will not be sufficiently submerged at closure to prevent oxidisation.<br>• All three pods will be exposed (in-pit) until the pit is flooded at closure and likely to be generating acid and metalliferous drainage in the intervening period before a pit lake is formed.<br>The pods and wall rock will be exposed to ongoing oxidation and generating acid mine drainage for some time before full submergence.<br>It is stated that the runoff from these pods will be managed within the pit perimeter and as part of the ongoing dewatering of the pit during mining as described in Section 3.3 of the Draft EIS - through the pit dewatering process i.e. reporting to the evaporation pond. | 1. As the storage capacity is three times the estimated volume of PAF material to be stored, clarify this discrepancy, and provide additional information and details on the design, location, and operation of pods 1, 2 and 3.<br>2. Clarify that the predicted volume of PAF material is 280,000 m$^3$.<br>3. Provide a detailed description of the movement, placement and management of the PAF material.<br>4. Provide a detailed description of the methods to differentiate, and classify, the various water types likely to be encountered in the pit, and the proposed management options for each type.<br>5. Clarify the probable volume of acid and metalliferous drainage (seepage and runoff from pods) likely to be generated during the mining phase (Phase 2) of the project (following initial dewatering operations, and prior to flooding of the pit) that requires management.<br>6. Review and improve the models and site water balance (refer to comments from Water Resources, DEPWS), and focus on the collection, storage and disposal of this incidental water type. |
| The Fountain Head pit and post mining pit lake:<br>Section 3.4<br>Appendix 5, Appendix 6 and Appendix 8 | Noting model limitations, and extrapolation from only 4 data points (Appendix 8), the modelling suggests that the water quality of the pit lake during the mining and post mining phases of the Project is likely to deteriorate where the primary dissolved constituent of concern is arsenic.<br>High concentrations of arsenic will be generated from the likely sources of PAF material placed into the pit, wall rock interaction, evaporation, and seepage into groundwater from the evaporation pond.<br>Contaminants will likely be transported to the downstream environment along the regional groundwater flow direction.<br>A pit water quality assessment was undertaken to assess the storage of PAF material within the pit, and to understand the long term water quality.<br>Elevated concentrations of dissolved metals (Al, As, Co, Cu, Fe and Mn) in surface water (run-off) and groundwater (throughflow) means that groundwater and possibly surface water, is generally not suitable for drinking (for humans or livestock).<br>Post mining, the dissolved arsenic concentration is predicted to remain above the current average pit water concentration of 600 µg/L. This is higher than the livestock drinking water guideline (500 µg/L), and the aquatic ecosystem 80% protection level trigger value (140 µg/L). | 1. Additional information is required to demonstrate that the disposal of up to two million tonnes of PAF material in the pit reflects best practice at closure, and will not result in an unacceptable impact on sensitive receptors and values in the downstream environment, particularly the relevant GDEs identified in Figure 1.<br>2. Demonstrate that the option to submerge PAF waste rock beneath a water cover in the Fountain Head pit (scenario 1 as the base case) will result in achieving best practice closure (and an environmental improvement over the pre-existing conditions at the Proposal site).<br>3. Due to the expected presence of groundwater through-flow (in a northerly direction) forming a pathway for contaminant transport, demonstrate that contaminants are prevented from migrating from the sources, and an unacceptable impact on the environment would be avoided.<br>4. Provide estimations of the potential arsenic concentrations and other contaminant loads from the identified sources (evaporation pond and Fountain Head pit) along flow-paths in surface and groundwater both within, and outside the mine site.<br>5. Describe the processes and mechanisms that lead to a predicted rapid decline in arsenic concentrations in those areas likely to be contaminated both within, and beyond the boundary of the proposal site, post-closure.<br>6. Specify measures to mitigate the risk of contaminants entering the downstream environment, including development and implementation of trigger action response plans for water quality. |
| Post mining pit lake scenarios – water management options | Two scenarios are described for management of the pit post mining, both of which have potential risks.<br>Scenario 2 is presented as the preferred option (assumes diversion of 80% of the Fountain Head upper catchment water through the Fountain Head pit at the end of mining).<br>However, diversion of run-off from the upstream catchment through the Fountain Head pit (in scenario 2) may be problematic due to the design, location and construction of the Integrated Waste Landform becoming a barrier. | 1. Clarify that scenario 2 as the preferred option (where catchment inflows are diverted to flood the pit), can be effectively implemented without compromising the long term stability of the constructed IWL.<br>2. Provide details of the design that demonstrate how the scenario can be implemented without reconfiguring the IWL.<br>3. Provide details on how any flow-on effects of the design changes, including the potential impacts from diverting flood flows to the pit, will be managed in accordance with the environmental decision-making hierarchy stipulated in the EP Act. |

| Relevant section | Comment | Additional information required |
|---|---|---|
| Surface and groundwater quality | The Proponent advised that potential residual impacts to aquatic biodiversity were assessed in the Draft EIS and Supplement as negligible to low with impacts predicted to be either short term, localised, or undetectable with respect to natural variation.<br>However, the concentrations of arsenic, for example, in the proposed discharges via groundwater and surface waters, the water quality is several orders of magnitude above the national default guideline value (DGV).<br>DGVs are established by modelling the results of standard laboratory ecotoxicology tests to determine the threshold concentrations above which there may be a risk of causing harm to aquatic biota. It is also several orders of magnitude above the human health and livestock drinking guidelines.<br>An evaluation of post closure pit water quality was requested in the Direction to prepare the Supplement, and<br>this has been provided as Appendix 8 of the Supplement.<br>The modelling is showing concerning amounts of arsenic and metals will be generated. | 1. Conduct an environmental risk assessment of the proposed discharges via groundwater and surface water in accordance with ANZG (2018) Water Quality Guidelines - Applying the framework.<br>2. Describe the toxicity of arsenic and other contaminants of concern noting that suspended sediment, nutrients, ionic composition and ionic strength, hydrology are all potential stressors to be considered, and where:<br>• Seepage effects (mounding), the loss of containment of waste products, and transport of contaminants and waste into the downstream environment, are likely at the evaporation pond.<br>• Levels of dissolved arsenic concentrations are predicted in the modelling to increase in the evaporation pond from current levels to over 40,000 µg/L from mid-2023, and then to around 80,000 µg/L by 2024, and<br>• Concentrations are predicted to decline to levels below the respective stock water guideline (500µg/L) by the end of 2027 and the guideline for aquatic ecosystems (80% protection) shortly after in early 2028.<br>3. Demonstrate that the inland water environmental quality (surface and groundwater) is maintained or improved at the end of mining i.e. where the water quality objective meets the ANZG (2018) 95% species protection default guideline values. |

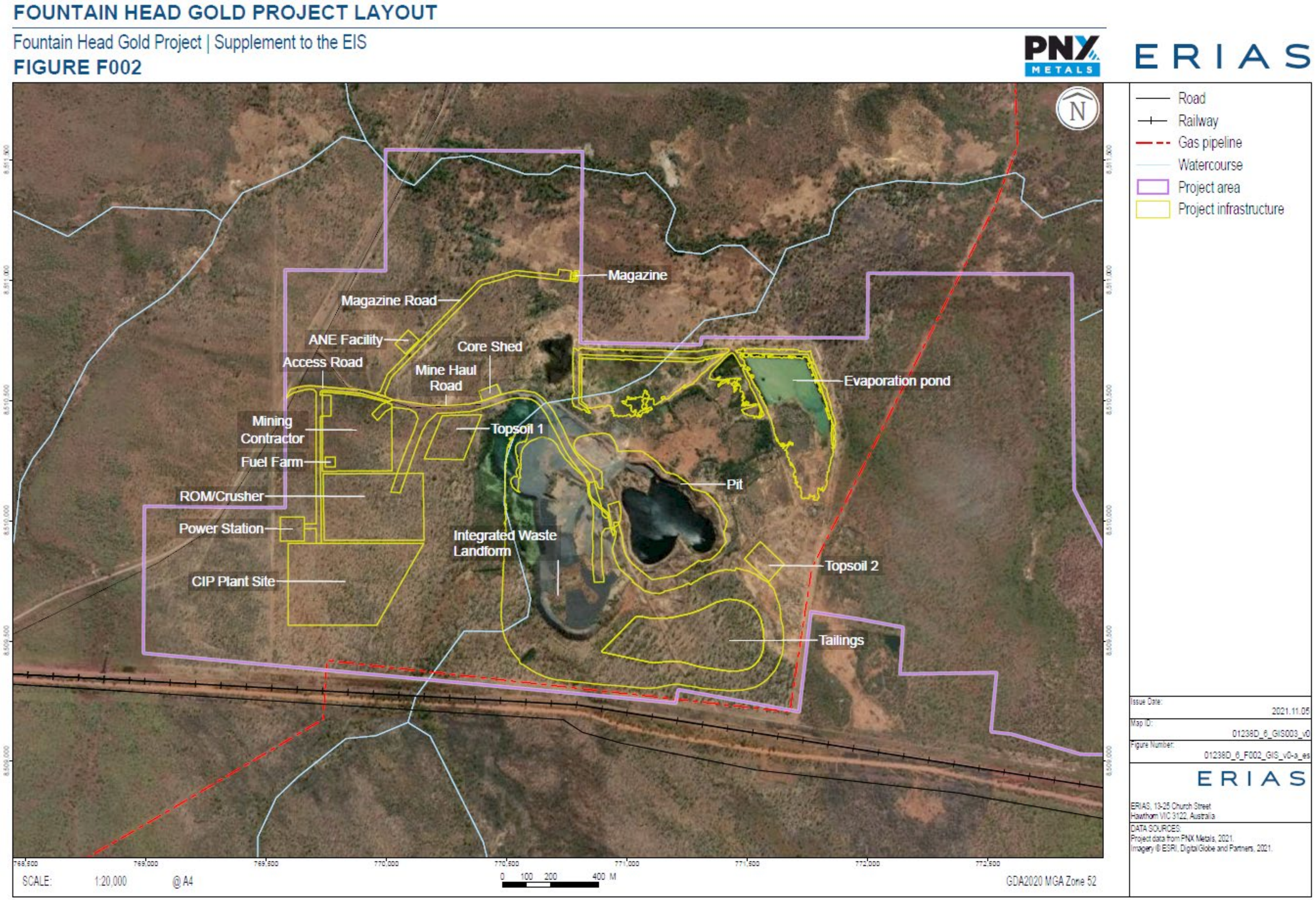

**Figure 1-1** **Proposed Fountain Head Gold Project Layout (ERIAS, 2021a)**

## 1.4 Methodology and Structure

A process flow diagram outlining the methodology and structure of this assessment is presented in Figure 1-2 and is summarised below:

- Step 1 (Section 2) – Establish a conceptual site model (source-pathway-receptor) to understand the processes that lead to acid generation/neutralisation and solubilisation of contaminants of potential concern (COPC) which contribute to changed water quality of the Fountain Head pit and EP.
- Step 2 (Section 3) – Define the source term for which the assessment will focus by characterising and screening the chemistry of PAF material, and the Project water types for COPC.
- Step 3 (Section 4) – Using the latest kinetic test data, predict concentrations of the source term constituents in the PAF contact water (leachate).
- Step 4 (Section 5) – Using the PAF leachate water quality predictions, model the evolution of Fountain Head pit lake and EP water quality by:
  - Incorporating the PAF leachate into a reactive mixing model (Geochemists Workbench) to predict the concentration of the source term constituents within the Fountain Head pit lake.
  - Predicting a loading rate for one source term constituent (arsenic) and addition of these data into a non-reactive solute balance model (Goldsim) paired with the FHGP water balance model (WBM) to estimate the evolution of water quality in the Fountain Head pit lake and EP over time.
- Step 5 (Section 6) – Discuss the implications of the proposed water management strategy for the FHGP.

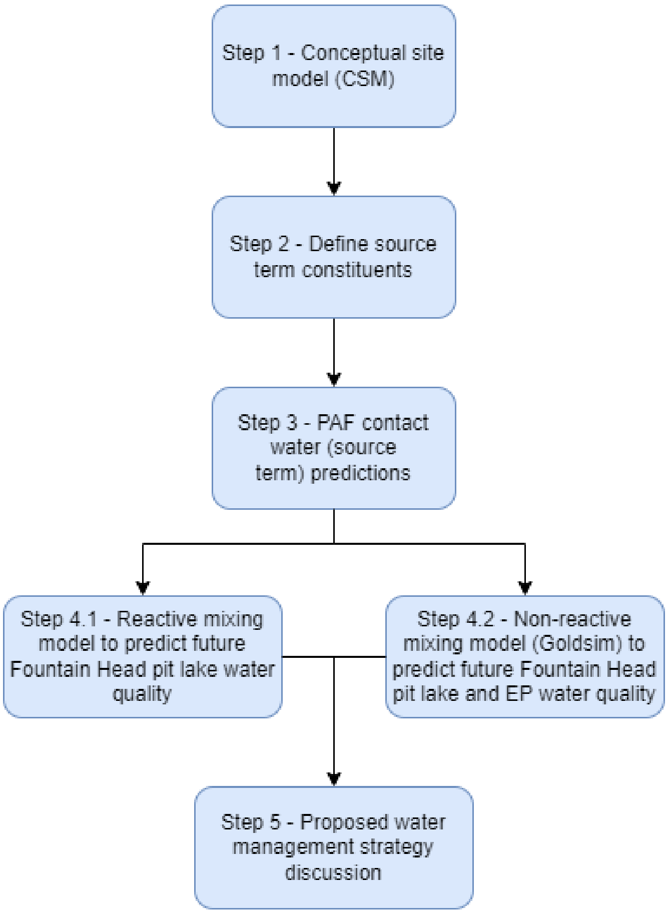

**Figure 1-2 Methodology**

# Section 2 Conceptual Site Model

## 2.1 Overview

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 by Land and Water Consulting Pty Ltd (LWC) to identify potential source(s), pathway(s) and receptor(s) associated with the geochemistry of storing PAF rock within the Fountain Head pit. The CSM contributes to an understanding of possible effects posed to environmental values (EVs) associated with in pit storage of acid generating waste materials.

The following sections summarise each of the source-pathway-receptor assessment components as well as providing context for the planned PAF storage and management within Fountain Head pit. The full source-pathway-receptor assessment is provided as Appendix B.

## 2.2 PAF Storage / Management Concept

The current proposed PAF management strategy is to dispose of the PAF rock within the Fountain Head pit to ensure best practice sub-aqueous disposal is met. Three storage 'pods' have been identified as potential in-pit storages of waste material with a combined total in-pit storage of ~957,700 Loose Cubic Metres (LCM) equivalent to around 2 Mt of waste rock storage (Figure 2-1). Of this storage capacity, around 53,900 LCM is proposed for storing PAF material, where assuming a bulk density of 2.73t/m$^3$ equates to around 150,000 tonnes (0.15 Mt).

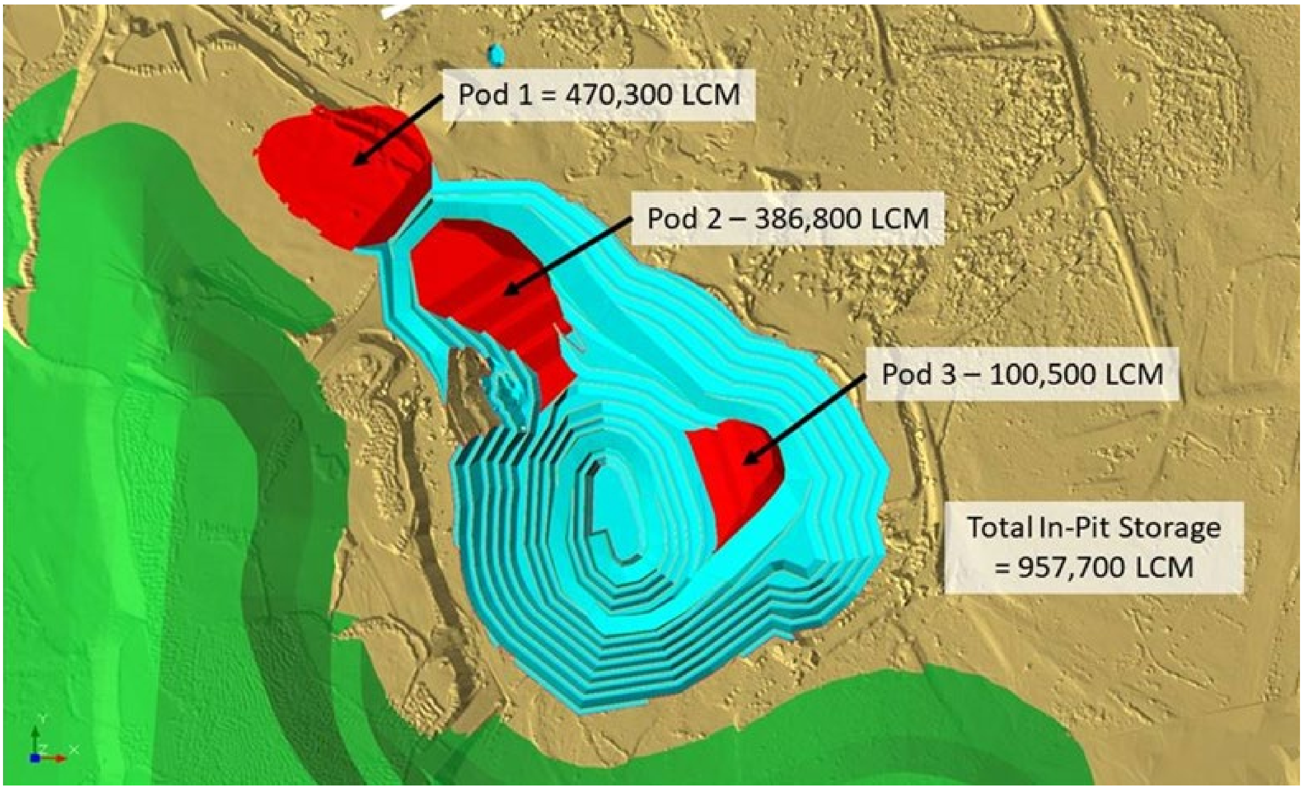

**Figure 2-1 Identified in pit storage pods**

The PAF material will be stored within the pit during mining, where at completion of mining all PAF material will be pushed to the bottom of the pit becoming submerged within a matter of months post mining and ensuring sub-aqueous disposal. A key benefit of sub-aqueous disposal is the exclusion of oxygen in order to prevent oxidation (or ongoing oxidation) of sulfide in the rock. The distribution of the PAF pods with regard to the pit lake water level recovery is annotated on Figure 2-2.

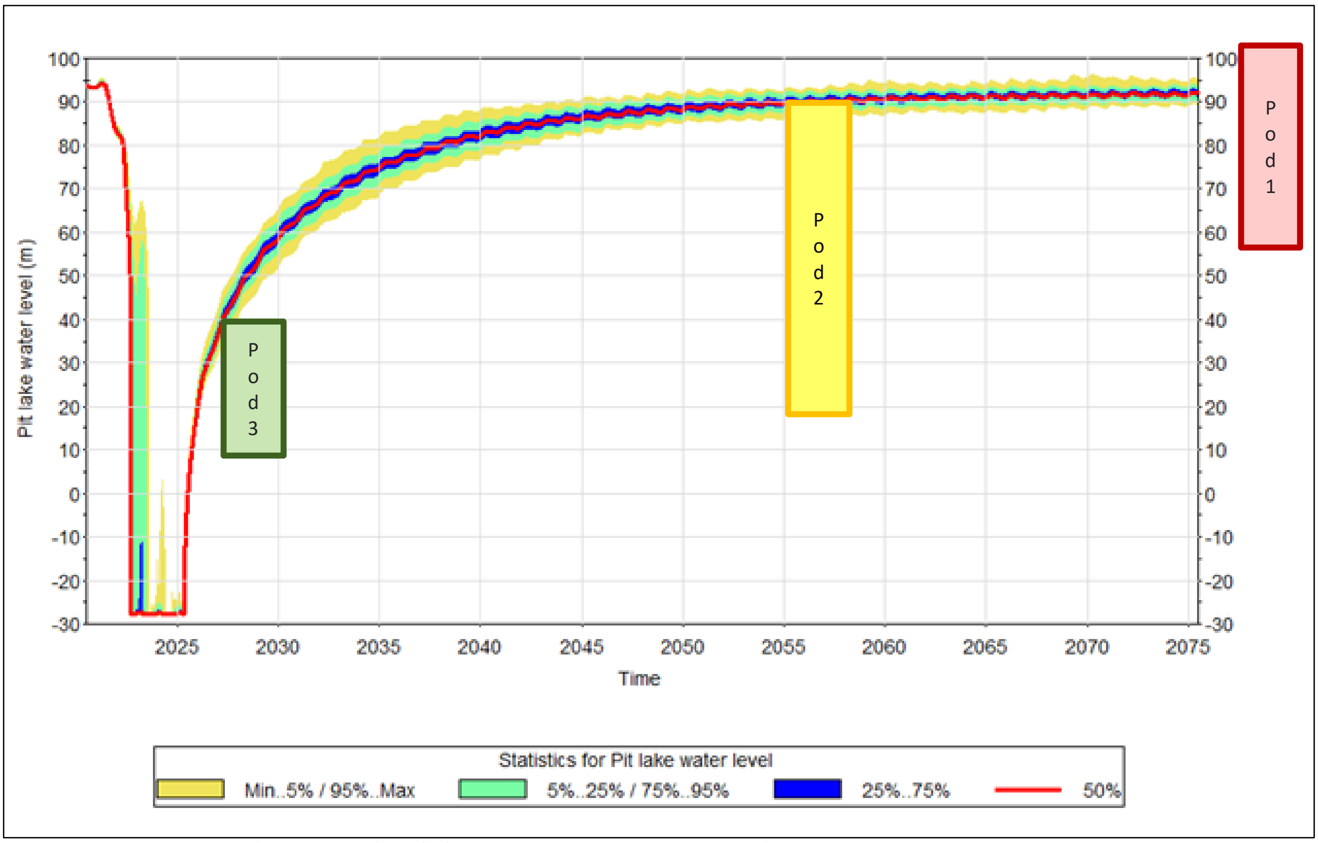

**Figure 2-2 Predicted pit water level change during dewatering and recovery**

## 2.3 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 (EGI, 2020) natural enrichments of metals and metalloids are present in these geological materials. Table 2-1 presents the geochemical sources for pit-lake water quality impacts.

**Table 2-1 Identified Sources**

| Geochemical Source (S) | Description | Discussion | Considered herein |
|---|---|---|---|
| S1 | PAF rock in base of Pit as PODS 1 – 3 (refer Figure 2-1). | 0.15 Mt of PAF rock with leach chemistry represented by kinetic sample 21363. | ☑ |

| Geochemical Source (S) | Description | Discussion | Considered herein |
|---|---|---|---|
| S2 | Open Pit – rock walls – as per Figure 2-3. | Sulfide oxidation in wall rock – dewatering and excavation exposes wall rock to atmospheric oxygen and solutes released by oxidation of sulfide minerals are flushed into the Pit by rainfall runoff or groundwater seepage through the rock wall.<br>PNX provided an estimation of the PAF wall exposures in the pit (email ERIAS to CDM Smith 13 October 2021).<br>As per Figure 2-3 there is approximately 18.8% of the 295,549 m$^2$ of pit wall which will be ore or PAF in nature (55,563 m$^2$). | ☑ |

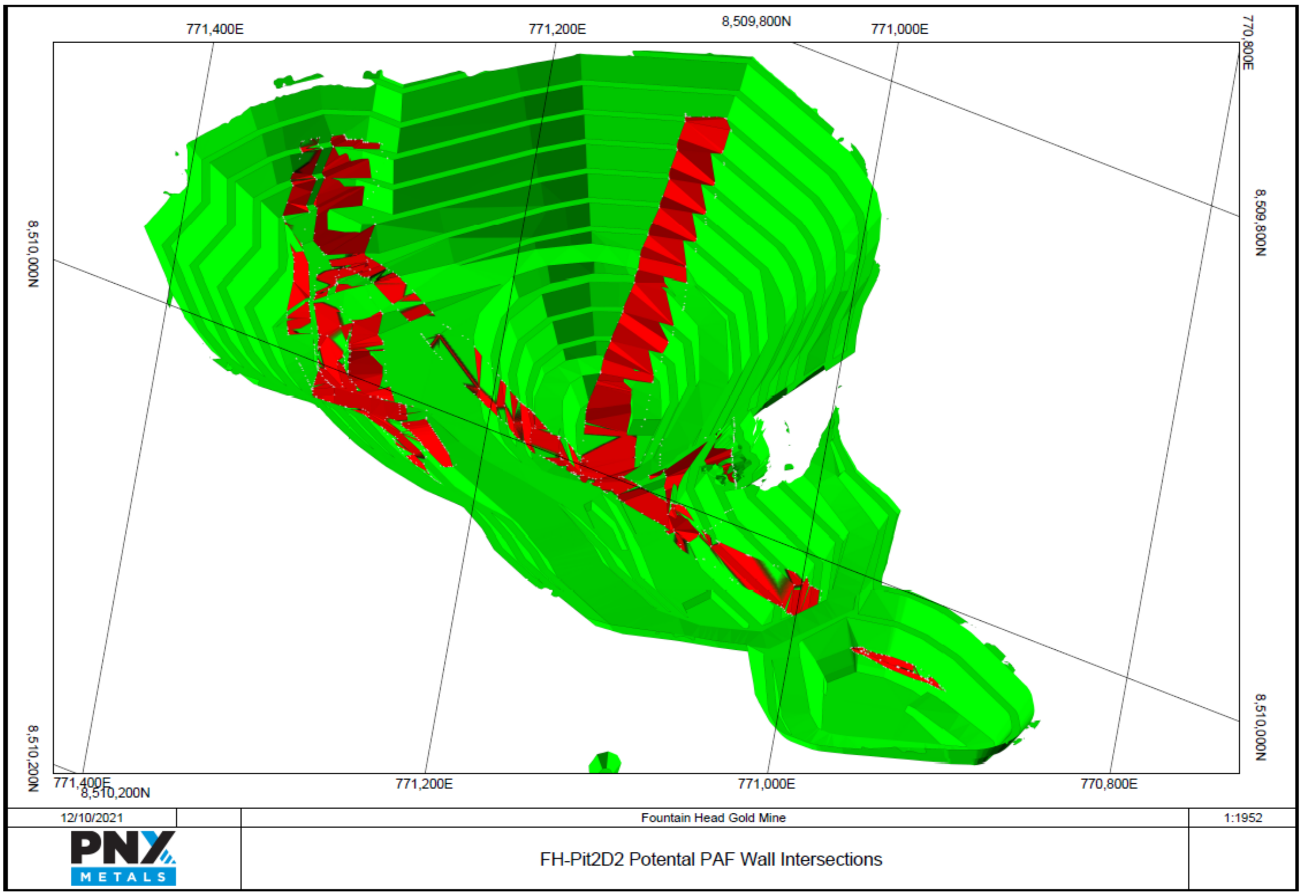

**Figure 2-3** **Fountain Head pit PAF wall intersection (red material denotes PAF rock and green material denotes remaining pit lithology)**

## 2.4 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 2-2. 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 EVs of groundwater).

**Table 2-2 Identified pathways**

| Pathways (P) | Description | Relevant to this study? |
|---|---|---|
| P1 | Groundwater/surface water 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) | ☑ |

Notes: ☒ Not identified or not relevant, not considered further in this assessment
☑ Potentially relevant, considered in this assessment

## 2.5 Receptors

For the source pathway receptor assessment, the receptor (R) represents the component, or receiving environment of an EV. These are summarised in Table 2-3.

**Table 2-3 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 |
| | Springs and pools | ☑ Perennial billabong approximately 2 km to the northeast of the FHGP.<br>☑ Possible groundwater dependant ecosystems 1 km to the north of the FHGP in an unnamed creek. |
| | Ecosystems supporting significant flora, vegetation and fauna | ☒ Stygofauna<br>☒ Troglofauna<br>☒ Terrestrial vegetation<br>☑ Migratory aquatic birds |
| | Ecosystems supporting significant amenity, recreation and cultural [4] values | ☒ None identified |
| | 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 |
| | Inland waters with high levels of active and passive recreation including multiple use wetlands | ☒ None identified |
| | Inland waters with significant cultural[4] or aesthetic values | ☑ Perennial billabong approximately 2 km to the northeast of the FHGP. Used only for cultural purposes. |

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

# Section 3 Source Term

## 3.1 Overview

The source term can be defined as the suite of elements with a propensity to leach from the source material. The source term is derived by screening the concentrations measured in any leachate generated (in this instance, the kinetic test data and background pit lake water) against generic water quality guidelines. This process identifies which elements may pose as a threat to receptors and informs the elements in which this assessment should focus. I.e. rather than modelling all elemental concentrations, this assessment uses the source term to narrow the suite modelled. This approach ensures the assessment is risk focused in that only the elements showing potential for environmental harm are investigated. The screening process is summarised in Figure 3-1.

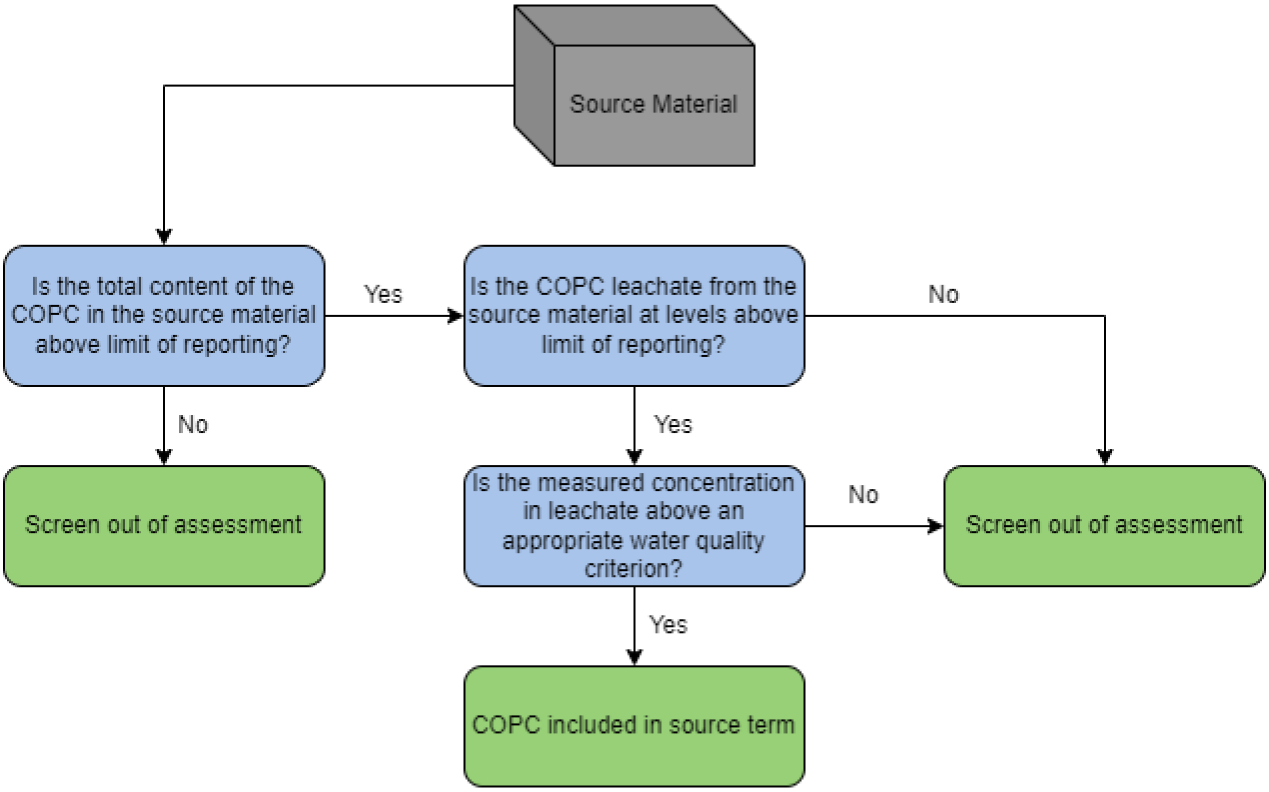

**Figure 3-1 Source Term Screening Process**

As part of the source term derivation, the FHGP geochemical data (waste rock and ore) have been characterised in this section by Environmental Geochemistry International (EGI) (EGI, 2020; EGI, 2022) along with the Project water quality baseline data. These results have been used to understand the processes which lead to the current and forecasted water quality at the FHGP.

## 3.2 Geochemical Characterisation

In order to obtain rock samples which would satisfactorily represent the distribution of waste rock types to be mined during the expansion of the existing Fountain Head pit, a number of drill holes were selected by EGI from the many drilled during resource definition drilling. Samples from these drill holes were selected to cover variations in lithology, oxidation and chemical composition of the waste rock, while also achieving appropriate spatial coverage of the proposed expanded pit. A value of 1 ppm Au (fire assay results) was used in most instances to delineate between ore (Au >1 ppm) and waste rock.

In total 111 drill hole samples, 18 waste rock samples (WRSs) samples and 3 samples from the existing waste rock stockpile and ore and 3 cyanide leached samples were tested for the following:

- Total sulfur (S).
- Paste (1:2) pH and EC.
- Single addition net acid generation (NAG) test.
- Acid neutralising capacity (ANC).

### 3.2.1 Elemental Speciation

Multi element composition testing of Fountain Head pit waste rock and ore was undertaken by EGI (2020) and is presented as Table H1 in such document.

Arsenic concentrations are very noticeable in terms of magnitude compared to other elements, reporting concentrations in excess of 10,000 mg/kg (for context general crustal concentration would be in the range 5 – 30 mg/kg). Arsenopyrite (an iron arsenic sulfide (FeAsS)) is present at the Site. Arsenic has a calculated geochemical abundance indices of over 10. Anything of 3 or above is generally counted as being heavily mineralised. Other elements reporting with a Geochemical Abundance Index (GAI) at or >3 is (as per Table H2 of the EGI report):

- Silver (Ag).
- Beryllium (Be).
- Bismuth (Bi).
- Cobalt (Co) (in the ore only).
- Copper (Cu) (in the ore only).
- Manganese (Mn).
- Lead (Pb).
- Sulfur (S).
- Selenium (Se).
- Uranium (U).
- Tungsten (W).

### 3.2.2 Static Testing

The EGI (2020) results of geochemical testing of samples obtained from drilling in the Fountain Head pit show:

- There is no immediately available acidity and low salinity in these samples when contacted with water, indicating that freshly mined rock is unlikely to provide low pH or saline drainage.
- Total S analysis showed a broad range up to 3%S, but with the vast majority (90%) having a relatively low S value of 0.5%S or less, suggesting the occurrence of pyritic rock is not widespread.
- ANC was relatively low, ranging up to 33 kg $H_2SO_4$/t, indicating a general lack of excess buffering.
- Carbon speciation analysis indicates carbonate content is negligible, with the total carbon content of these samples generally low. This is consistent with Acid Buffering Characteristic Curve test results which also suggest little carbonate content, and that the small amount of carbonate present in these samples is predominantly iron carbonates (ferroan dolomite, siderite), which will react relatively slowly.
- Most samples were net acid producing potential (NAPP) negative, with the majority of these having ANC/MPA ratios of 2 or more, indicating a high factor of safety.

- The majority (70%) of NAGpH values were 4.5 or greater, corroborating the Acid Base Accounting results which indicated most samples are likely to be non-acid forming (NAF).
- Chromium Reducible Sulfur measurements show that greater than 90% of Total S is contained in sulfide minerals, suggesting that Total S measurements can be used as suitable guide to the sulfide (pyrite) content of these materials.
- Test results were used to classify samples as NAF, PAF, PAF-LC or UC. Around 80% of samples tested were classified NAF (including unclassified [UC] equivalents), 15% PAF-LC (including UC equivalents) and 5% PAF. Overall results indicate most waste materials to be mined will be NAF, with a minor proportion of PAF.

Given the relatively low ANC and poor reactivity, criteria based on Total S was selected as the best potential option for routine classification of Acid Rock Drainage (ARD) rock types. Using the results from detailed geochemical testing, sulfur distributions were determined for each of NAF, PAF-LC (Low Capacity) or PAF ARD classifications. The results show:

- NAF samples can be differentiated from PAF/PAF-LC samples by applying a Total S cut-off of 0.2%S
- 95% of samples classified NAF have a Total S value of 0.2% or less, and all PAF samples and 60% of PAF-LC samples have a Total S value of greater than 0.2%S.
- Although using a ≤0.2%S criteria for NAF waste rock includes 40% PAF-LC material, these have low acid potential and operational blending with NAF materials would be expected to account for any minor acidity generated.

### 3.2.3 Single Addition Leach Testing

In addition to the above testing, water and peroxide extractions were conducted on selected samples to understand the likely quality of drainage from freshly mined and oxidised waste rock respectively. EGI (2020) reported the results of these tests show:

- All water extracts produced circum-neutral to mildly alkaline solutions with low salinity. Metal concentrations in water extracts were also very low to non-detectable.
- These results suggest leachates from freshly mined waste rock from the Fountain Head pit will, in general, be of reasonable quality. However, segregation of the PAF waste rock using a Total S value of 0.2% may improve leachate quality for the majority of fresh waste rock containing ≤0.2%S.
- Water extracts for WRS samples had neutral pH and low salinity. Metal/metalloid concentrations were also very low or non-detectable.
- Water extractions conducted on an ore sample and the same sample following cyanidation showed that cyanide leaching has significantly increased arsenic mobility in this sample.
- Arsenic is significantly enriched in the majority of samples tested relative to average crustal and soil abundance.
- Iron, copper, cobalt, nickel and arsenic concentrations in peroxide leachates correlated with Total S content of the samples, indicating that segregation of samples with significant sulfur content is likely to reduce the concentration of these heavy metals/ metalloids in drainage from oxidised waste rock in the WRS.
- Peroxide leachates suggest drainage from oxidised waste rock containing more than 0.2% sulfur may contain substantial concentrations of Al, Co, Mn, Ni, Pb, Zn and waste rock with Total S concentrations above this value should be managed to minimise oxidation and release of heavy metals.

### 3.2.4 Kinetic Testing

Column leach tests are typically conducted by filling a length of pipe or funnel with a solid sample and passing water (or another leachate) 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).
- Leachate composition (water or another reagent, sparged to remove $O_2$, 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.

EGI's standard free-draining column leach method was used for kinetic testing, as described in the AMIRA ARD Test Handbook[1]. Each column comprises 2.0 kg (dry weight) of crushed solids housed within a plastic Buchner funnel measuring 174 mm in diameter and 100 mm in height. Immediately following setup, the samples were flushed with 800 mL of deionised water and first-flush leachates were collected for analysis on 12 July 2021. Thereafter, samples were subjected to cyclic wetting and drying on a weekly basis over a four-week leach cycle. During the first three weeks of each cycle the samples were moistened by a once weekly addition of water at a rate of 100 mL/kg. On the fourth week the samples were flushed by addition of 400 mL/kg, with the leachates collected in plastic containers positioned immediately beneath the funnel spouts. Typically, 450 to 500 mL of leachate were collected from a column per cycle.

At the time of project delivery, the column leach data spans 24 weeks (July 2021 to December 2021) totalling seven test measurements. A total of five columns have been tested including the following material:

1. PAF Rock.
2. PAF-LC Rock.
3. NAF Rock.
4. Blend of PAF and NAF rock (10/90).
5. Tailings.

For the purposes of pit lake water quality prediction, the PAF data is of interest in the first instance. The kinetic test for PAF uses sample 21363 of which is summarised in Table 3-1.

**Table 3-1 Sample 21363 characteristics**

| Sulfur | ANC | NAPP | $NAG_{4.5}$ | $NAG_{7.0}$ | NAGpH | Weight | Start | Sample |
|---|---|---|---|---|---|---|---|---|
| %S | $kgH_2SO_4/t$ | $kgH_2SO_4/t$ | $kgH_2SO_4/t$ | $kgH_2SO_4/t$ | pH Units | g | Date | Code |
| 0.67 | 9 | 12 | 4 | 10 | 3.3 | 2001 | 09/01/21 | FH/21363 |

General trends observable from sample 21363 are:

- In line with elemental speciation, arsenic is by far the predominant element in terms of metal/ metalloid magnitude.
- All metals are generally in a steady state other than copper which has ~doubled.
- No alkalinity is recorded.
- Sulfate has decreased three to four-fold.

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[1] EGI 2002. AMIRA ARD Test Handbook. Project P387A. Prediction and Kinetic Control of Acid Mine Drainage, AMIRA International Limited, Melbourne, Australia.

- Acidity doubled in the first 12 weeks with a concomitant decrease in pH from 5.9 to 4.8.
- Acidity is relatively stable at week 24 relative to week 12 (38 mg/L versus 59 mg/L).
- pH is relatively stable around 4.6 in week 24 (4.8 in week 12).

EGI provided the following commentary to ERIAS on 1 February 2022:

- Heavy metal concentrations of the PAF waste leachates contained elevated concentrations of Co, Ni, Mn and Zn across the 24 weeks of testing.
- Copper concentrations appear to be pH controlled and as the pH dropped in the leachate from the PAF material, the concentration increased significantly.
- Colloidal species of aluminium in particular are not likely to have the same toxicity as dissolved aluminium species, aluminium should not be regarded as a potential toxic species present in waste rock drainage. It should be noted however, that for the PAF sample, calculated solution concentrations of aluminium and measured concentrations matched from week 12 onwards. This coincides with a decrease in leachate pH to below 5, where aluminium solubility would be expected to increase. Dominant solution species predicted from solution modelling include AlSO4+ and AlF2+ at lower pH which may contribute to toxicity of PAF leachates.
- Concentrations of arsenic are elevated in leachate from the PAF-LC column, increasing as leaching continued, without any obvious correlation to leachate pH or sulphate release. Leachate concentrations of arsenic appear to reflect the amount of arsenic in the sample in the order PAF-LC>PAF>NAF≈Blend. Leaching of arsenic from the cyanide leached ore was significantly higher than from waste rock, probably reflecting both the relatively high concentration of arsenic in the ore and the reduced particle size compared to waste rock. While arsenic concentrations in leachates from the PAF-LC sample might suggest a potential issue with leaching from PAF-LC rock in the IWL, arsenic concentrations in leachates from the blended sample were very low throughout testing. If dilution of the PAF-LC waste in the blended sample was taken into account, leachate concentrations from the blended sample were slightly lower than would be expected from dilution alone. This may suggest retention of arsenic in the blended column, perhaps as a result of sorption processes.
- Further, co-disposal of PAF-LC waste with NAF waste would seem unlikely to impact seepage water quality. Even if arsenic in seepage from the IWL were occur at concentrations slightly higher than those measured in leachates from leach column tests, the impact on groundwater and pit water would likely be minimal, given the elevated background arsenic concentrations in groundwater at the site.
- The predicted small volume (≈2%) of PAF waste expected during the pit expansion at Fountain Head is likely to produce low quality drainage if exposed to atmospheric conditions. This could include elevated concentrations of a number of metals including aluminium, cobalt, copper, manganese, nickel and zinc. Based on the results of the leach column tests, the lag time to increased concentrations of metals in pore water could be as short as 2 – 3 months and, depending on rainfall, drainage containing elevated levels of metals potentially shortly after this. Although the pH may remain above 4.5 for some considerable time, this does not appear to preclude significant increases in metal concentrations.
- EGI considered that concentrations of arsenic were elevated in leachate from the PAF-LC column, increasing as leaching continued, without any obvious correlation to leachate pH or sulfate release.

## 3.3 Project Water Quality

### 3.3.1 Water Quality and Seasonal Variability

A piper diagram of various waters associated with the FHGP is presented in Figure 3-2, while the sample locations are shown in Figure 3-4. The waters have been categorised into five groups (including “dry” and “wet” sub-groups for dry and wet season samples, respectively) to give an indication of the potential mixing of waters that could be occurring on site. It should be noted that FH Lake is a different site to FH pit and that both of these sampling locations are thought to be influenced by mine-related water-rock interaction processes (i.e. the source of altered chemical water composition as shown at the top of diamond section of Figure 3-2). Key observations relating to these data are:

- The Fountain Head Pit contains a considerable historical dataset including depth profiling in October 2016.
- The groundwater and surface water types range from Mg- to Na-$HCO_3$ and are similarly grouped, suggesting these waters have undergone similar degrees of water-rock interaction (i.e. conceptually, shallow groundwater may be sourced from surface water as sheet-flow or creek flow, noting that surface water samples are from both wet and dry seasons).
- The groundwater samples have elevated Mg and $HCO_3^-$ relative to surface water samples suggesting interaction with dolomitic rocks.
- Fountain Head Lake is predominantly a Mg-$SO_4$ type water with some spread towards Mg-$HCO_3$ suggesting localised water-rock interaction (e.g. from adjacent WRS or waste rock within the pit).
- The Fountain Head Pit water samples are more tightly grouped as a Mg-$HCO_3$ type water.
- The Fountain Head Pit grouping appears to be a mixture of the local source that contributes to the FH Lake samples (i.e. water type found at the top of diamond section of Figure 3-7) and a groundwater source from the near-vicinity of the Pit.

Analysis of historical time series water quality data shows that runoff originating in the southern part of the catchment (represented by FHSW03 shown in Figure 3-4) strongly influences the concentrations of water quality analytes in Fountain Head Lake. Effectively, the volume of water stored in the Lake is flushed each year during the wet season prior to returning to concentrations indicative of mine-drainage (see next section). This is represented in Figure 3-3 where hardness (as $CaCO_3$) and dissolved iron concentrations are shown for Fountain Head Lake and FHSW03 over time (other major ions and metals show similar changes).

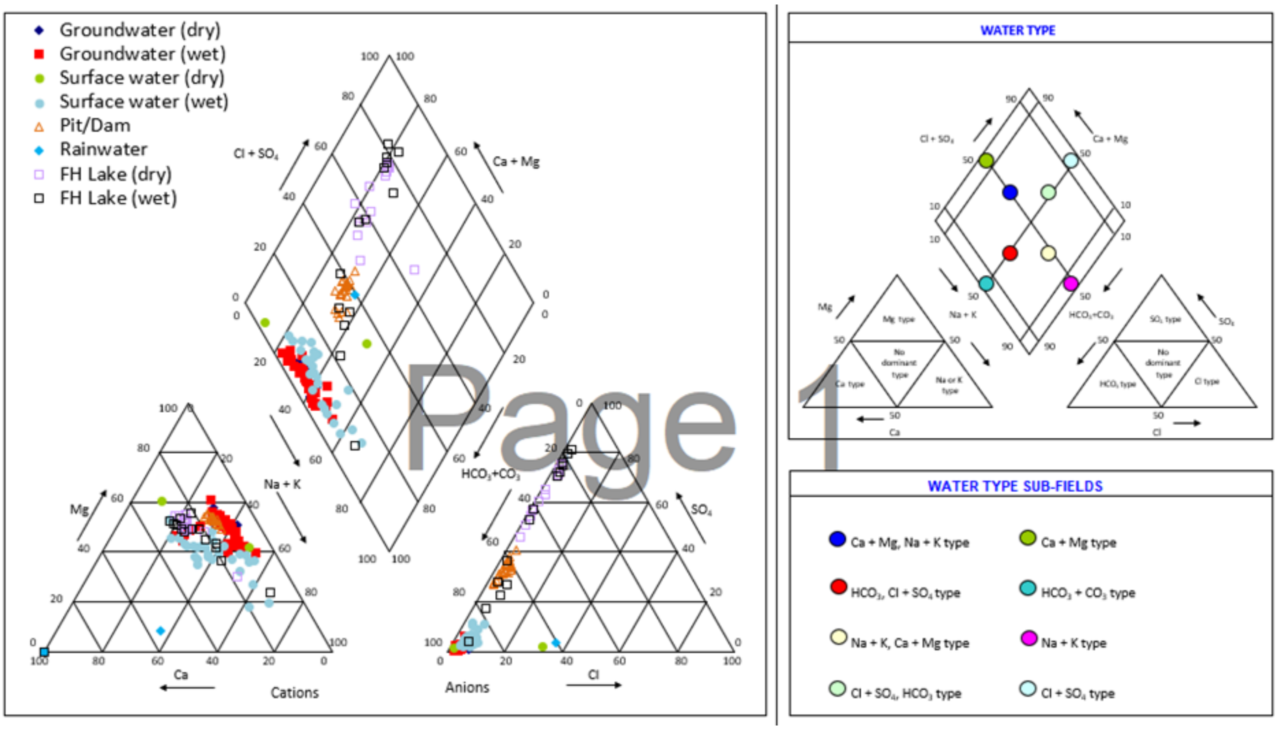


Figure 3-2 Piper diagram of project area water types (CDM Smith, 2021)

This flushing effect is most-easily seen following the 2014 dry season where increasing major ion concentrations suddenly drop at the onset of the 2014/15 wet season. This corresponds with a spike in dissolved iron and other metals (aluminium, copper and zinc), which are thought to be the result of dissolution from the relatively old and weathered soils in the region by rainfall-runoff.

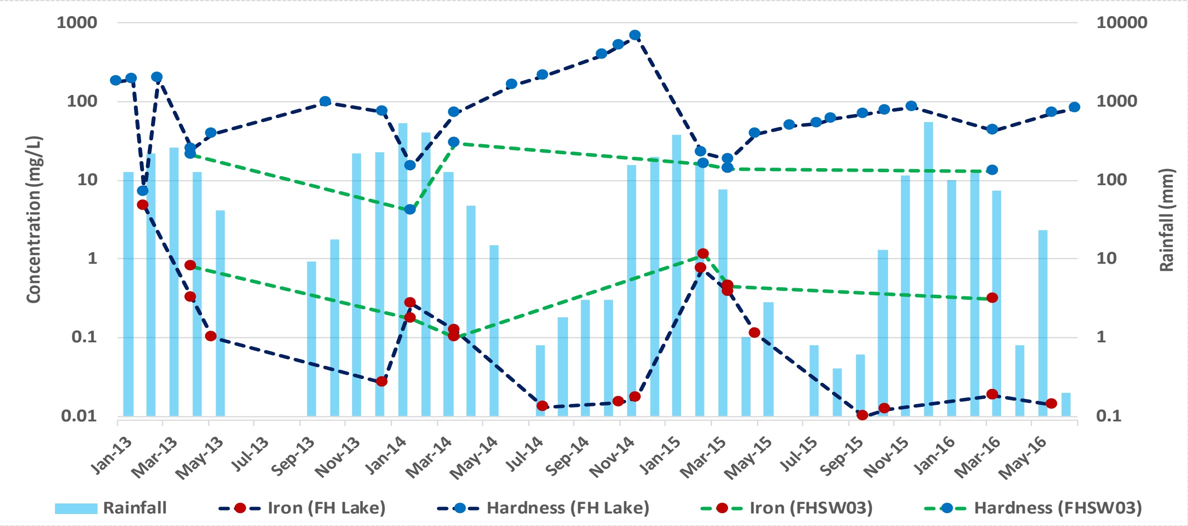
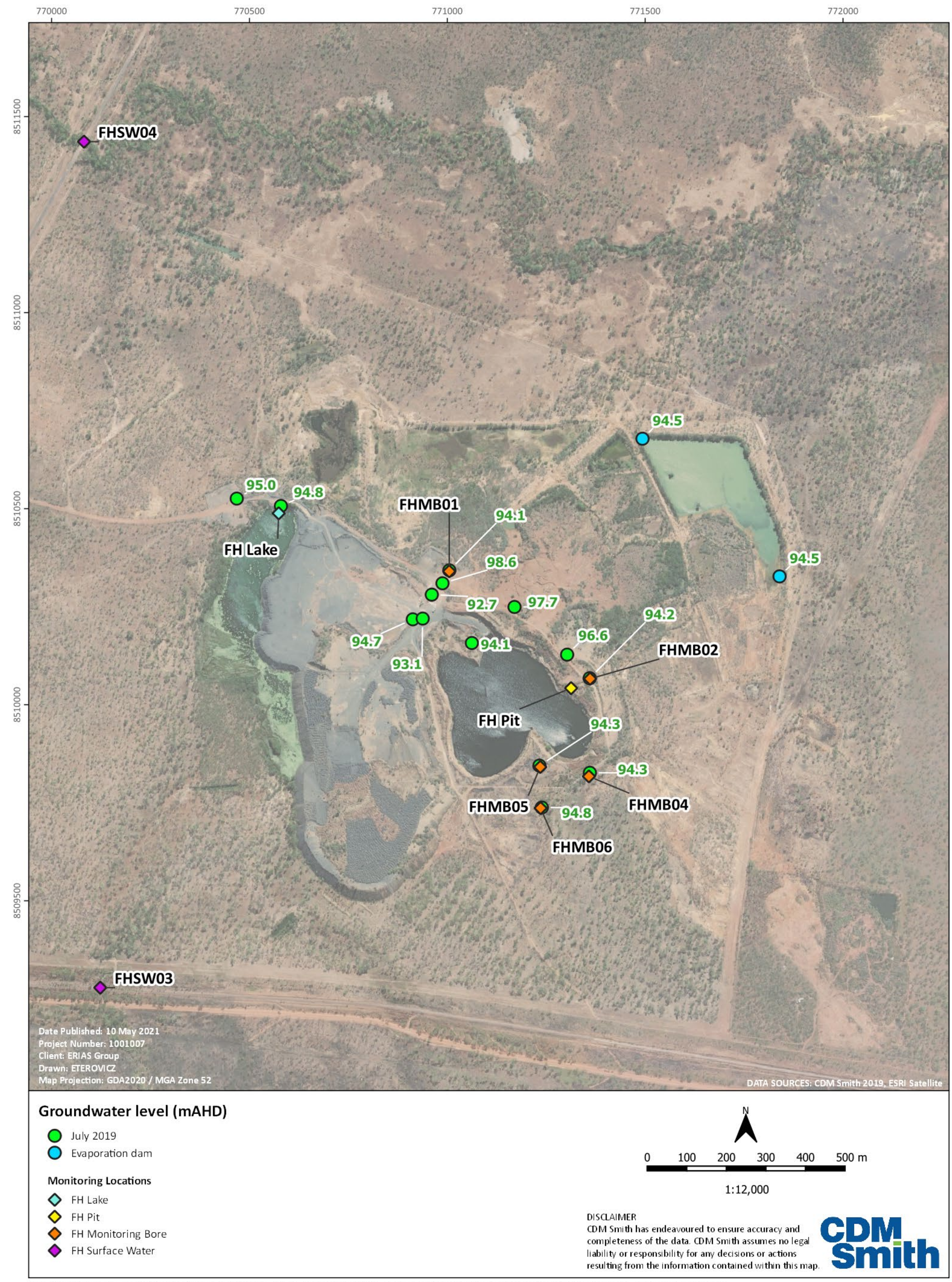


**Figure 3-3** **Fountain Head Lake and FHSW03 selected water quality analyte concentrations over time**



\\cdminc.internal.cdm.com\offices\AUST\Project\1001007 - ERIAS_FountainHead2021_WaterModelUpdates_Soil Sampling\7Work\3GIS\QGZ\ERIAS_groundwater levels.qgz

Figure 3-4 July 2019 groundwater levels and monitoring sites

### 3.3.2 Mine Drainage Water Quality Evolution

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. Ficklin Diagrams provide a method for illustrating the influence of these processes and can be used to interpret variations in mine drainage water chemistry between different deposits. Traditionally the diagram is populated by plotting the sum of base metals zinc, copper, lead, cadmium, cobalt, and nickel against pH which allows for a diagnosis on different geological controls.

Figure 3-5 provides an overview for means of interpreting a Ficklin Diagram. The location in which data points plot on the diagram can provide an indicative diagnosis of the mine drainage type, i.e. whether the drainage type is acid mine drainage (AMD) or neutral mine drainage (NMD) / saline drainage. The locality of the data points, however, should not be construed as representing strict classifications as there are no formal guidelines for quantitative definitions of the mine drainage types mentioned (GARDGuide, 2015). Also depicted on the figure are the principles which govern the mine water quality that can explain increases/decreases in acidity and base metal concentrations.

The water groups at Fountain Head have been plotted on a Ficklin Diagram in Figure 3-6. Using the earlier figure as a diagnostic reference it can be observed that water groups at the Fountain Head site can be classified as NMD water due to their near-neutral pH and base metal concentrations. Using the principles outlined in the Ficklin Diagram it is likely that the water groups are influenced by the presence of carbonate minerals which provide a neutralising effect. Additionally surface water inflows are likely to increase dilution of the water's pH and major ions although, conversely to the principles suggested by the Ficklin Diagram, the addition of surface water to the Lake increases the concentration of metals as a result of interaction with weathered soils in and around the mining area.

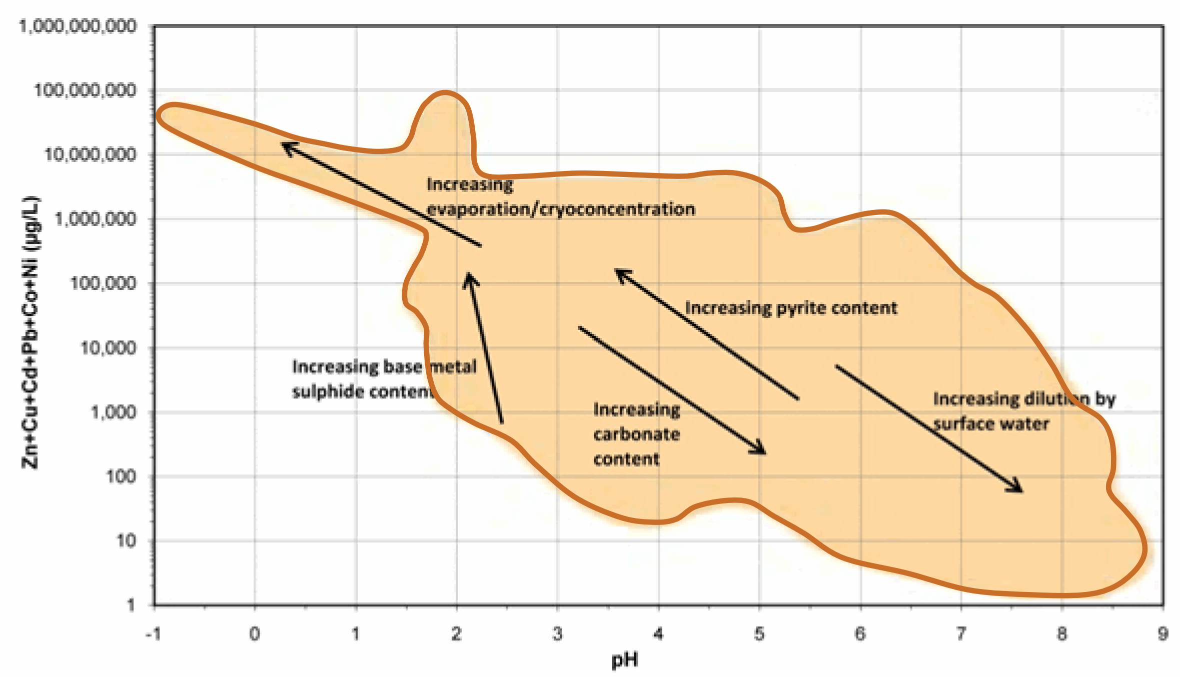


**Figure 3-5 Ficklin Diagram showing selected principles that govern mine water quality (GARDGuide, 2015)**

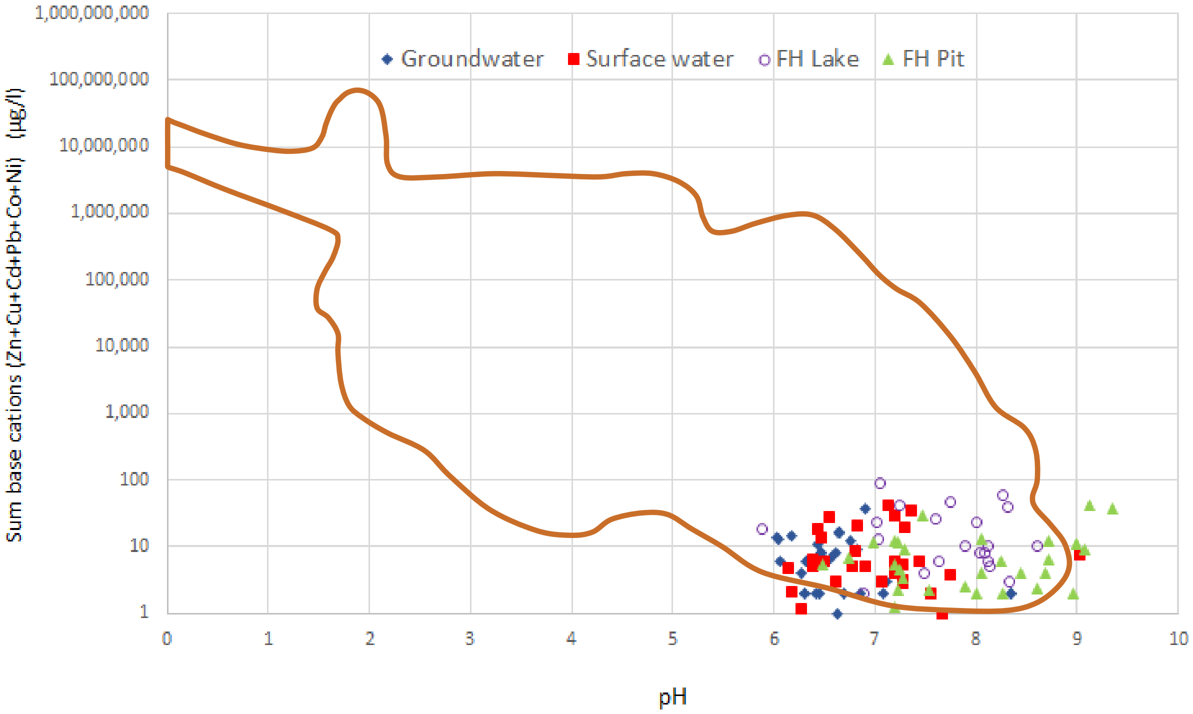


**Figure 3-6** **Ficklin Diagram of Fountain Head water groups relative to reference shape of GARDGuide (2015)**

### 3.3.3 Representative Concentrations for Solute Balance

Geometric mean parameter concentrations of each water type are presented in Table 3-2. Geometric mean concentrations were adopted to compare the water composition of each water source at the FHGP and due to uncertainty on the spatial extent and volume of groundwater with different chemical signatures. For example, groundwater monitoring wells FHMB01, FHMBO02 and FHMB03 which are located to the northern and eastern sides of the pit, generally have elevated metal concentrations compared to groundwater samples collected from bores located to the south of the pit, i.e. FHMB04, FMB05 and FMB06. This observation supports the conceptualisation that the current Fountain Head pit has a minor throughflow component with groundwater flowing to the northeast (CDM Smith, 2022), however, these data also suggest the pit lake acts predominantly as a groundwater sink given the metal concentrations in the northeast (down gradient) monitoring bores are substantially lower than the pit lake. Further discussion is made regarding the threat to downstream EVs as a result of pit lake COPC concentrations in Section 5.2.5.

Comparison of these data demonstrate a strong distinction in arsenic and sulfate concentrations of the Fountain Head pit lake as opposed to concentrations in surface and groundwater. This is consistent with a NMD signature as shown in Figure 3-6.

**Table 3-2 Geometric mean parameters for Fountain Head water sources (CDM Smith, 2021a)**

| Parameter | Stock water guidelines (ANZECC, 2000) | Surface water | Rainfall [1] | FHSW03 | Groundwater | Fountain Head Pit | Fountain Head Lake | Evaporation Pond |
|---|---|---|---|---|---|---|---|---|
| FLS EC (µS/cm) | - | 184 | - | 70 | 378 | 409 | 357 | 38 |
| TDS calc EC (mg/L) | 4,000 – 5,000 [2] | 119 | 7 | 45 | 246 | 266 | 232 | 25 |
| Hardness (mgCaCO$_3$/L) | - | 27 | - | 14 | 102 | 141 | 72 | 10 |
| Total Alkalinity as CaCO$_3$ (mg/L) | - | 45.6 | 2.7 | 35 | 158 | 136 | 38 | 26 |
| Calcium-Dissolved (mg/L) | 1,000 | 3.9 | 1.2 | 1.5 | 8.6 | 13 | 9.4 | - |
| Chloride (mg/L) | - | 2.6 | 1.9 | 1.7 | 4.3 | 5.5 | 2.6 | 30 |
| Magnesium-Dissolved (mg/L) | - | 5.2 | 0.1 | 2.4 | 19 | 25 | 12 | 2.3 |
| Potassium-Dissolved (mg/L) | - | 1.4 | 0.1 | 1.0 | 1.9 | 1.8 | 1.6 | 0.6 |
| Sodium - Dissolved (mg/L) | - | 7.8 | 0.9 | 6.2 | 25 | 29 | 11 | 2.3 |
| Sulfate (mg/L) | 1,000 | 4 | 0.2 | - | 2.5 | 68 | 59 | - |
| Aluminium-Dissolved (µg/L) | 5,000 | 111 | - | 143 | 58 | 5.2 | 70 | - |
| Arsenic-Dissolved (µg/L) | 500 | 2.6 | - | 1.8 | 56 | 567 | 7.6 | 0 |
| Cobalt (µg/L) | 1,000 | 0.5 | - | 1 | 1 | 0.6 | 0.9 | - |
| Copper-Dissolved (µg/L) | 1,000 | 1.4 | - | - | 1.3 | 0.7 | 1.8 | - |
| Iron-Dissolved (µg/L) | - | 223 | - | 375 | 1272 | 26 | 74 | - |
| Zinc-Dissolved (µg/L) | 20,000 | 4.4 | - | 4.1 | 5.1 | 4.4 | 9.6 | - |

Notes: 1. Darwin rainfall data from Crosbie et al. (2012)
2. Beef cattle

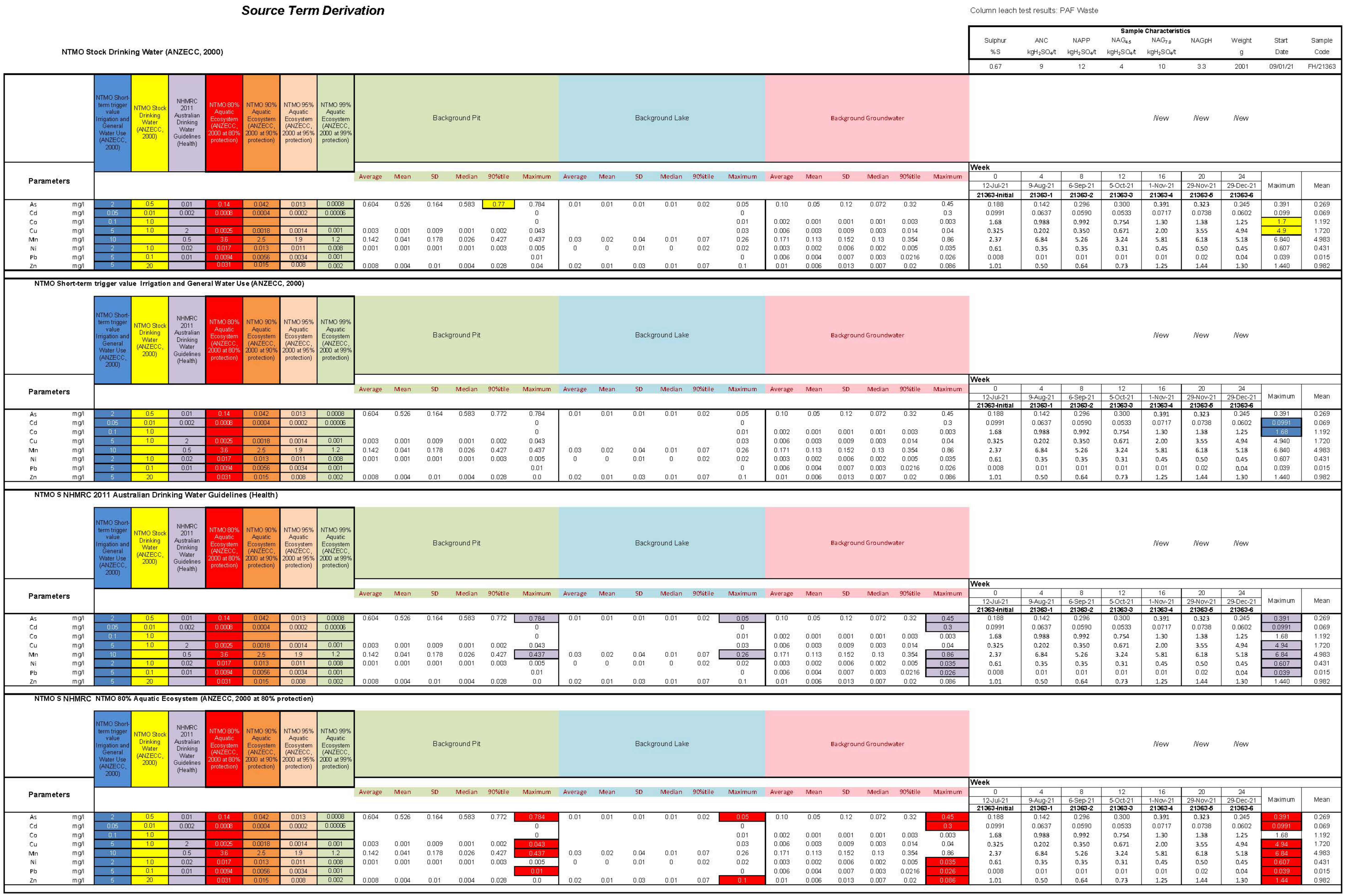
## 3.4 Derivation of Source Term

Existing groundwater, Fountain Head Lake and pit lake water quality have been compared to the following water quality criteria with respect to the screening process summarised in Figure 3-1:

- NTMO Short-term trigger value Irrigation and General Water Use (ANZECC, 2000)
- NTMO Stock Drinking Water (ANZECC, 2000)
- NHMRC 2011 Australian Drinking Water Guidelines (Health)
- NTMO 80% Aquatic Ecosystem (ANZG 2018 at 80% protection)
- NTMO 90% Aquatic Ecosystem (ANZG 2018 at 90% protection)
- NTMO 95% Aquatic Ecosystem (ANZG 2018 at 95% protection)
- NTMO 99% Aquatic Ecosystem (ANZG 2018 at 99% protection)

The results of the screen are presented in Table 3-3.

## Table 3-3 Source term derivation



***Source Term Derivation***

Column leach test results: PAF Waste

| Sample Characteristics | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sulphur | ANC | NAPP | $NAG_{4.5}$ | $NAG_{7.0}$ | NAGpH | Weight | Start | Sample |
| %S | $kgH_2SO_4/t$ | $kgH_2SO_4/t$ | $kgH_2SO_4/t$ | $kgH_2SO_4/t$ | | g | Date | Code |
| 0.67 | 9 | 12 | 4 | 10 | 3.3 | 2001 | 09/01/21 | FH/21363 |

NTMO Stock Drinking Water (ANZECC, 2000)

| Parameters | | NTMO Short-term trigger value Irrigation and General Water Use (ANZECC, 2000) | NTMO Stock Drinking Water (ANZECC, 2000) | NHMRC 2011 Australian Drinking Water Guidelines (Health) | NTMO 80% Aquatic Ecosystem (ANZECC, 2000 at 80% protection) | NTMO 90% Aquatic Ecosystem (ANZECC, 2000 at 90% protection) | NTMO 95% Aquatic Ecosystem (ANZECC, 2000 at 95% protection) | NTMO 99% Aquatic Ecosystem (ANZECC, 2000 at 99% protection) | Background Pit | | | | | | Background Lake | | | | | | Background Groundwater | | | | | | Week | | | | New | New | New | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum | 0 | 4 | 8 | 12 | 16 | 20 | 24 | Maximum | Mean |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | 12-Jul-21 | 9-Aug-21 | 6-Sep-21 | 5-Oct-21 | 1-Nov-21 | 29-Nov-21 | 29-Dec-21 | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | **21363-Initial** | **21363-1** | **21363-2** | **21363-3** | **21363-4** | **21363-5** | **21363-6** | | |
| As | mg/l | 2 | 0.5 | 0.01 | 0.14 | 0.042 | 0.013 | 0.0008 | 0.604 | 0.526 | 0.164 | 0.583 | 0.77 | 0.784 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.05 | 0.10 | 0.05 | 0.12 | 0.072 | 0.32 | 0.45 | 0.188 | 0.142 | 0.296 | 0.300 | 0.391 | 0.323 | 0.245 | 0.391 | 0.269 |
| Cd | mg/l | 0.05 | 0.01 | 0.002 | 0.0008 | 0.0004 | 0.0002 | 0.00006 | | | | | | 0 | | | | | | 0 | | | | | | 0.3 | 0.0991 | 0.0637 | 0.0590 | 0.0533 | 0.0717 | 0.0738 | 0.0602 | 0.099 | 0.069 |
| Co | mg/l | 0.1 | 1.0 | | | | | | | | | | | 0 | | | | | | 0.01 | 0.002 | 0.001 | 0.001 | 0.001 | 0.003 | 0.003 | 1.68 | 0.988 | 0.992 | 0.754 | 1.30 | 1.38 | 1.25 | 1.7 | 1.192 |
| Cu | mg/l | 5 | 1.0 | 2 | 0.0025 | 0.0018 | 0.0014 | 0.001 | 0.003 | 0.001 | 0.009 | 0.001 | 0.002 | 0.043 | | | | | | 0.03 | 0.006 | 0.003 | 0.009 | 0.003 | 0.014 | 0.04 | 0.325 | 0.202 | 0.350 | 0.671 | 2.00 | 3.55 | 4.94 | 4.9 | 1.720 |
| Mn | mg/l | 10 | | 0.5 | 3.6 | 2.5 | 1.9 | 1.2 | 0.142 | 0.041 | 0.178 | 0.026 | 0.427 | 0.437 | 0.03 | 0.02 | 0.04 | 0.01 | 0.07 | 0.26 | 0.171 | 0.113 | 0.152 | 0.13 | 0.354 | 0.86 | 2.37 | 6.84 | 5.26 | 3.24 | 5.81 | 6.18 | 5.18 | 6.840 | 4.983 |
| Ni | mg/l | 2 | 1.0 | 0.02 | 0.017 | 0.013 | 0.011 | 0.008 | 0.001 | 0.001 | 0.001 | 0.001 | 0.003 | 0.005 | 0 | 0 | 0.01 | 0 | 0.02 | 0.02 | 0.003 | 0.002 | 0.006 | 0.002 | 0.005 | 0.035 | 0.61 | 0.35 | 0.35 | 0.31 | 0.45 | 0.50 | 0.45 | 0.607 | 0.431 |
| Pb | mg/l | 5 | 0.1 | 0.01 | 0.0094 | 0.0056 | 0.0034 | 0.001 | | | | | | 0.01 | | | | | | 0 | 0.006 | 0.004 | 0.007 | 0.003 | 0.0216 | 0.026 | 0.008 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.04 | 0.039 | 0.015 |
| Zn | mg/l | 5 | 20 | | 0.031 | 0.015 | 0.008 | 0.002 | 0.008 | 0.004 | 0.01 | 0.004 | 0.028 | 0.04 | 0.02 | 0.01 | 0.03 | 0.01 | 0.07 | 0.1 | 0.01 | 0.006 | 0.013 | 0.007 | 0.02 | 0.086 | 1.01 | 0.50 | 0.64 | 0.73 | 1.25 | 1.44 | 1.30 | 1.440 | 0.982 |

NTMO Short-term trigger value Irrigation and General Water Use (ANZECC, 2000)

| Parameters | | NTMO Short-term trigger value Irrigation and General Water Use (ANZECC, 2000) | NTMO Stock Drinking Water (ANZECC, 2000) | NHMRC 2011 Australian Drinking Water Guidelines (Health) | NTMO 80% Aquatic Ecosystem (ANZECC, 2000 at 80% protection) | NTMO 90% Aquatic Ecosystem (ANZECC, 2000 at 90% protection) | NTMO 95% Aquatic Ecosystem (ANZECC, 2000 at 95% protection) | NTMO 99% Aquatic Ecosystem (ANZECC, 2000 at 99% protection) | Background Pit | | | | | | Background Lake | | | | | | Background Groundwater | | | | | | Week | | | | New | New | New | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum | 0 | 4 | 8 | 12 | 16 | 20 | 24 | Maximum | Mean |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | 12-Jul-21 | 9-Aug-21 | 6-Sep-21 | 5-Oct-21 | 1-Nov-21 | 29-Nov-21 | 29-Dec-21 | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | **21363-Initial** | **21363-1** | **21363-2** | **21363-3** | **21363-4** | **21363-5** | **21363-6** | | |
| As | mg/l | 2 | 0.5 | 0.01 | 0.14 | 0.042 | 0.013 | 0.0008 | 0.604 | 0.526 | 0.164 | 0.583 | 0.772 | 0.784 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.05 | 0.10 | 0.05 | 0.12 | 0.072 | 0.32 | 0.45 | 0.188 | 0.142 | 0.296 | 0.300 | 0.391 | 0.323 | 0.245 | 0.391 | 0.269 |
| Cd | mg/l | 0.05 | 0.01 | 0.002 | 0.0008 | 0.0004 | 0.0002 | 0.00006 | | | | | | 0 | | | | | | 0 | | | | | | 0.3 | 0.0991 | 0.0637 | 0.0590 | 0.0533 | 0.0717 | 0.0738 | 0.0602 | 0.0991 | 0.069 |
| Co | mg/l | 0.1 | 1.0 | | | | | | | | | | | 0 | | | | | | 0.01 | 0.002 | 0.001 | 0.001 | 0.001 | 0.003 | 0.003 | 1.68 | 0.988 | 0.992 | 0.754 | 1.30 | 1.38 | 1.25 | 1.68 | 1.192 |
| Cu | mg/l | 5 | 1.0 | 2 | 0.0025 | 0.0018 | 0.0014 | 0.001 | 0.003 | 0.001 | 0.009 | 0.001 | 0.002 | 0.043 | | | | | | 0.03 | 0.006 | 0.003 | 0.009 | 0.003 | 0.014 | 0.04 | 0.325 | 0.202 | 0.350 | 0.671 | 2.00 | 3.55 | 4.94 | 4.940 | 1.720 |
| Mn | mg/l | 10 | | 0.5 | 3.6 | 2.5 | 1.9 | 1.2 | 0.142 | 0.041 | 0.178 | 0.026 | 0.427 | 0.437 | 0.03 | 0.02 | 0.04 | 0.01 | 0.07 | 0.26 | 0.171 | 0.113 | 0.152 | 0.13 | 0.354 | 0.86 | 2.37 | 6.84 | 5.26 | 3.24 | 5.81 | 6.18 | 5.18 | 6.840 | 4.983 |
| Ni | mg/l | 2 | 1.0 | 0.02 | 0.017 | 0.013 | 0.011 | 0.008 | 0.001 | 0.001 | 0.001 | 0.001 | 0.003 | 0.005 | 0 | 0 | 0.01 | 0 | 0.02 | 0.02 | 0.003 | 0.002 | 0.006 | 0.002 | 0.005 | 0.035 | 0.61 | 0.35 | 0.35 | 0.31 | 0.45 | 0.50 | 0.45 | 0.607 | 0.431 |
| Pb | mg/l | 5 | 0.1 | 0.01 | 0.0094 | 0.0056 | 0.0034 | 0.001 | | | | | | 0.01 | | | | | | 0 | 0.006 | 0.004 | 0.007 | 0.003 | 0.0216 | 0.026 | 0.008 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.04 | 0.039 | 0.015 |
| Zn | mg/l | 5 | 20 | | 0.031 | 0.015 | 0.008 | 0.002 | 0.008 | 0.004 | 0.01 | 0.004 | 0.028 | 0.0 | 0.02 | 0.01 | 0.03 | 0.01 | 0.07 | 0.1 | 0.01 | 0.006 | 0.013 | 0.007 | 0.02 | 0.086 | 1.01 | 0.50 | 0.64 | 0.73 | 1.25 | 1.44 | 1.30 | 1.440 | 0.982 |

NTMO S NHMRC 2011 Australian Drinking Water Guidelines (Health)

| Parameters | | NTMO Short-term trigger value Irrigation and General Water Use (ANZECC, 2000) | NTMO Stock Drinking Water (ANZECC, 2000) | NHMRC 2011 Australian Drinking Water Guidelines (Health) | NTMO 80% Aquatic Ecosystem (ANZECC, 2000 at 80% protection) | NTMO 90% Aquatic Ecosystem (ANZECC, 2000 at 90% protection) | NTMO 95% Aquatic Ecosystem (ANZECC, 2000 at 95% protection) | NTMO 99% Aquatic Ecosystem (ANZECC, 2000 at 99% protection) | Background Pit | | | | | | Background Lake | | | | | | Background Groundwater | | | | | | Week | | | | New | New | New | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum | 0 | 4 | 8 | 12 | 16 | 20 | 24 | Maximum | Mean |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | 12-Jul-21 | 9-Aug-21 | 6-Sep-21 | 5-Oct-21 | 1-Nov-21 | 29-Nov-21 | 29-Dec-21 | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | **21363-Initial** | **21363-1** | **21363-2** | **21363-3** | **21363-4** | **21363-5** | **21363-6** | | |
| As | mg/l | 2 | 0.5 | 0.01 | 0.14 | 0.042 | 0.013 | 0.0008 | 0.604 | 0.526 | 0.164 | 0.583 | 0.772 | 0.784 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.05 | 0.10 | 0.05 | 0.12 | 0.072 | 0.32 | 0.45 | 0.188 | 0.142 | 0.296 | 0.300 | 0.391 | 0.323 | 0.245 | 0.391 | 0.269 |
| Cd | mg/l | 0.05 | 0.01 | 0.002 | 0.0008 | 0.0004 | 0.0002 | 0.00006 | | | | | | 0 | | | | | | 0 | | | | | | 0.3 | 0.0991 | 0.0637 | 0.0590 | 0.0533 | 0.0717 | 0.0738 | 0.0602 | 0.0991 | 0.069 |
| Co | mg/l | 0.1 | 1.0 | | | | | | | | | | | 0 | | | | | | 0.01 | 0.002 | 0.001 | 0.001 | 0.001 | 0.003 | 0.003 | 1.68 | 0.988 | 0.992 | 0.754 | 1.30 | 1.38 | 1.25 | 1.68 | 1.192 |
| Cu | mg/l | 5 | 1.0 | 2 | 0.0025 | 0.0018 | 0.0014 | 0.001 | 0.003 | 0.001 | 0.009 | 0.001 | 0.002 | 0.043 | | | | | | 0.03 | 0.006 | 0.003 | 0.009 | 0.003 | 0.014 | 0.04 | 0.325 | 0.202 | 0.350 | 0.671 | 2.00 | 3.55 | 4.94 | 4.94 | 1.720 |
| Mn | mg/l | 10 | | 0.5 | 3.6 | 2.5 | 1.9 | 1.2 | 0.142 | 0.041 | 0.178 | 0.026 | 0.427 | 0.437 | 0.03 | 0.02 | 0.04 | 0.01 | 0.07 | 0.26 | 0.171 | 0.113 | 0.152 | 0.13 | 0.354 | 0.86 | 2.37 | 6.84 | 5.26 | 3.24 | 5.81 | 6.18 | 5.18 | 6.84 | 4.983 |
| Ni | mg/l | 2 | 1.0 | 0.02 | 0.017 | 0.013 | 0.011 | 0.008 | 0.001 | 0.001 | 0.001 | 0.001 | 0.003 | 0.005 | 0 | 0 | 0.01 | 0 | 0.02 | 0.02 | 0.003 | 0.002 | 0.006 | 0.002 | 0.005 | 0.035 | 0.61 | 0.35 | 0.35 | 0.31 | 0.45 | 0.50 | 0.45 | 0.607 | 0.431 |
| Pb | mg/l | 5 | 0.1 | 0.01 | 0.0094 | 0.0056 | 0.0034 | 0.001 | | | | | | 0.01 | | | | | | 0 | 0.006 | 0.004 | 0.007 | 0.003 | 0.0216 | 0.026 | 0.008 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.04 | 0.039 | 0.015 |
| Zn | mg/l | 5 | 20 | | 0.031 | 0.015 | 0.008 | 0.002 | 0.008 | 0.004 | 0.01 | 0.004 | 0.028 | 0.0 | 0.02 | 0.01 | 0.03 | 0.01 | 0.07 | 0.1 | 0.01 | 0.006 | 0.013 | 0.007 | 0.02 | 0.086 | 1.01 | 0.50 | 0.64 | 0.73 | 1.25 | 1.44 | 1.30 | 1.440 | 0.982 |

NTMO S NHMRC NTMO 80% Aquatic Ecosystem (ANZECC, 2000 at 80% protection)

| Parameters | | NTMO Short-term trigger value Irrigation and General Water Use (ANZECC, 2000) | NTMO Stock Drinking Water (ANZECC, 2000) | NHMRC 2011 Australian Drinking Water Guidelines (Health) | NTMO 80% Aquatic Ecosystem (ANZECC, 2000 at 80% protection) | NTMO 90% Aquatic Ecosystem (ANZECC, 2000 at 90% protection) | NTMO 95% Aquatic Ecosystem (ANZECC, 2000 at 95% protection) | NTMO 99% Aquatic Ecosystem (ANZECC, 2000 at 99% protection) | Background Pit | | | | | | Background Lake | | | | | | Background Groundwater | | | | | | Week | | | | New | New | New | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum | 0 | 4 | 8 | 12 | 16 | 20 | 24 | Maximum | Mean |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | 12-Jul-21 | 9-Aug-21 | 6-Sep-21 | 5-Oct-21 | 1-Nov-21 | 29-Nov-21 | 29-Dec-21 | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | **21363-Initial** | **21363-1** | **21363-2** | **21363-3** | **21363-4** | **21363-5** | **21363-6** | | |
| As | mg/l | 2 | 0.5 | 0.01 | 0.14 | 0.042 | 0.013 | 0.0008 | 0.604 | 0.526 | 0.164 | 0.583 | 0.772 | 0.784 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.05 | 0.10 | 0.05 | 0.12 | 0.072 | 0.32 | 0.45 | 0.188 | 0.142 | 0.296 | 0.300 | 0.391 | 0.323 | 0.245 | 0.391 | 0.269 |
| Cd | mg/l | 0.05 | 0.01 | 0.002 | 0.0008 | 0.0004 | 0.0002 | 0.00006 | | | | | | 0 | | | | | | 0 | | | | | | 0.3 | 0.0991 | 0.0637 | 0.0590 | 0.0533 | 0.0717 | 0.0738 | 0.0602 | 0.0991 | 0.069 |
| Co | mg/l | 0.1 | 1.0 | | | | | | | | | | | 0 | | | | | | 0.01 | 0.002 | 0.001 | 0.001 | 0.001 | 0.003 | 0.003 | 1.68 | 0.988 | 0.992 | 0.754 | 1.30 | 1.38 | 1.25 | 1.68 | 1.192 |
| Cu | mg/l | 5 | 1.0 | 2 | 0.0025 | 0.0018 | 0.0014 | 0.001 | 0.003 | 0.001 | 0.009 | 0.001 | 0.002 | 0.043 | | | | | | 0.03 | 0.006 | 0.003 | 0.009 | 0.003 | 0.014 | 0.04 | 0.325 | 0.202 | 0.350 | 0.671 | 2.00 | 3.55 | 4.94 | 4.94 | 1.720 |
| Mn | mg/l | 10 | | 0.5 | 3.6 | 2.5 | 1.9 | 1.2 | 0.142 | 0.041 | 0.178 | 0.026 | 0.427 | 0.437 | 0.03 | 0.02 | 0.04 | 0.01 | 0.07 | 0.26 | 0.171 | 0.113 | 0.152 | 0.13 | 0.354 | 0.86 | 2.37 | 6.84 | 5.26 | 3.24 | 5.81 | 6.18 | 5.18 | 6.84 | 4.983 |
| Ni | mg/l | 2 | 1.0 | 0.02 | 0.017 | 0.013 | 0.011 | 0.008 | 0.001 | 0.001 | 0.001 | 0.001 | 0.003 | 0.005 | 0 | 0 | 0.01 | 0 | 0.02 | 0.02 | 0.003 | 0.002 | 0.006 | 0.002 | 0.005 | 0.035 | 0.61 | 0.35 | 0.35 | 0.31 | 0.45 | 0.50 | 0.45 | 0.607 | 0.431 |
| Pb | mg/l | 5 | 0.1 | 0.01 | 0.0094 | 0.0056 | 0.0034 | 0.001 | | | | | | 0.01 | | | | | | 0 | 0.006 | 0.004 | 0.007 | 0.003 | 0.0216 | 0.026 | 0.008 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.04 | 0.039 | 0.015 |
| Zn | mg/l | 5 | 20 | | 0.031 | 0.015 | 0.008 | 0.002 | 0.008 | 0.004 | 0.01 | 0.004 | 0.028 | 0.0 | 0.02 | 0.01 | 0.03 | 0.01 | 0.07 | 0.1 | 0.01 | 0.006 | 0.013 | 0.007 | 0.02 | 0.086 | 1.01 | 0.50 | 0.64 | 0.73 | 1.25 | 1.44 | 1.30 | 1.44 | 0.982 |

The results show background groundwater concentrations generally exceed the 80% Aquatic Ecosystem protection guidelines (ANZG 2018) as well as the Australian DWGs (NHMRC, 2011) for numerous elements including arsenic, cadmium, manganese, nickel, lead and zinc, however, do not exceed the Short-term trigger value (TV) for irrigation and general water use (ANZECC, 2000) or stock water guidelines (ANZECC, 2000). Similarly, elemental concentrations within the Fountain Head pit lake exceed the 80% Aquatic Ecosystem protection guidelines (ANZG 2018) and Australian DWGs (NHMRC, 2011), however, no exceedances occur against the Short-term TV for irrigation and general water use (ANZECC, 2000). Only one exceedance for arsenic is noted against stock water guidelines (ANZECC, 2000) for this water type.

As outlined in the CSM in 1.4 and supported by these results, stock water (ANZECC, 2000) is the only potential beneficial use associated with groundwater at the FHGP. Therefore, this criterion has been used as the sole metric to provide the source term definition. Note, as most metals in the background groundwater exceed the 80% Aquatic Ecosystem protection guidelines, this guideline is not considered relevant for defining the source term and has not been considered further in this assessment.

Adopting the Stock Drinking Water Guidelines (DWGs) (ANZECC, 2000) as the metric for determining the source term, the following four elements have been selected for further investigation as part of this report:

- Arsenic – exceedance from background pit lake water (mean concentration of 0.53 mg/L versus criterion of 0.5 mg/L).
- Acidity - due to the relationship between acidity and base metal concentrations described in Section 3.3.2.
- Cobalt (maximum of 1.7 mg/L versus criterion of 1 mg/L (mean of 1,2 mg/L)).
- Copper (maximum of 4.9 mg/L versus criterion of 1 mg/L (mean of 1.7 mg/L)).

To assist in understanding the elemental behaviour of the source term constituents in the leach test system, Eh/pH diagrams have been plotted using ACT 2 software of Geochemists Work Bench (GWB, version 11.06.0) and are shown in Figure 3-7Figure 3-5 for arsenic and copper and cobalt. Eh/pH diagrams can be interpreted as follows:

- Blue colouration represents element is in solution.
- Brown colouration represents solid phase.
- Eh (volts) represents the redox condition of the system with higher numbers indicating a more oxidised system and lower numbers indicating a reducing system.

The figures show arsenic to be relatively stable as an aqueous specie regardless of pH or redox. The broad existence of arsenic in the solution phase supports EGI’s conclusion that arsenic can be elevated in leachate from the PAF-LC column without any obvious correlation to leachate pH (or inferring sulfate release and generation of sulfuric acid).

Conversely, EGI considers copper increase is likely to be associated with pH (acidity) and speciation of the specific system as per column test week 24. The Eh/ pH diagram matched to the specific kinetic test environment supports this conclusion (refer Figure 3-5; aqueous copper species <pH 5.2 – blue zones). Copper is predicted to be largely in the solid phase unless the pH begins to decrease, and the system becomes more acidic (see the blue $Cu_{++}$ triangle to the left of the image). Low levels of copper (geomean 0.06 mg/L) in the Fountain Head pit lake suggest copper is mostly within the solid phase.

Cobalt demonstrates a similar distribution between solid and solution under decreasing pH (Figure 3-6).

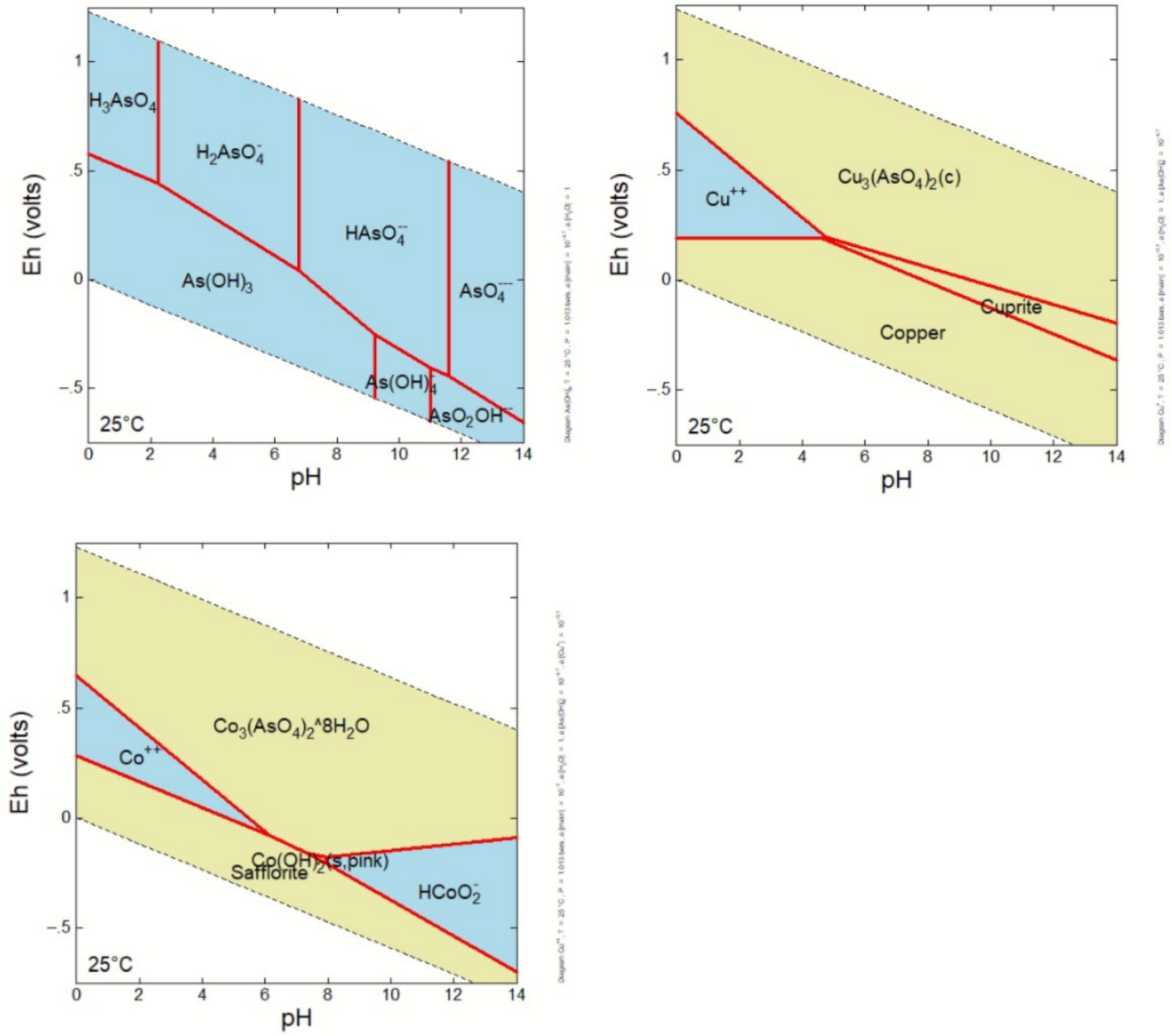


**Figure 3-7** Eh / pH diagram for arsenic (top left), copper (top right) and cobalt (bottom left) as per kinetic column at 24 weeks

# Section 4 PAF Contact Water Predictions

## 4.1 Overview

This section describes the processes for predicting the future PAF contact water for the source term constituents for PAF material stored within the pit during and post operations.

The parameters considered in this assessment are acidity, arsenic, cobalt and copper. These parameters have been identified by the source term analysis (Section 3) as having propensity to leach from the source (PAF) material resulting in change to the pit water quality and potential harm to receptors.

Predictions have been made for the PAF contact water (leachate) source term by extrapolating kinetic test concentrations and bulk scaling these results for rock mass (0.15 Mt PAF material) and runoff. Source term concentrations for PAF leachate have been assessed for the two sources of PAF identified by the CSM (i.e. S1 PAF rock storages in pit and S2 exposed PAF material in the pit walls) and are presented in the below sub-sections.

## 4.2 Source S1 – PAF Rock in Pit

### 4.2.1 Kinetic Testing Extrapolation

Seven data points (i.e. 24 weeks measured every four weeks) are currently available from the kinetic testing of the PAF material. Using these data, a trend line was applied to the existing data points to formulate a regression equation. The regression equations have been used to extrapolate the potential concentration of the source term constituents (i.e. acidity, arsenic, cobalt and copper) over a 52-week period[2] and are shown in Appendix A respectively. This method is conservative in that it assumes leachate release continues to increase for 52 weeks and ignores any plateauing that may occur during the kinetic tests. Note the broad observations and assumptions made with respect to the kinetic data in Section 3.5 of Appendix B.

### 4.2.2 Bulk Scale Drainage

A major 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 per equation 1 (Kirchner and Mattson, 2015):

$$Predicted\ Concentration = \frac{HC\ Load\ x\ Time\ x\ Mass\ of\ Rock\ in\ Dump}{Volume\ of\ Infiltrating\ Water} \tag{Eq1}$$

It has long been recognised that the predicted loads calculated from bulk scaling commonly overestimate actual geochemical loads seen in drainage from waste dumps (Morin & Hutt, 1994; Malmström et al., 2000). This is largely attributed to discrepancies in geochemical and physical conditions between laboratory kinetic reactors and full-scale waste dumps, including but not limited to, water-rock interaction, gas transport and oxygen content, reactive grain size distribution and temperature. As a result, “scaling factors[3]” are often 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.

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[2] Points shown after 24 weeks denote extrapolated values; points shown prior to 24 weeks denote kinetic test concentrations.

[3] Refer to Section 5.1.2 Appendix B for further detail

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. Thus, depending on the number of comparative tests, multiple scaling factors may be derived for individual solutes and kinetic tests. Research by Lapakko and Olsen (2015) suggests modelling should use cumulative probability distribution as opposed to a single value (i.e. an individual scaling factor) to derive what is known as a cumulative scaling factor (CSF). A CSF, defined as the product of all individual scaling factors, can be calculated empirically where laboratory kinetic and waste drainage chemistry data are available.

No such field tests have been conducted to derive a site-specific CSF, however, studies by Andrina et al. (2012); Hanna and Lapakko (2012); and Morin and Hutt (1994) suggest CSFs can range in the order of 0.05 to 0.6 (i.e. 5 to 60%) with Lapakko and Olsen (2015) deriving a CSF of 0.4. Given the range observed from relevant literature, a CSF of 0.4 has been adopted based on Lapakko and Olsen (2015), which is considered reasonably conservative given the mean CSF of this study was 0.127 and the upper values lies comfortably within the 5 to 60% range commonly observed in the literature. Further explanation regarding CSF selection is provided in Appendix B.

### 4.2.3 Parameterisation and Assumptions

The parameters used to calculate the total scaled up predicted concentration have been summarised in Table 4-1. Note the milligrams of solute have been adjusted for an average leach column volume of 503 L and bulk scaled according to the PAF rock mass and expected rainfall contributions over this stockpile. These predictions assume the PAF stockpile will remain uncovered and open to rainfall and oxidation while in the pit.

**Table 4-1 S1 scale up parameters**

| Parameter | Value | Source/ Reference/ Rationale |
|---|---|---|
| Time (weeks) | Mean 52-week extrapolation | Refer value for 52 weeks in Appendix A, which mimics 1 year of oxidation. Arbitrary extrapolation – can be extended forward to any week value. |
| Mass of Rock | 0.15 Mt | LCM of 53,900 x bulk density of 2.73 t/m$^3$ as advised by PNX. |
| PAF pile footprint | 25,000 m$^2$ | Section 4.1.4 of Appendix B. |
| Saturated quantity of PAF material to generate leach | 30,000 t | Section 4.1.4 of Appendix B. |
| Rainfall | 1250 mm | ERIAS, 2021a |
| Rainfall contribution to PAF material | 0.6ML | Section 4.1.4 of Appendix B. |
| HC Load | Kinetic data from sample 21363 using unforced linear intercept | Kinetic data from sample 21363 |
| CSF | 0.40 | Lapakko and Olsen (2015) |

### 4.2.4 Results / Rates

The predicted leach at week 52 is summarised for the key parameters in Table 4-2 while the calculations used to predict the leachate concentrations are presented in Appendix A. The results show high concentrations for cobalt and copper concentrations are predicted for the S1 leachate, that exceed the stock water guideline (1 mg/L) regardless of whether a CSF is applied. Arsenic, however, remains below the stock water guideline (0.5 mg/L) when a CSF is applied, although exceeds when no CSF is used.

Table 4-2 Predicted 52-week bulk scaled concentrations for S1 source term

| Parameter | Without CSF | | With CSF of 0.4 | |
|---|---|---|---|---|
| | Mean 52-week extrapolation | Bulk scaled | Mean 52-week extrapolation | Bulk scaled |
| Acidity (mg/L $CaCO_3$) | 44 | - | 44 | - |
| Arsenic (mg/L) | 0.35 | 1.1 | 0.14 | 0.44 |
| Cobalt (mg/L) | 1.17 | 3.3 | 0.47 | 1.32 |
| Copper (mg/L) | 4.49 | 6.3 | 1.8 | 2.52 |

Notes: - This extrapolation method is not able to predict pH noting the logarithmic nature of pH, however an acidity of 224 mg/L $CaCO_3$ (assuming no buffering capacity) would equate to a pH of 2.3.

## 4.3 Source S2 - Pit Wall

### 4.3.1 Parameterisation and Assumptions

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

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, for example:

- 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 ANFO (ammonium nitrate and fuel oil) 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 $m^2$ (1 $m^3$) is increased by a factor of 1.41 to account for an assumed average pit wall slope of 45 degrees, i.e. 1.41 $m^3$. Finally, the mass of rock is determined by multiplying the effective volume by average waste density of 2.7 $t/m^3$ 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 and fractured influenced zones, total mass of rock would be 14.8 tonne (14,800 kg).

The bulk scaled parameters for the pit wall contributions are presented in

Table 4-4. This represents:

- Single load transfer available once the pit wall is submerged.
- Ongoing loading from exposed rock (current), during and post mining.

The proportion of exposed rock throughout the life of mine and post closure will be governed by the elevation of the water table. For simplicity, this calculation assumes that all PAF wall rock is exposed. When the pit water level rebounds the loading will decrease due to less exposed surface area and has been considered as part of later mixing shown in Section 5.1. The final calculations carry a CSF of 0.4 to account for mass loading correction factors between laboratory and field scale calculations (e.g. grains size, seasonality, temperature, water contact etc.).

Note, acidity, not alkalinity, is 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 sulfide minerals will largely be inhibited.

**Table 4-3 S2 scale up parameters**

| Parameter | Unit | Value |
|---|---|---|
| **Total area of exposed PAF in wall rock** | **$m^2$** | **55,563** |
| Area of exposed wall rock (planar unit area) | $m^2$ | 1 |
| Average assumes pit wall side slope angle | Degrees | 45 |
| Surface area of exposed unsubmerged pit wall rock | $m^2$ | 1.41 |
| Density of pit wall rock | Tonne/$m^3$ | 2.7 |
| Depth of blast fractured zone | m | 1.0 |
| Depth of blast influenced zone | m | 3.0 |
| Total volume of wall rock in the 4 m deep blast affected zone | $m^3$ | 5.64 |
| Total mass of wall rock in the 4 m deep blast affected zone | kg | 15,228 |
| Mean annual precipitation | mm/year | 1,245.2 (from section 4 of the EIS) |
| Mean annual precipitation volume (per 1$m^2$ of exposed unsubmerged wall rock) | $m^3$ | 1.25 |

### 4.3.2 Results / Rates

The bulk scaled predictions for the pit wall contributions are presented in Table 4-3. The calculations for arsenic, cobalt and copper loading as well as acidity (as CaCO3) are presented in Appendix B. Unlike acidity and metals, alkalinity will not accumulate on mineral surfaces, hence, a stored alkalinity load cannot be calculated as alkalinity associated with pit wall rock is stored in carbonate minerals and associated ANC available on the wall rock surfaces. During subaerial exposure pit wall ANC will be consumed in response to acid production. However, for indicative purposes the alkalinity data acquired from the kinetic testing was used to calculate an annual loading. Groundwater reports an alkalinity of 178 mg/L $CaCO^3$, and this is presented for comparison against predictive pit wall loading with respect to acid base assessment.

**Table 4-4 Predicted 52-week bulk scaled concentrations for S2 source term**

| Chemical/ Parameter | Predicted contact water concentration |
|---|---|
| Arsenic (mg/L) | 1.5 |
| Cobalt (mg/L) | 6.1 |
| Copper (mg/L) | 10.6 |
| Acidity (mg/L CaCO3) | 109 |

| Chemical/ Parameter | Predicted contact water concentration |
|---|---|
| Alkalinity (mg/L CaCO3) - predicted | 129 |
| Nett alkalinity (predicted from loading) | 20 |

# Section 5 Pit Lake Water Quality Predictions

## 5.1 Mixing Model – Geochemists Work Bench

### 5.1.1 Approach

LWC has created a mixing model using Geochemists Work Bench GSS software2 where the S1 and S2 representative rock leachate predicted in Section 4 (52-week bulk scaled concentrations) have been mixed to account for pit wall runoff and rainfall with four mixing scenarios (500 ML, 3,500 ML, 6,000 ML and 7,500 ML) of pit lake water (represented by groundwater composition) to represent different stages of the pit lake recovery. GSS is a spreadsheet program designed for geochemical analysis. The software is used to convert units, create plots and diagrams, mix samples, compare replicate analyses and check standards, calculate speciation and saturation, and mix compositions. GSS datasheets hold the results of chemical analyses, as well as values calculated from those results.

### 5.1.2 Parameterisation

The parameters informing the GSS predictions are summarised in Table 5-2 and presented in full in Appendix B. Consistent with the leachate predictions in Section 4, a CSF 0.4 has been applied to these results to account for the overestimation of laboratory derived column testing data. The WBM predicts approximately 116 ML of run-off will be recovered by the pit per annum with rainfall making up around 92 ML/y (CDM Smith (2021). Note, the model does not take into account the possibility for arsenic, cobalt and copper to bind with available ferric oxyhydroxides (FeOH) and have colloidal behaviour which may result in the arsenic becoming enriched in sediment rather than water column over time. This can be seen in Appendix B which shows oversaturation of several iron phases.

**Table 5-1 Estimated model parameters (LWC, 2022)**

| Parameter | 500 ML | 3500 ML | 6000 ML | 7500 ML |
|---|---|---|---|---|
| Time (weeks) | 52 | 52 | 52 | 52 |
| Mass of waste (PAF) rock (Mt) | 0.15 | 0.15 | 0.15 | 0.15 |
| Rainfall (ML) | 92 | 92 | 92 | 92 |
| Run-off volume (ML) | 116 | 116 | 116 | 116 |
| Groundwater influx (ML) | 500 | 3,500 | 6,000 | 7,500 |
| Cumulative rainfall and groundwater (ML) | 592 | 3,592 | 6,092 | 7,592 |
| Ratio run-off: lake volume | 0.196 | 0.0323 | 0.019 | 0.0153 |
| Run-off contribution | 0.8 | 0.6 | 0.4 | 0 |

Following expansion on the Fountain Head pit, the pit lake volume is expected to increase from around 2,000 ML at present to around 7,500 ML when pit water levels recover to above 90 mAHD. Figure 5-1 presents the mean pit lake water level recovery with respect to volume in the years following mining. Groundwater level recovery is predicted to be rapid, with the bulk of the recovery occurring within the first 20 years at end of mine. This has implications for the generation and release of leachate from the PAF material within the Fountain Head pit where the PAF material is expected to become progressively submerged and therefore reduce leachate contributions to the pit lake. To account for this process a 20% reduction per mixing increment described in Table 5-1 has been applied for S2 leachate until a volume of 7,500 ML is reached where PAF wall rock contribution is assumed to be zero. S1 leachate loading contributions are assumed to cease after one year post mining where the 0.15 Mt of PAF rock is predicted to become submerged by recovering pit water levels.

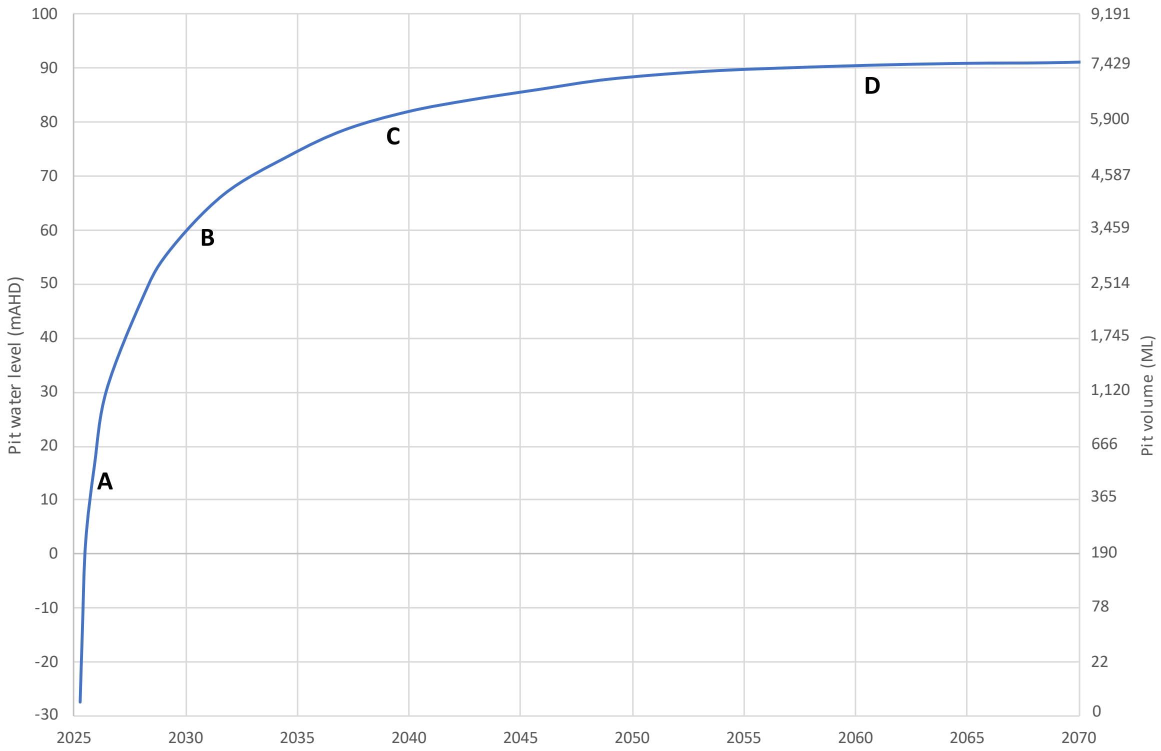

**Figure 5-1** Predicted Fountain Head pit lake mean volume and water level change post mining

### 5.1.3 Results

The GSS mixing predictions are presented in Table 5-2 with annotations of the predictions illustrated on the previous figure (Figure 5-1). The results show, cobalt and copper concentrations are predicted to exceed their respective stock water guideline during the first year of pit water level recovery, however, within five years post mining, all source term constituents decrease to below these guidelines as further submersion and cessation of oxidation / leaching of wall rock and dilution effects of rainfall and groundwater inflow occurs. During this time, the Fountain Head pit is predicted to act as a groundwater sink (CDM Smith, 2022). As the pit walls are expected to remain exposed following mining, leachate contributions from this source (S2) are predicted be greater than those from the PAF material stored within the pit (S1).

**Table 5-2** GSS mixing model predictions summary (LWC, 2022)

| Parameter | Stock water guideline (ANZECC, 2000) (mg/L) | Leachate concentration [1] | | Predicted pit lake concentration - S1 and S2 combined leachate mixed with groundwater inflow (ML) | | | |
|---|---|---|---|---|---|---|---|
| | | S1 – 0.15 Mt PAF material | S2 – Pit walls | 500 (A) – 2026 | 3,500 (B) – 2031 | 6,000 (C) – 2039 | 7,500 (D) – 2061 |
| Acidity (mg/L) (HCO$_{3}$-) [2] | - | - | 129 | - | 114 | 114 | 114 |
| Arsenic (mg/L) | 0.5 | 0.44 | 1.5 | 0.41 | 0.10 | 0.07 | 0.06 |
| Cobalt (mg/L) | 1 | 1.32 | 6.1 | 1.3 | 0.05 | 0.02 | 0.001 |
| Copper (mg/L) | 1 | 2.52 | 10.6 | 3.3 | 0.1 | 0.08 | 0.003 |

Notes: 1. Assuming 116 ML runoff and 92 ML rainfall
2. Predicted pit lake acidity for >2 years post mining.
All concentrations reported have an applied CSF of 0.4 and used mean concentrations for rainfall and groundwater to represent the mixing volumes
'-' denotes not calculated

Following recovery of the pit lake to around 7,500 ML (90 mAHD), arsenic, cobalt and copper concentrations are predicted to be less than or close to the current pit lake concentration (0.567 mg/L, 0.0006 mg/L and 0.0007 mg/L respectively). This might suggest other broader process and sources to those considered by this assessment are contributing to the current pit lake water quality. Therefore, given the low source term concentrations predicted, the placement of PAF material for storage in pit will have a negligible impact to the long-term pit water quality..

## 5.2 Water Balance Model - Goldsim

### 5.2.1 Approach

As part of a supporting scope for the FHGP EIS, CDM Smith (CDM Smith, 2021) developed a non-reactive solute balance within the existing Goldsim water balance model (WBM) to provide predictions of COPCs in the Fountain Head Pit and EP (representative concentrations for each source water component are reported in Section 3.3). This approach enables the transfer of solutes between each water body (i.e. Fountain Head pit and EP) to be modelled, and reporting of predictions dynamically such that the constant changes in water inflow/outflows across the site are captured. This is particularly useful to predict solute concentrations within the EP for which the water volume varies considerably over the life of mine (CDM Smith, 2021) and differs to the GSS mixing model, which is static (non-varying) in its predictions and models only a single subset (mix) of waters per output. Therefore, the function of the non-reactive solute balance WMB is two-fold and has been used to (i) provide dynamic predictions of solute concentrations within the EP, and (ii) validate the GSS mixing model predictions of solutes within the Fountain Head pit lake.

The WBM and non-reactive solute balance function has been updated with the latest kinetic test data to inform the input of contaminant loads and provide estimates of the EP and Fountain Head pit lake water quality assuming PAF material storage within the pit.

The modelling is conservative[4], such that there is no decay or transformation of the source water components into other compounds and no precipitation due to geochemical reactions. The modelling does, however, consider the kinetic results of arsenic and dissolution of this element from the source material (S1 and S2) within the Fountain Head pit. Arsenic has been selected as a conservative proxy in place of the other source term constituents due to its inclusion in the source term and independent relationship to pH, i.e. other COPCs should not exceed the rate of change predicted for arsenic. Section 5.2.4 provides further explanation to this effect and discussion on the WBM limitations.

### 5.2.2 Model Structure

As reported by CDM Smith (2021), the WBM simulates the water management of the mine site from the existing pit dewatering Stage (Stage I), the mining Stage (Stage II) and the post-mining period up to 500 years post-mining (Stage III). Figure 5-2 presents a schematic of these stages noting the schedule has since been updated at the time of writing. The WBM assumes the dates and timeframes outlined in Figure 5-2, however, remains applicable to future scenarios provided similar operating timeframes and sequence are maintained.

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[4] A conservative approach does not aim at making exact and reliable predictions but aims at making overestimated (or underestimated) predictions. A conservative approach addresses uncertainty by generating a buffer between the model prediction and the future and unknowable reality of the natural system. A conservative approach doesn't attempt to quantify the magnitude of the buffer (i.e. uncertainty is not quantified), and the confidence in the assessment arises from demonstrating that the reality outcomes will be contained within the envelope provided by the conservative predictions. For instance, it is not possible to predict exactly what the pit lake water chemistry will be at a given point in time, but it is possible to overestimate the chemical concentration by systematically adopting conceptual assumptions and model parameterisation that are defensibly overestimating drawdown. The benefit of a conservative approach is that if the prediction is not triggering any alarm, then project stakeholders can have confidence that the real system is not going to be threatened.

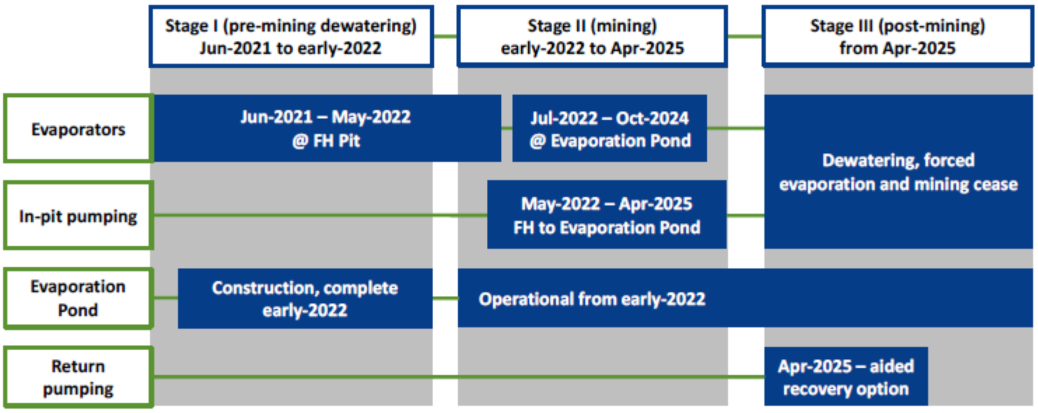

Figure 5-2 Overview of Fountain Head Pit and Evaporation Pond water balance Stages

The physical structure of the site comprises three main water balance components / sub-catchments which form part of the overall Fountain Head Lake catchment area (Figure 5-4):

- The Fountain Head Pit – during the dewatering period the pit shape used in the mass balance is the historical pit shape but, from the start of the proposed mining operation, the pit shape and associated bathymetry is swapped to the planned final pit shape at the end of mining.
- The EP – has a volume to level relationship based on the upgrade works proposed for the site.
- The Fountain Head Lake – has bathymetry defined by the latest digital elevation models available and includes the proposed Carbon-in-Pulp (CIP) and other catchments related to proposed sedimentation dams.
- The WBM concurrently simulates the Fountain Head Pit, the EP and the Fountain Head Lake to allow for a seamless transfer of water from the three sub-systems when applicable. The whole water management system and the structure of the GoldSim WBM is illustrated in Figure 5-3 while the model parameters are presented in Section 4.4.2.8 in CDM Smith (2021) and also as Appendix C.

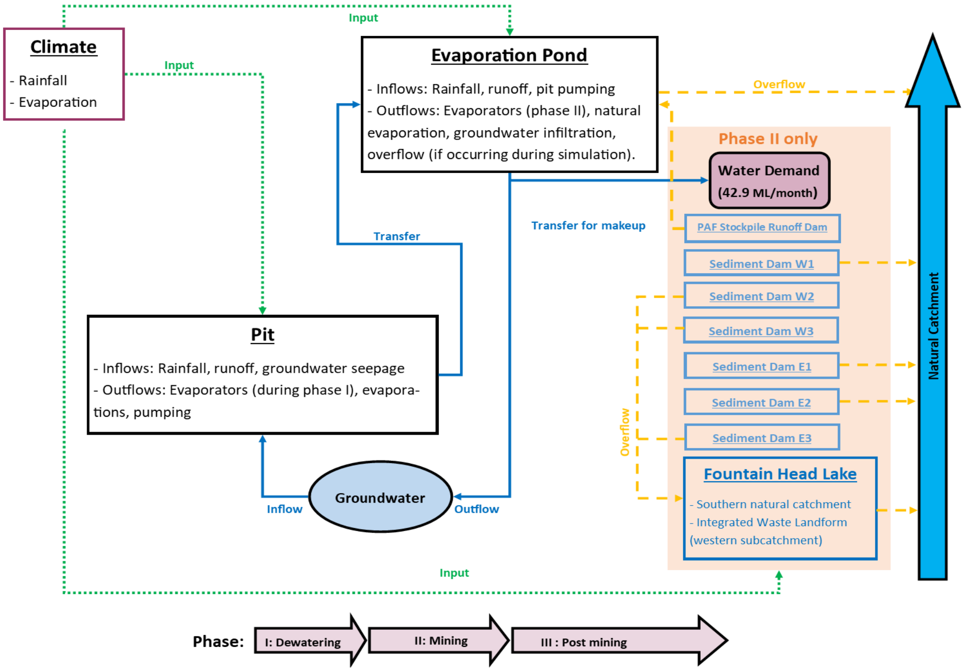

Figure 5-3 Fountain head site water balance schematic

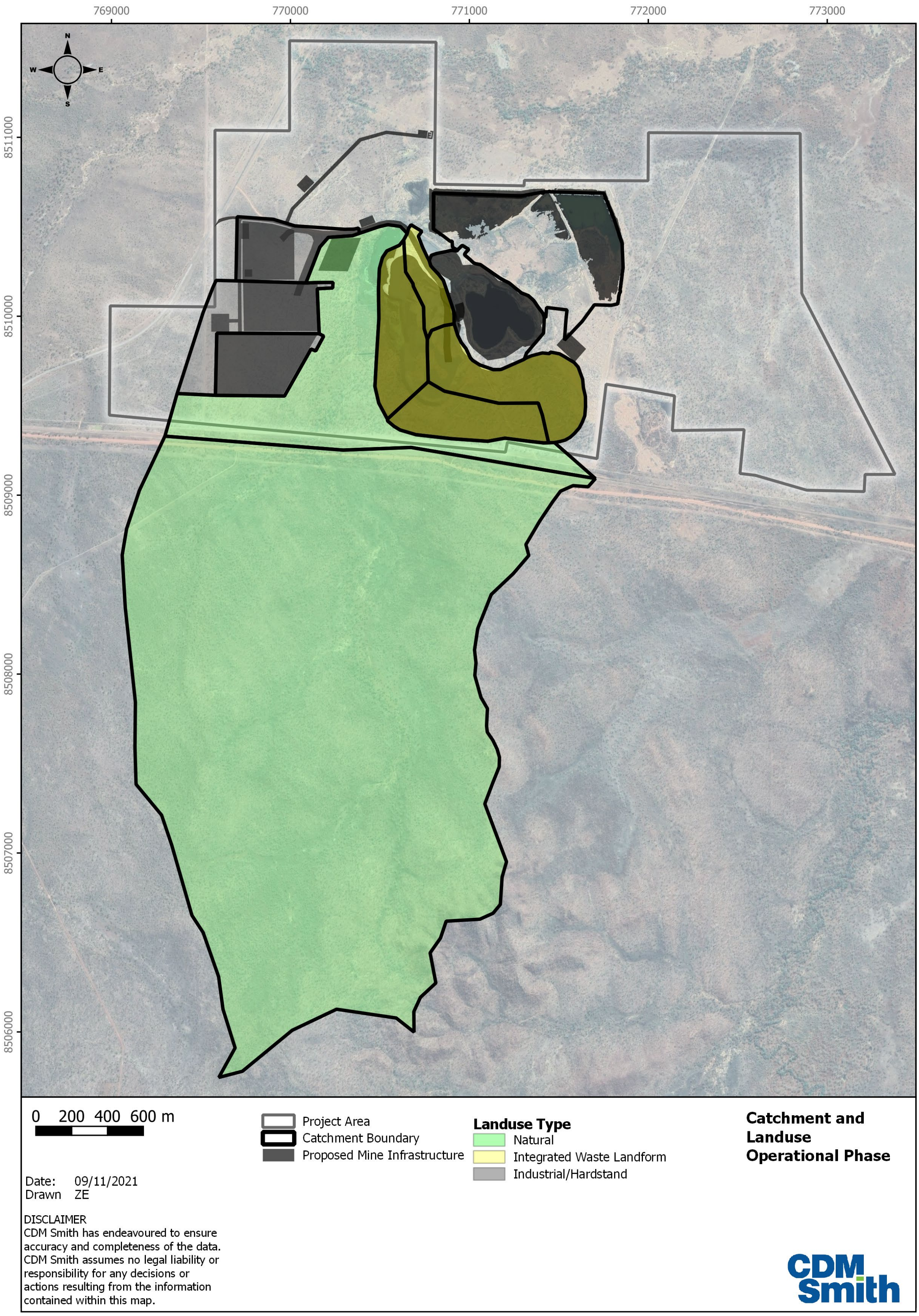

Figure 5-4 Fountain Head Lake catchment and land use

### 5.2.3 Updated Model Inputs and Assumptions

To enable prediction of water quality associated with the in-pit PAF material storage scenario, the WBM has been updated with the kinetic test data for arsenic. The updated parameters are listed in Table 5-3. Note, the addition of these data into the WBM assumes:

- The 52-week extrapolated value from the kinetic test data has been used to derive loading rates for arsenic which is highly conservative given this method ignores any plateauing concentrations observed from the kinetic tests.
- The arsenic loading rate remains in steady state from 52 weeks post Stage I (dewatering) until the end of Stage III (500 years post mining) as per Table 5-3.
- All PAF material is of the equivalent geochemical make up as the PAF sample used in the column leach test and has the same reaction with water.
- Loading rates of S1 and S2 have been estimated based on full exposure to the atmosphere, i.e. that no submergence by water is occurring, during Stage II (mining stage). Furthermore, it is assumed the entire quantity of PAF rock (~0.15 Mt) will be exposed at the onset of mining. Given exposure of these materials during mining is likely to occur gradually, this approach is considered conservative.
- Key parameter loading rates are expressed in kg/d, which is assumed to mix with a combination of runoff water, rainwater and groundwater for which contain their own unique chemistry (as listed in Table 3-2).
- No changes to the surface water and/or groundwater inflows to those reported by CDM Smith (2021).
- PAF is stored within the Fountain Head pit at elevations between 10.5 and 40.5 m AHD, to resemble placement within PAF Pod 3. This assumption is conservative as in reality, the PAF material is likely to sit lower within the pit and allowed less time to oxidise following submersion by dozing of this material to the pit base at end of mining.
- A CSF of 0.4 has been applied to the predictions to account for the overestimation of kinetic test results.

**Table 5-3 Key model inputs [1]**

| Source | Parameter | Unit | Value | Comments |
|---|---|---|---|---|
| S1 – PAF rock pods | Arsenic | kg/d | 0.62 [2] | 52-week scaled up kinetic. Assumes 0.15 Mt PAF rock refer Appendix D |
| S2 – PAF pit walls | Annual average wall rock runoff concentration - arsenic | mg/L | 2.5 | As per CDM Smith. Surface area of PAF in pit walls provided by PNX |

Notes: 1. Inputs represent steady state loading rates.
2. Refer Appendix D for S1 loading rates during first 52 weeks of PAF exposure.

To account for the PAF material storage within the Fountain Head pit, a number of model ‘rule’ changes have been incorporated into the WBM including:

- Adjustment of total mass loading to be a function of the percentage of source rock (both S1 and S2) exposed with regard to the pit water level. The loading rates (model inputs) presented in Table 5-3, apply only to exposed PAF rock, not submerged, i.e. if 100% of PAF rock is exposed, unit loading will apply to 100% of the source rock, however, if only 50% of PAF rock is exposed, then only half the rock mass will generate a release. Therefore, as pit levels recover over time, the rate at which arsenic is generated will also decrease as the PAF material becomes submerged. Note, some release is still expected post submergence, albeit at a slower rate.
- Implementation of maximum possible elemental concentrations as upper limits in the WMB. Should the cumulative concentrations for the key parameters be reached, generation will cease, as the source is considered completely exhausted.

### 5.2.4 Model Limitations

Although the key parameter kinetic test data has been incorporated into the WBM, the model itself does not allow for reactive modelling, i.e. decay or transformation of the source water components into other compounds, nor does it consider this effect when mixing waters of different chemistry. This is an important limitation to understand, as the extent to which certain parameters react within a solution differs greatly. For example, accumulation of arsenic within Fountain Head pit, is thought to occur relatively independent of other parameters, notably acidity. However, the accumulation of acidity, is both a function of sulfuric acid generated from the PAF rock, as well as the buffering capacity (alkalinity) of the solution. A non-reactive model such as the FHGP WBM, only considers the mixing of constituents independently. Therefore, acidity, which is co-dependent on the amount of available alkalinity, and cobalt and copper, which as demonstrated by the Eh/pH diagram in Figure 3-7 are controlled by pH, cannot be predicted by the WBM with the same accuracy as arsenic. For this reason, only arsenic has been included in this assessment and will serve as a conservative proxy in place of other COPCs.

Other limitations of the WBM include:

- Current data has been inferred from the collection of 24-weeks (7 points) of column leach testing data of the PAF material. Common practice, however, prefers the utilisation of kinetic data from the 28-week mark onwards. To account for this limitation, the kinetic test data has been extrapolated through till 52 weeks and the associated loading rate used. This is conservative as it ignores any plateauing and stabilisation of the kinetic within the 52-week period.
- Arsenic is derived from three sources, S1 (PAF material in pit) and S2 (PAF rock in pit walls) and groundwater. Contributions of arsenic from other sources have not been considered.
- The WBM assumes uniform mixing of water storages. In a real-life scenario this is likely to be untrue, as stratification will naturally occur in deeper water bodies such as the Fountain Head pit lake. This may result in different layers (i.e. epilimnion – upper most layer, metalimnion – transition layer, hypolimnion – lower most layer which participates in mixing and monimolimnion – semi-permanent stratified bottom layer) that may not mix with one another. The implication of stratification on water quality is parameter concentrations will likely vary with depth rather than reporting as a single value as suggested by the WBM. As a generalisation the upper layers (epilimnion and hypolimnion) are often oxic resulting in lower concentrations of redox-sensitive metals and anions and higher concentrations of major ions like sodium and chloride. Conversely, the monimolimnion layer often has higher concentrations of calcium, magnesium and sulfate than the upper layers.
- It is possible that arsenic, cobalt and copper may bind with available ferric oxyhydroxides (FeOH) and therefore have colloidal behaviour. This may result in the arsenic becoming enriched in sediment rather than water column over time, however, such predictions are not considered by the WBM.

### 5.2.5 Model Results

#### 5.2.5.1 Overview

One water management scenario has been modelled which assumes the Fountain Head pit is closed once mining ceases, the EP remains in place and no further pumping or water management activities are implemented. This scenario is consistent with that described in the Fountain Head Mine Water Management Plan (ERIAS, 2021b). Results for the EP and Fountain Head pit lake are presented and discussed below.

#### 5.2.5.2 Evaporation Pond

The WBM assumes dewatering activities will occur from June 2022 till end of mining in April 2026, around four years in duration. The generation of leachate is assumed to be instant once mining begins in early 2023 which coincides with dewatering (via evaporation and pumping) of the Fountain Head pit to the EP. During dewatering, the dissolved arsenic concentration[5] within the EP is predicted to reach around 3 mg/L from mid-2023, and around 4.3 mg/L by mid-2024 (Figure 5-5). The varying concentration of arsenic within the EP is inversely related to the volume of water within this storage facility which is driven by evaporative processes (i.e. forced and natural evaporation) that change with respect to seasons. E.g. during the wet season, rainfall is captured within the EP, increasing the pond volume and diluting the solute concentrations, whereas during the dry season, evaporation exceeds precipitation and solutes within the EP concentrate as the water volume diminishes. This relationship is shown in Figure 5-5 where the green line represents the arsenic concentration and the blue line the EP volume.

At the onset of 2026, when forced evaporation ceases and pumping from the pit to the EP ends, the arsenic concentration within the EP is predicted to decline below the stock water guideline for arsenic (0.5 mg/L) by early 2026. The arsenic concentration, thereafter, is predicted to continually decline due to seasonal dilution by rainfall. This effect can also be viewed in terms of other COPCs where solutes following mining will decrease to below their respective groundwater concentrations by 2027 as the water chemistry becomes dominated by rainfall.

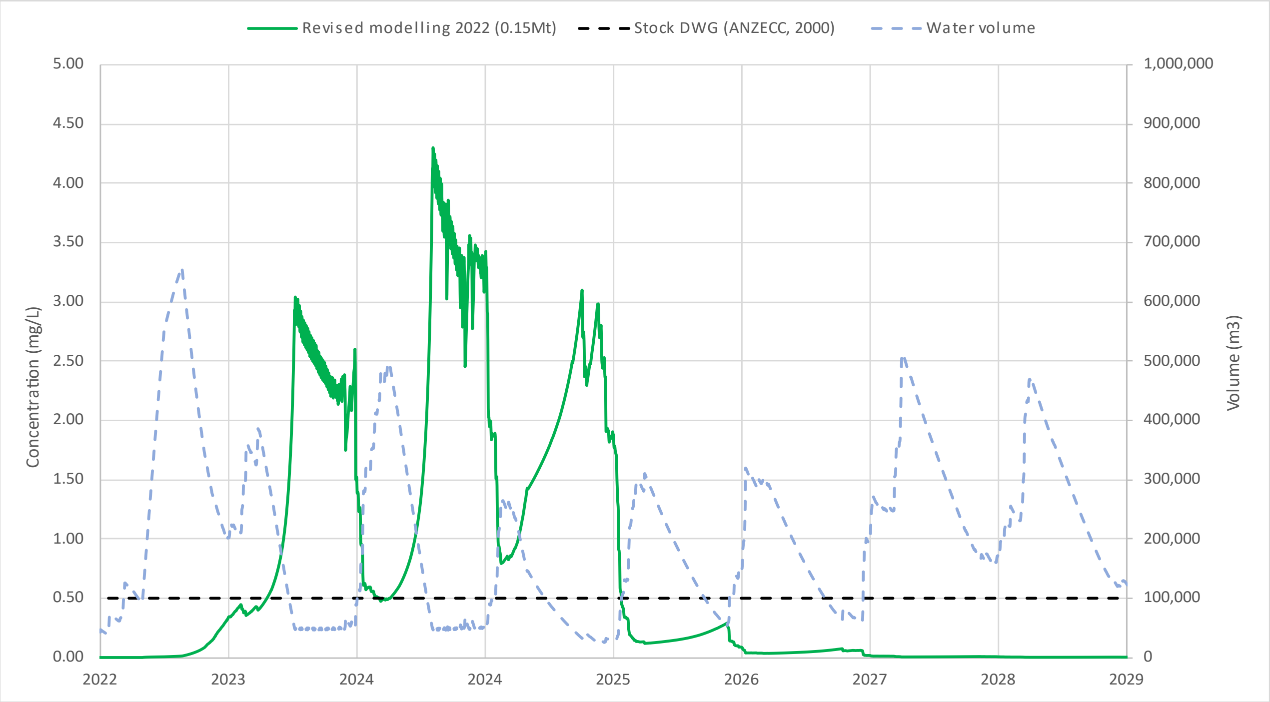

**Figure 5-5** **Predicted dissolved arsenic concentration of the evaporation pond 2022 to 2029**

To account for water outflows in the WBM, CDM Smith (2021) estimated the infiltration (seepage) expected from the EP may average around 0.5 ML/d and range from as little as around 0.2 ML/d to around 1.5 ML/d. Further updates to the MODFLOW groundwater model have recently been completed (CDM Smith, 2022) and predict seepage from the EP is expected to flow towards the pit during mining and for a period of five years post mining. The predicted arsenic concentration within the EP with respect to the predicted groundwater elevation beneath this storage facility (in the northeastern most corner) is presented in Figure 5-6. As shown, the arsenic concentration at end of mining (April 2026) is predicted to be around 0.13 mg/L, less than the stock water guideline (0.5 mg/L) and declines to less than the background groundwater concentration (0.06 mg/L) for arsenic by the early 2027. During this time the drawdown extent is expected to encompass the EP with a hydraulic gradient occurring towards the Fountain Head pit and capture seepage from the EP. Following groundwater level recovery beneath the facility and return of groundwater gradients to current conditions, i.e. a northeast gradient that would allow for downstream flow of EP seepage water, the arsenic concentration is predicted to be lower than the background concentration for groundwater (0.06 mg/L).

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[5] All predicted concentrations referenced are as dissolved. Note in comparing predicted arsenic concentrations against stock water guidelines (as total species) caution should be considered, as it is likely total concentrations will be equal to or higher than dissolved concentrations.

These findings suggest the impact resulting from seepage water from the EP to downstream receptors is considered low and the EP should be suitable for storage of mine contact water during and post mining. However, the EP is unlikely to be suitable for domestic watering purposes during operations.

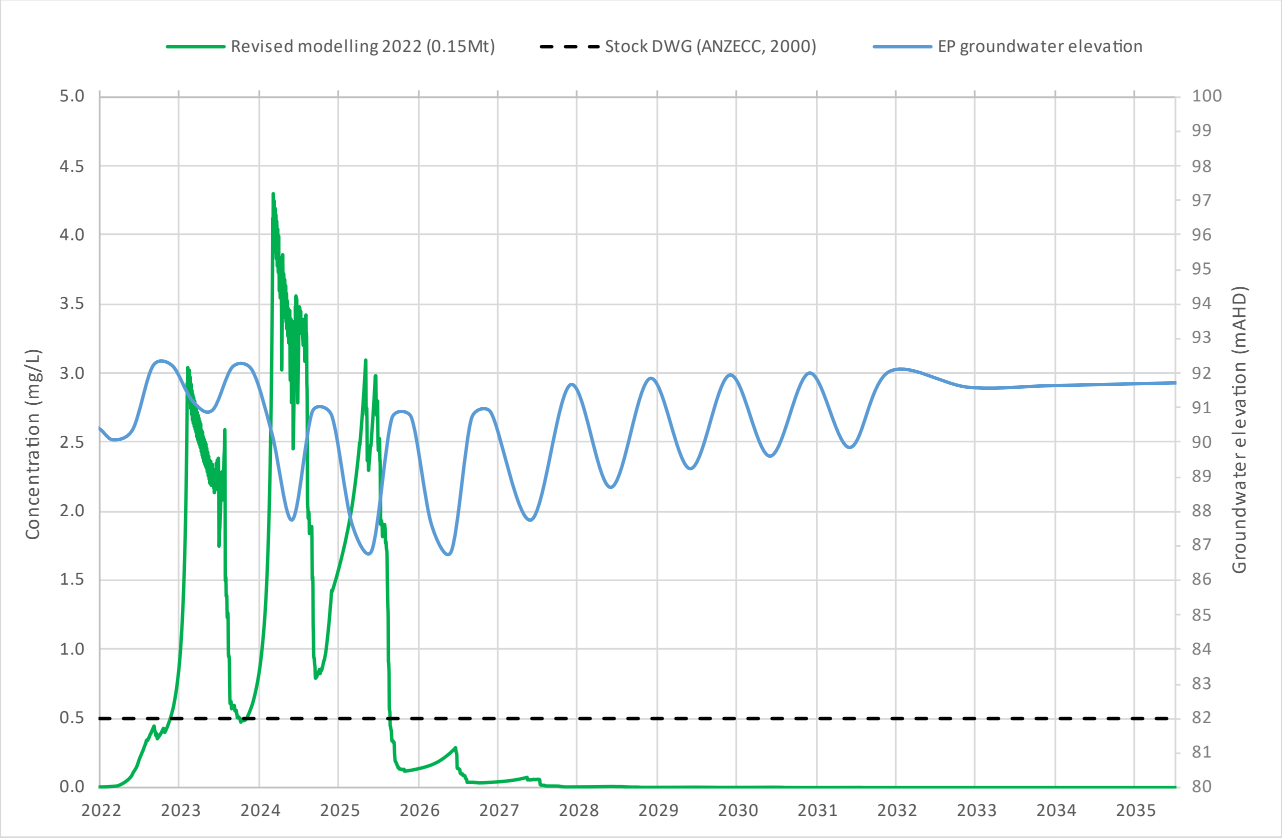

**Figure 5-6** Predicted evaporation pond dissolved arsenic concentration versus groundwater elevation

#### 5.2.5.3 Fountain Head Pit Lake

The predicted arsenic concentration within the Fountain Head pit lake is shown in Figure 5-7. The WBM predicts during mining the arsenic concentration could reach around 0.8 mg/L before decreasing to below the stock water guideline (0.5 mg/L) to around 0.15 mg/L once mining ceases and groundwater inflow, which has a relatively low arsenic concentration, resumes to the pit. These results are somewhat in agreeance with the GSS mixing model which predicts the pit lake arsenic concentration to be around 0.41 mg/L following mining and around 0.10 mg/L some five years after mining and are less than the concentration of the current pit lake (0.56 mg/L). As mentioned, this might suggest other sources to those considered by this assessment are contributing to the current pit lake arsenic concentration.

The WBM assumes the PAF material is stored within PAF Pod 3 which is illustrated in Figure 5-8 with respect to pit elevation, water level recovery and volume. As explained, the WBM intentionally assumes storage of the PAF rock within this pod to allow for conservatism, as in reality the PAF material will be pushed to the base of the pit and become submerged sooner by recovering pit water levels following mining. As shown in Figure 5-8, full submersion of PAF Pod 3, which resides between 10.5 m AHD and 40 m AHD, occurs within 2 years post mining (when the blue line is higher than the green box) meaning the model predicts further oxidation and leachate generation to occur up until this point in time. Therefore, in reality, the pit lake arsenic concentration can be expected to decrease at a faster rate than the model predicts. These results suggest subaqueous storage of PAF material within the Fountain Head pit has a negligible impact to the pit lake water chemistry given the low arsenic concentration predicted post mining.

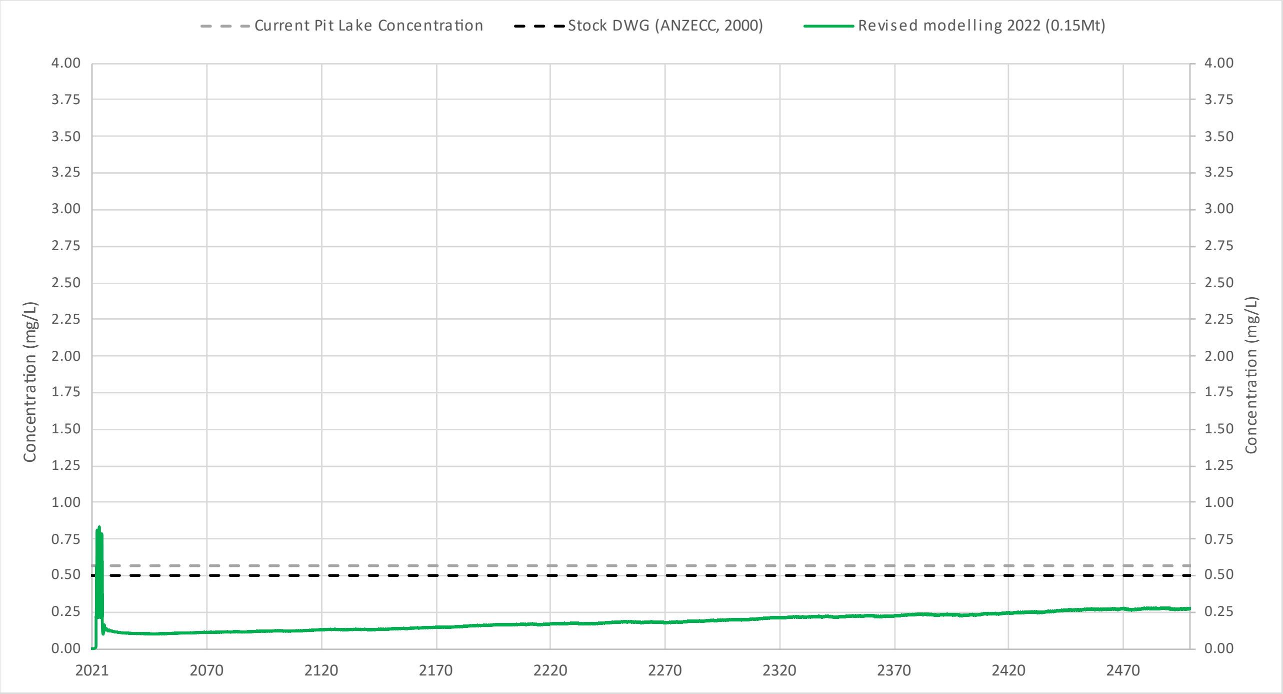

**Figure 5-7** Predicted dissolved arsenic concentration of the Fountain Head pit lake over 500 years post mining

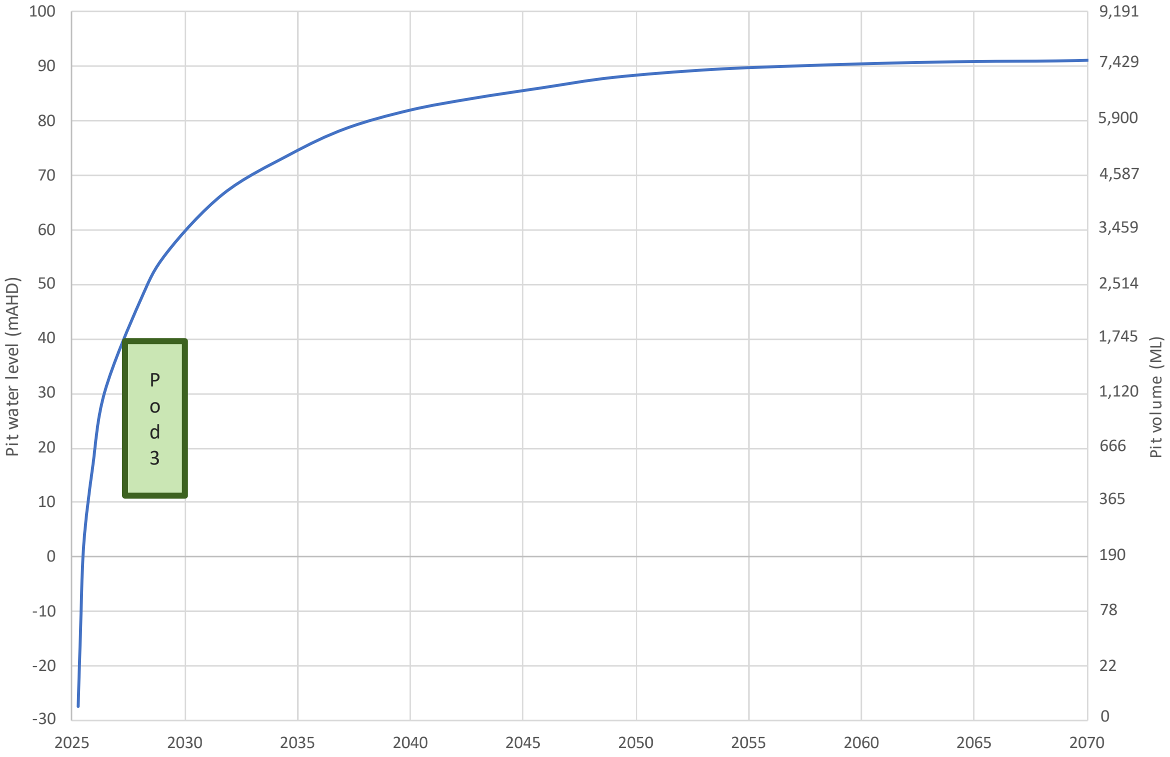

**Figure 5-8** Predicted Fountain Head pit lake mean volume and water level change post mining (the vertical extent of Pod 3 is shown by the green extent)

Following pit water level recovery (Figure 5-8), the solute concentrations are predicted to increase over time due to evapo-concentration and ongoing leaching from the pit walls (S2), a phenomenon likely occurring under current conditions. As no intervention of the Fountain Head pit is planned following mining, it is important to consider the potential impact of the residual pit lake to any downstream receptors. The predicted particle migration from the EP is discussed by CDM Smith (2022) which concluded the probability of particles travelling distances of greater than 3,500 m from the EP is less than 20% and the factor driving particle flow distances was likely the hydraulic conductivity of the aquifers to the sites north and northeast. However, using existing groundwater chemistry data presented in Section 3.3, an assessment can be made on the expected migration of solutes from the current pit lake.

As mentioned, these data demonstrate monitoring bores to the northeast of the Fountain Head pit (FHMB01, FHMB02, FHMB03) which reside within a 100 to 500 m proximity, are elevated in metals when compared with monitoring bores to the south (FHMB04, FHMB04, FHMB06). Even so, groundwater arsenic concentrations within the Fountain Head pit lake exceeds that of the northeast monitoring bores by a factor of around 7 and a factor of around 10 when compared with the geometric mean groundwater concentration for this parameter (Table 5-4). This suggests that solutes are mostly contained within the pit lake with metal concentrations in groundwater downstream of the pit remaining well below the current pit lake concentrations as well as stock water guidelines (refer Table 3-3). Therefore, the current pit lake presents a low environmental risk to downstream receptors. Given the arsenic concentration is predicted to be lower than concentrations within the current pit lake, the risk associated with the future development of the FHGP is considered low and no greater than the current state.

**Table 5-4 Geometric mean arsenic concentration of Fountain Head pit and groundwater**

| Fountain Head pit (mg/L) | Northeast monitoring bores (FHMB01, FHMB02, FHMB03) (mg/L) | Southern monitoring bores (FHMB04, FHMB05, FHMB06) (mg/L) | Groundwater (FHMB01 – FHMB06) (mg/L) |
|---|---|---|---|
| 0.567 | 0.08 | 0.022 | 0.056 |

### 5.2.6 Addressing Uncertainty of Pit Lake Predictions

CDM Smith (2021) provided post mining predictions for other groundwater elements (i.e. including and in addition to the source term) which are presented in Table 5-5. This approach ignores contributions of solute loads from the PAF material assuming the sole source of contamination arises through groundwater inflow, however, it is considered highly conservative in that there is no dispersion of solutes away from the pit or mineral precipitation within the pit lake. To calculate the chemical concentration at a given time, the source concentration is adjusted in accordance with the relationship presented in Figure 4-28 of CDM Smith (2021) by multiplying the normalised concentration value at a future time by the estimate of the source concentration. This method assumes all elements increase (or decrease) at the same rate.

These predictions can, therefore, be viewed as unrealistic and less likely to occur as the results are significantly higher than solute predictions in the already conservative GSS and Goldsim WMB mixing models. Under this prediction method, only arsenic exceeds the stock water guideline with all other elements reporting under their respective guideline value. Given these predictions do not render significantly extreme results that may trigger an unacceptable impact, there is a reasonable level of confidence the real system will not be threatened by the FHGP.

**Table 5-5 Current and predicted concentration of water chemical elements after 30 and 500 years in Fountain Head Pit (CDM Smith, 2021)**

| Parameter | ANZECC, 2000 Guideline – Stock Drinking Water [2] | Current [1] | 30 years [1] | 500 years [1] |
|---|---|---|---|---|
| EC (µS/cm) | - | 409 | 407 | 1,083 |
| TDS (mg/L) | 5,000 | 266 | 265 | 704 |
| Hardness (mgCaCO$_3$/L) | - | 141 | 140 | 373 |
| Total Alkalinity as CaCO$_3$ (mg/L) | - | 136 | 135 | 360 |
| Calcium (mg/L) | 1,000 | 13 | 13 | 34 |
| Chloride (mg/L) | - | 5.5 | 5.5 | 15 |
| Magnesium (mg/L) | - | 25 | 25 | 66 |
| Potassium (mg/L) | - | 2 | 2 | 5 |
| Sodium (mg/L) | - | 29 | 29 | 77 |
| Sulfate (mg/L) | 1,000 | 68 | 68 | 180 |
| Aluminium (µg/L) | 5,000 | 5 | 5 | 13 |
| Arsenic (µg/L) [3] | 500 | 567 | 554 | 1,501 |
| Cobalt (µg/L) | 1,000 | 1 | 1 | 3 |
| Copper (µg/L) | 1,000 | 0.7 | 0.6 | 2 |
| Iron (µg/L) | - | 26 | 26 | 69 |
| Zinc (µg/L) | 20,000 | 4.4 | 4.4 | 12 |

Notes:
1. Concentrations as dissolved species
2. Concentrations as total species
3. Inferred from column leach tests and assumed to be as dissolved species

# Section 6 Water Management

## 6.1 Contact Water

Contact water is defined as those waters that become altered during the mining process, either by contact through mineral processing or as contact with mine workings. At the FHGP, contact water is expected to occur from several sources including (i) direct rainfall, (ii) runoff (S1 and S2 leachate), (iii) groundwater inflows, and (iv) initial water storage (pit water). Table 6-1 presents the predicted water balance from CDM Smith (2021) which shows the contribution of these water types during mining operations between the Fountain Head pit and EP. As shown, the largest contribution of contact water for the Fountain Head pit is expected to be sourced from groundwater with around a third of inflow water occurring as the initial pit lake water and around 8% as runoff.

Contact water will be managed through containment within the Fountain Head pit during operations where the different source water types will mix and be captured within a sump at the base of the pit. The contact water will be managed as a single water type and be transferred from the Fountain Head pit to the EP through ongoing dewatering while also subject to forced evaporation (via the use of evaporators) as well as natural evaporation. Under this water management strategy, no transfer of water from the Fountain Head pit and EP off-site is planned.

**Table 6-1 Predicted Fountain Head Pit and evaporation pond water balance summary during mining operations**

| Component | Fountain Head pit (ML) | Evaporation Pond (ML) |
|---|---|---|
| **Inflow** | | |
| Rainfall [1[ | 92 (2%) | 605 (13%) |
| Runoff [2] | 465 (8%) | 886 (19%) |
| Groundwater inflow [1] | 3,222 (55%) | - |
| Initial water storage [1] | 2,060 (35%) | - |
| Pumping from Fountain Head pit (groundwater, pit water, rainfall and runoff) [2] | - | 3,106 (68%) |
| **Total** | **5,840** | **4,597** |
| **Outflow** | | |
| Forced evaporation | 1,270 (22%) | 2,809 (61%) |
| Natural evaporation | 127 (2%) | 734 (16%) |
| Pumping (incl. site water consumption) | 4,443 (76%) | - |
| Groundwater infiltration | - | 858 (19%) |
| Supply to site water demand | - | 161 (>3%) |
| Remaining water in pond | - | 15 (<1%) |
| **Total** | **5,840** | **4,578** |

Notes: 1. Refer Table 3-2 for chemistry
2. Refer Table 5-2 for chemistry

## 6.2 PAF Storage

The proposed PAF management strategy for the FHGP is to dispose of the PAF rock within the Fountain Head pit underwater. During mining, up to 0.15 Mt of PAF material will be stored within the Fountain Head pit before being pushed further to the base ensuring full submersion by recovering pit water levels following mining. For reactive waste disposal, assurance that the water cover will be maintained is critical to prevent ongoing oxidation and leachate generation following mining. As discussed, total submersion of the PAF rock stored within the pit is predicted to occur within one year following mining as pit water levels recover. Site hydrochemistry data and groundwater modelling completed by CDM Smith (2022) suggest the pit is currently acting and is predicted to act as an evaporative sink. Therefore, and given the low solute concentrations predicted for the future pit lake, the pit is considered suitable to accommodate storage of PAF rock sub-aqueously. While it is likely some generation of acidity and concomitant metal solubilisation may occur as a result of in-pit storage of the PAF rock in the interim period, the risk of this has been modelled and deemed to be acceptable.

The proposed management of the PAF rock is outlined in the FHGP Waste Rock Management Plan. To ensure adequacy of this plan, environmental monitoring (as outlined in the FHGP Mine Water Management Plan) should be completed during and post the operation phase to assess potential changes in the risk profile as a result of the PAF rock storage and inform any further measures on the handling of such material.

# Section 7 Conclusions and Recommendations

## 7.1 Conclusions

The following conclusions present the key outcomes of this study:

- Water groups at the Fountain Head site can be classified as NMD water due to their near-neutral pH and base metal concentrations. It is likely the water groups are influenced by the presence of carbonate minerals which provide a neutralising effect.
- The source term has been updated to include acidity, arsenic, cobalt and copper, which from the kinetic test data, show propensity to leach from the source material and therefore, warrant further consideration regarding water quality modelling.
- Concentrations of copper and cobalt appear to be controlled by pH while no obvious correlation between pH has been determined for arsenic.
- Estimated concentrations for the source term constituents (acidity, arsenic, cobalt and copper) have been derived from the 24-week column leach testing data.
- Given the short-term status of the kinetic data, a level of uncertainty exists regarding the magnitude of predicted concentrations of the key parameters.
- To account for this uncertainty, the bulk scaling method used in this assessment purposely overpredicts the loading rates by extrapolating a linear trend of increasing PAF dissolution from 7 data points of column leach testing results and using the mean extrapolated 52-week concentration, i.e. ignoring any plateauing expected over this period. This is considered an appropriate measure given the relatively short mine life and exposure of PAF material.
- Two mixing models have been created to predict the concentration of the source term constituents in the Fountain Head pit lake and EP and include:
    - A 'static' reactive mixing model (GSS) which uses the kinetic test data to mix the bulk scaled leachate concentration with varying quantities of groundwater in order to model the final pit lake water quality.
        - The Fountain Head pit lake cobalt and copper concentrations are predicted to exceed their respective stock water guideline (1 mg/L) during the first year of pit water level recovery, however, within five years post mining, all source term constituents decrease to below these guidelines, i.e. arsenic ~0.1 mg/L, cobalt ~0.05 mg/L and copper ~0.1 mg/L.
    - A 'dynamic' non-reactive mixing model (Goldsim WMB) which is paired with the current WBM to provide estimates of arsenic concentrations within the EP capturing the constant flow of water from the Fountain Head pit (to the EP) and validate against the GSS mixing model pit lake predictions.
        - The arsenic concentration within the EP peak at around 4.3 mg/L during mining and decline to below the stock water guideline for arsenic (0.5 mg/L) by early 2026 once mining ceases.
        - The arsenic concentration within Fountain Head pit increases to around 0.8 mg/L during mining before decreasing to around 0.15 mg/L (below the stock water guideline) within several months following mining as pit water levels recover and the PAF material is submerged.
        - The predicted pit lake arsenic concentration is in agreement with the GSS mixing model results and is less than the current pit lake concentration. This suggests subaqueous storage of PAF material within the Fountain Head pit has a low impact to the pit lake water chemistry.
- Based on the predicted groundwater drawdown beneath the EP during and post operations, the arsenic concentration is predicted to be less than the background groundwater concentration (0.056 mg/L) by the time

groundwater gradients recover and seepage from the EP can travel down gradient. The EP is therefore considered suitable for storing contact water during operations.

- Analysis of groundwater chemistry data from bores immediately adjacent to the Fountain Head pit demonstrates solutes are mostly contained within the pit lake. Arsenic concentrations of monitoring bores within 100 m and downstream of the pit are below the stock water guideline for this COPC. Given the predicted source term concentrations are expected to be close to or lower than concentrations within the current pit lake, the risk associated with the future development of the FHGP is considered low.

## 7.2 Recommendations

As stated, the modelling outcomes detailed in this report demonstrate the risk associated with the future development of the FHGP is considered acceptable. Nevertheless, the level of risk should be continually monitored during and post operations to enable effective mitigation in the event to the risk profile is changed. Therefore, the following recommendations have been made:

- Continue existing environmental monitoring (i.e. groundwater / surface water gauging and water quality sampling) especially in areas to the north and northeast of the site during mining and post operations and in accordance with procedures outlined in the FHGP Mine WMP.
- Complete the proposed installation of additional groundwater monitoring bores as outlined in CDM Smith (2022) to enable broader environmental monitoring at the FHGP.
- Should environmental monitoring indicate changes to the risk profile of the FHGP, consideration should be made as to whether these changes warrant further updates to the water quality modelling.
- The in-pit disposed PAF rock should be managed in accordance with the FHGP Waste Rock Management Plan and updated if ongoing environmental monitoring indicates an increased level of risk from the Project.

# Section 8 References

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# Appendix A PAF Column Leach Calculations

## Extrapolations and Release Rates

†McPherson et al., 2014
‡RIVM 2020

Column leach test results: PAF Waste

| Sample Characteristics | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sulphur<br>%S | ANC<br>$kgH_2SO_4/t$ | NAPP<br>$kgH_2SO_4/t$ | $NAG_{4.5}$<br>$kgH_2SO_4/t$ | $NAG_{7.0}$<br>$kgH_2SO_4/t$ | NAGpH | Weight<br>g | Start<br>Date | Sample<br>Code |
| 0.67 | 9 | 12 | 4 | 10 | 3.3 | 2 | 09/01/21 | FH/21363 |

| Parameters | | NTMO Short-term trigger value Irrigation and General Water Use (ANZECC, 2000) | NTMO Stock Drinking Water (ANZECC, 2000) | NHMRC 2011 Australian Drinking Water Guidelines (Health) | NTMO 80% Aquatic Ecosystem (ANZECC, 2000 at 80% protection) | NTMO 90% Aquatic Ecosystem (ANZECC, 2000 at 90% protection) | NTMO 95% Aquatic Ecosystem (ANZECC, 2000 at 95% protection) | NTMO 99% Aquatic Ecosystem (ANZECC, 2000 at 95% protection) | Background Pit | | | | | | Background Lake | | | | | | Background Groundwater | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum |
| Volume | ml | | | | | | | | | | | | | | | | | | | | | | | | | |
| pH | - | | | | | | | | | | | | | | | | | | | | | | | | | |
| EC | dS/m | | | | | | | | | | | | | | | | | | | | | | | | | |
| Alkalinity | mg/l | | | | | | | | | | | | | | | | | | | | | | | | | |
| Acidity | mg/l | | | | | | | | | | | | | | | | | | | | | | | | | |
| DOC | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Total CN | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ag | mg/l | | | 0.1 | 0.0002 | 0.0001 | 0.00005 | 0.00002 | | | | | | | | | | | | | | | | | | |
| Al | mg/l | 20 | 5 | 0 | 0.15 | 0.08 | 0.055 | 0.027 | 0.05 | 0.015 | 0.169 | 0.012 | 0.055 | 0.906 | 0.98 | 0.2 | 3.38 | 0.12 | 0.87 | 20 | 0.655130435 | 0.086579 | 2.074198 | 0.046 | 2.23 | 13 |
| As | mg/l | 2 | 0.5 | 0.01 | 0.14 | 0.042 | 0.013 | 0.0008 | 0.604 | 0.526 | 0.164 | 0.583 | 0.77 | 0.784 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.05 | 0.100550725 | 0.04985 | 0.115298 | 0.072 | 0.32 | 0.45 |
| B | mg/l | 0.5 - 1.0 | 5 | 4 | 1.3 | 0.68 | 0.37 | 0.09 | 0.016 | 0.016 | 0.002 | 0.015 | 0.019 | 0.02 | | | | | | 0.02 | | | | | | |
| Ba | mg/l | | | | | | | 0.093† | | | | | | | | | | | | | | | | | | |
| Be | mg/l | 0.5 | | 0.06 | | | | | | | | | | 0 | | | | | | 0 | | | | | | |
| Ca | mg/l | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cd | mg/l | 0.05 | 0 | 0.002 | 0.0008 | 0.0004 | 0.0002 | 0.00006 | | | | | | 0 | | | | | | 0 | | | | | | 0.3 |
| Cl | mg/l | | | | | | | | | | | | | | | | | | | | | | | | | |
| Co | mg/l | 0.1 | 1 | | | | | | | | | | | 0 | | | | | | 0.01 | 0.002 | 0.001 | 0.001 | 0.001 | 0.003 | 0.003 |
| Cr | mg/l | 1 | 1 | | 0.04 | 0.006 | 0.001 | 0.00001 | | | | | | 0.001 | | | | | | 0.04 | 0.005 | 0.002 | 0.012 | 0.002 | 0.01 | 0.053 |
| Cu | mg/l | 5 | 1 | 2 | 0.0025 | 0.0018 | 0.0014 | 0.001 | 0.003 | 0.001 | 0.009 | 0.001 | 0.002 | 0.043 | | | | | | 0.03 | 0.006 | 0.003 | 0.009 | 0.003 | 0.014 | 0.04 |
| F | mg/l | | | | | | | | | | | | | | | | | | | | | | | | | |
| Fe | mg/l | 10 | | | | | | | 0.082 | 0.035 | 0.175 | 0.028 | 0.239 | 0.852 | | | | | | 26 | 5.3 | 0.65 | 7.6 | 1.4 | 18.2 | 32 |
| Hg | mg/l | 0.002 | 0 | 0.001 | 0.0054 | 0.0019 | 0.0006 | 0.00006 | | | | | | 0 | | | | | | 0 | | | | | | |
| K | mg/l | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mg | mg/l | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mn | mg/l | 10 | 0.00000 | 0.5 | 3.6 | 2.5 | 1.9 | 1.2 | 0.142 | 0.041 | 0.178 | 0.026 | 0.427 | 0.437 | 0.03 | 0.02 | 0.04 | 0.01 | 0.07 | 0.26 | 0.171 | 0.113 | 0.152 | 0.13 | 0.354 | 0.86 |
| Mo | mg/l | 0.05 | 0.15 | 0.05 | 0 | 0 | 0 | | | | | | | 0.009 | | | | | | 0 | | | | | | |
| Na | mg/l | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ni | mg/l | 2 | 1 | 0.02 | 0.017 | 0.013 | 0.011 | 0.008 | 0.001 | 0.001 | 0.001 | 0.001 | 0.003 | 0.005 | 0 | 0 | 0.01 | 0 | 0.02 | 0.02 | 0.003 | 0.002 | 0.006 | 0.002 | 0.005 | 0.035 |
| P | mg/l | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pb | mg/l | 5 | 0 | 0.01 | 0.0094 | 0.0056 | 0.0034 | 0.001 | | | | | | 0.01 | | | | | | 0 | 0.006 | 0.004 | 0.007 | 0.003 | 0.0216 | 0.026 |
| Sb | mg/l | | | | | | | | | | | | | | | | | | | | | | | | | |
| Se | mg/l | 0.05 | 0 | 0.01 | 0 | 0 | 0 | 0 | | | | | | 0 | | | | | | 0 | | | | | | |
| Si | mg/l | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sn | mg/l | | | | | | | | | | | | | | | | | | | | | | | | | |
| $SO_4$ | mg/l | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sr | mg/l | | | | | | | 10.7‡ | | | | | | | | | | | | | | | | | | |
| Th | mg/l | | | | | | | | | | | | | | | | | | | | | | | | | |
| Tl | mg/l | | | | | | | | | | | | | | | | | | | | | | | | | |
| U | mg/l | 0.1 | 0.2 | 0.017 | | | | | | | | | | 0.006 | | | | | | 0 | | | | | | |
| Zn | mg/l | 5.000 | 20.000 | 0.000 | 0.031 | 0.015 | 0.008 | 0.002 | 0.008 | 0.004 | 0.01 | 0.004 | 0.028 | 0.040 | 0.02 | 0.01 | 0.03 | 0.01 | 0.07 | 0.1 | 0.01 | 0.006 | 0.013 | 0.007 | 0.02 | 0.086 |

| Parameters | | Week | | | | | | | Extrapolation | | | | | | | Average | maximum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 | 52 | | |
| | | 12-Jul-21 | 9-Aug-21 | 6-Sep-21 | 5-Oct-21 | 1-Nov-21 | 29-Nov-21 | 29-Dec-21 | | | | | | | | | |
| | | **21363-Initial** | **21363-1** | **21363-2** | **21363-3** | **21363-4** | **21363-5** | **21363-6** | **21363-7** | **21363-8** | **21363-9** | **21363-10** | **21363-11** | **21363-12** | **21363-13** | | |
| Volume | ml | 0.463 | 0.522 | 0.512 | 0.516 | 0.511 | 0.515 | 0.523 | 0.517 | 0.517 | 0.517 | 0.517 | 0.517 | 0.517 | 0.517 | | |
| pH | - | 5.9 | 5.9 | 5.1 | 4.8 | 4.9 | 4.7 | 4.6 | | | | | | | | | |
| EC | dS/m | 0.816 | 0.74 | 0.62 | 0.43 | 0.35 | 0.36 | 0.38 | | | | | | | | | |
| Alkalinity | mg/l | - | - | - | - | - | - | - | | | | | | | | | |
| Acidity | mg/l | 29 | 20 | 21 | 59 | 33 | 39 | 38 | | | | | | | | | |
| DOC | | - | - | 1 | 1 | 1 | <1 | <1 | | | | | | | | | |
| Total CN | | - | - | - | - | - | - | - | | | | | | | | | |
| Ag | mg/l | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | | | | | | | | | |
| Al | mg/l | 0.07 | 0.07 | 0.13 | 0.16 | 0.34 | 0.47 | 0.58 | | | | | | | | | |
| As | mg/l | 0.188 | 0.142 | 0.296 | 0.300 | 0.391 | 0.323 | 0.245 | 0.359 | 0.381 | 0.404 | 0.426 | 0.448 | 0.471 | 0.493 | 0.35 | 0.49 |
| B | mg/l | 0.09 | 0.06 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | | | | | | | | | |
| Ba | mg/l | 0.03 | 0.01 | 0.02 | 0.01 | 0.02 | 0.03 | 0.02 | | | | | | | | | |
| Be | mg/l | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.003 | 0.003 | | | | | | | | | |
| Ca | mg/l | 31 | 22 | 16 | 15 | 11 | 13 | 11 | | | | | | | | | |
| Cd | mg/l | 0.0991 | 0.0637 | 0.0590 | 0.0533 | 0.0717 | 0.0738 | 0.0602 | | | | | | | | | |
| Cl | mg/l | 13 | 4 | 2 | 1 | 2 | <1 | <1 | | | | | | | | | |
| Co | mg/l | 1.68 | 0.988 | 0.992 | 0.754 | 1.30 | 1.38 | 1.25 | 1.16 | 1.16 | 1.15 | 1.14 | 1.13 | 1.13 | 1.12 | 1.17 | 1.68 |
| Cr | mg/l | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | | | | | | | | | |
| Cu | mg/l | 0.325 | 0.202 | 0.350 | 0.671 | 2.00 | 3.55 | 4.94 | 4.89 | 5.68 | 6.47 | 7.27 | 8.06 | 8.85 | 9.64 | 4.49 | 9.64 |
| F | mg/l | 0.1 | 0.2 | 0.1 | <0.1 | 0.2 | 0.1 | 0.2 | | | | | | | | | |
| Fe | mg/l | 0.24 | 0.08 | 0.20 | 0.30 | 0.43 | 0.60 | 0.53 | | | | | | | | | |
| Hg | mg/l | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | | | | | | | | | |
| K | mg/l | 25 | 17 | 13 | 14 | 10 | 10 | 7 | | | | | | | | | |
| Mg | mg/l | 88 | 73 | 42 | 27 | 29 | 29 | 21 | | | | | | | | | |
| Mn | mg/l | 2.37 | 6.84 | 5.26 | 3.24 | 5.81 | 6.18 | 5.18 | | | | | | | | | |
| Mo | mg/l | 0.002 | <0.001 | 0.002 | <0.001 | <0.001 | 0.001 | <0.001 | | | | | | | | | |
| Na | mg/l | 16 | 8 | 5 | 4 | 4 | 9 | 5 | | | | | | | | | |
| Ni | mg/l | 0.61 | 0.35 | 0.35 | 0.31 | 0.45 | 0.50 | 0.45 | | | | | | | | | |
| P | mg/l | <1 | <1 | <1 | <1 | <1 | <1 | <1 | | | | | | | | | |
| Pb | mg/l | 0.008 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.04 | | | | | | | | | |
| Sb | mg/l | <0.001 | <0.001 | 0.002 | <0.001 | 0.001 | 0.001 | <0.001 | | | | | | | | | |
| Se | mg/l | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | | | | | | | | | |
| Si | mg/l | 1.4 | 2.7 | 1.2 | 1.3 | 1.1 | 1.0 | 0.9 | | | | | | | | | |
| Sn | mg/l | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | | | | | | | | | |
| $SO_4$ | mg/l | 448 | 327 | 209 | 131 | 136 | 166 | 136 | 142 | 142 | 142 | 142 | 142 | 142 | 142 | | |
| Sr | mg/l | 0.07 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | | | | | | | | | |
| Th | mg/l | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | | | | | | | | | |
| Tl | mg/l | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | | | | | | | | | |
| U | mg/l | 0.009 | 0.003 | 0.004 | 0.004 | 0.007 | 0.010 | 0.012 | | | | | | | | | |
| Zn | mg/l | 1.01 | 0.50 | 0.64 | 0.73 | 1.25 | 1.44 | 1.30 | | | | | | | | | |

**Calculated Parameters**

| | | 0 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 | 52 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SO_4$ Release | mg/kg/wk | - | 21 | 13 | 8 | 9 | 11 | 9 | 11.904 | 9 | 9 | 9 | 9 | 9 | 9 |
| IOR | kg O2/m3/s | - | 1.37E-08 | 8.59E-09 | 5.42E-09 | 5.58E-09 | 6.86E-09 | 5.71E-09 | 0.000 | | | | | | |
| Cumulative $SO_4$ | mg/kg | 104 | 189 | 243 | 276 | 311 | 354 | 389 | 266.582 | 303 | 340 | 377 | 413 | 450 | 487 |
| PAF | kg H2SO4/t | 0.11 | 0.19 | 0.25 | 0.28 | 0.32 | 0.36 | 0.40 | 0.272 | | | | | | |
| Cumulative ANC | kg H2SO4/t | 0.11 | 0.10 | 0.06 | 0.04 | 0.04 | 0.05 | 0.03 | 0.062 | | | | | | |
| Nett Acidity | kg H2SO4/t | 0.00 | 0.09 | 0.19 | 0.24 | 0.28 | 0.31 | 0.36 | 0.210 | | | | | | |
| Acidity | mg CaCO3/L | 467 | 341 | 218 | 136 | 142 | 173 | 142 | 148 | 148 | 148 | 148 | 148 | 148 | 148 |
| Alkalinity | mg CaCO3/L | 488 | 389 | 238 | 174 | 166 | 184 | 133 | | | | | | | |
| Nett Alkalinity | mg CaCO3/L | 21 | 48 | 20 | 37 | 24 | 11 | -9 | | | | | | | |
| Titrated Alkalinity | mg CaCO3/L | -29 | -20 | -21 | -59 | -33 | -39 | -38 | | | | | | | |
| Residual S | %S | 0.67 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.65 | 0.65 |
| $CaCO_3$ Consumption | mg/kg/wk | - | 23 | 14 | 10 | 9 | 10 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cumulative $CaCO_3$ | mg/kg | 102 | 195 | 249 | 288 | 325 | 364 | 394 | 394 | 394 | 394 | 394 | 394 | 394 | 394 |
| Residual ANC | kg $H_2SO_4$/t | 8.9 | 8.8 | 8.8 | 8.7 | 8.7 | 8.6 | 8.6 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| $CO_3/SO_4$ molar ratio | - | 0.9 | 1.0 | 1.0 | 1.1 | 1.0 | 0.9 | 0.8 | | | | | | | |

| | | |
|---|---|---|
| As Release (Cumulative) | mg/kg | 3720 |
| | % | |
| | mg/kg/week | |
| | | |
| Cobalt | mg/kg | 50.3 |
| Release | % | |
| Cum | mg/kg/week | |
| | | |
| Copper | mg/kg | 426 |
| Release | % | |
| Cum | mg/kg/week | |
| | | |
| Acidity | mg/kg | 110 |
| Release | % | |
| Cum | mg/kg/week | |

### Leach Concentrations from Rock Pile

| | A Release | Kg rock | mg | Bulk Density t/m3 | m3 | Possible Footprint (m2) | Rainfall (mm) | L per m2 | Litres per footprint | Weekly | mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Arsenic | 0.023 | 3.00E+07 | 6.90E+05 | 2.00E+00 | 7.50E+04 | 2.50E+04 | 1250 | 1250 | 3.13E+07 | 6.01E+05 | 1.1 |
| Cobalt | 0.072 | 3.00E+07 | 2.16E+06 | 2.00E+00 | 7.50E+04 | 2.50E+04 | 1250 | 1250 | 3.13E+07 | 6.01E+05 | 3.6 |
| Copper | 0.126 | 3.00E+07 | 3.78E+06 | 2.00E+00 | 7.50E+04 | 2.50E+04 | 1250 | 1250 | 3.13E+07 | 6.01E+05 | 6.3 |

### Release Rates

| As | | | 0 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 | 52 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cumul. | mg/kg | 3720 | 0.04 | 0.08 | 0.16 | 0.23 | 0.33 | 0.42 | 0.48 | 0.57 | 0.67 | 0.78 | 0.89 | 1.00 | 1.12 | 1.25 | | |
| Percent | % | | 0.001% | 0.002% | 0.004% | 0.006% | 0.009% | 0.011% | 0.013% | 0.015% | 0.018% | 0.021% | 0.024% | 0.027% | 0.030% | 0.034% | | |
| Per week | mg/kg/week | | - | 0.009 | 0.019 | 0.019 | 0.025 | 0.021 | 0.016 | 0.023 | 0.025 | 0.026 | 0.028 | 0.029 | 0.030 | 0.032 | 0.02 | 0.03 |
| **Cobalt** | | | | | | | | | | | | | | | | | | |
| Cumul. | mg/kg | 50.3 | 0.39 | 0.65 | 0.90 | 1.10 | 1.43 | 1.78 | 2.11 | 2.41 | 2.71 | 3.01 | 3.30 | 3.59 | 3.89 | 4.17 | | |
| Percent | % | | 0.773% | 1.286% | 1.791% | 2.177% | 2.838% | 3.544% | 4.194% | 4.792% | 5.386% | 5.976% | 6.562% | 7.145% | 7.724% | 8.299% | | |
| Per week | mg/kg/week | | | 0.064 | 0.063 | 0.049 | 0.083 | 0.089 | 0.082 | 0.075 | 0.075 | 0.074 | 0.074 | 0.073 | 0.073 | 0.072 | 0.07 | 0.09 |
| **Copper** | | | | | | | | | | | | | | | | | | |
| Cumul. | mg/kg | 426 | 0.08 | 0.13 | 0.22 | 0.39 | 0.90 | 1.82 | 3.11 | 4.37 | 5.84 | 7.51 | 9.39 | 11.47 | 13.76 | 16.26 | | |
| Percent | % | | 0.018% | 0.030% | 0.051% | 0.092% | 0.212% | 0.426% | 0.729% | 1.026% | 1.371% | 1.764% | 2.205% | 2.694% | 3.231% | 3.816% | | |
| Per week | mg/kg/week | | | 0.013 | 0.022 | 0.043 | 0.128 | 0.229 | 0.323 | 0.316 | 0.367 | 0.418 | 0.470 | 0.521 | 0.572 | 0.623 | 0.31 | 0.62 |

# Appendix B Fountain Head Pit Lake Water Quality Predictions

Land and Water Consulting

# PNX Fountain Head

## Pit Lake Water Quality Predictions

CDM Smith

11 July 2022

## Document Status

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## Project Details

| | |
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| **Project Name** | Pit Lake Water Quality Predictions |
| **Client** | CDM Smith |
| **Client Project Manager** | Jakob Pretzsch-Kalsgaard |
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# EXECUTIVE SUMMARY

CDM Smith is currently supporting ERIAS to address the comments received on the Environmental Impact Statement (EIS) for PNX Metal's proposed Fountain Head Gold project in the Northern Territory, Australia. CDM Smith engaged Land & Water Consulting to provide technical support in predicting pit lake water quality in relation to acid rock drainage (ARD) associated with potentially acid forming (PAF) rock that is proposed to be stored in the pit.

CDM Smith had previously undertaken a pit lake water quality study using Goldsim. The previous modelling was prepared to understand the effect that storage of PAF materials may have on water quality within the pit during and post mining.

CDM Smith's previous work involved a non-reactive modelling approach and assumed that PAF storage would occur outside the pit area.

The estimated tonnage of PAF rock at end of mine life is understood to be 0.15 million tonnes. ERIAS has recently confirmed that PAF rock storage will be within the Fountain Head pit comprising a "pod" of rock. The pit lake will be allowed to flood naturally (or be assisted in flooding) with a view to covering the waste PAF rock to exclude oxygen in order to prevent oxidation (or ongoing oxidation) of sulfide in the rock, and mitigate acid generation/ metals solubilisation.

Land & Water Consulting (LWC) undertook a pit lake water quality assessment in October / November 2021, with the released final version being version FR001 released November 2021 which used predictions made on the basis of four kinetic testing time points (weeks 0, 4, 8 and 12).

LWC was requested to update the study on 6 April 2022 on the following basis:

1. Incorporate a review of the most recent kinetic test dataset (16, 20 and 24 weeks) including investigation of metals and other parameter's response to oxidation.

    a. This review should expand on what was done previously in determining the source term and show visually (i.e. timeseries plots for multiple parameters) that all parameters have been considered by this review.
    b. Comparison of the leachate data against current pit lake water quality and tier 1 criteria
    c. Comment on the level of risk posed from the PAF oxidation regarding specific parameters, i.e. if Mg increases by a factor of 2 could this present as a problem for concern?
    d. Prepare series of plots to demonstrate the Eh/pH relationship which can be used to predict future water quality for given solutes
    e. A brief report/ memo summarising these tasks

This assessment used available kinetic data for PAF rock and extrapolated forward using linear trend analysis and bulk scaling factors. A cumulative scaling factor (CSF) was adopted for consideration from literature, and this reduces the predicted rates and leach concentrations, though scaling factors that are not site specific are problematic.

Arsenic concentrations are very noticeable in terms of magnitude compared to other elements, where concentrations in excess of 10,000 mg/kg (for context general crustal concentration would be in the range 5 – 30 mg/kg) have been reported. Arsenopyrite (an iron arsenic sulfide (FeAsS)) is present in project rock. Arsenic has a calculated geochemical abundance index (GAI) of over 10.

Arsenic and acidity are thus considered to be the key parameters, along with cobalt and copper (i.e. these form the source term).

Current pit lake water has an arsenic concentration above the stock watering guideline value of 0.5 mg/L.

It is understood the PAF rock would be left unmanaged within the pit for ~3 years and so further oxidation of sulfidic materials may occur, leading to a higher leach concentration of copper and cobalt, which appear to be pH sensitive (higher in concentration under more acidic conditions). Arsenic does not appear to be unduly driven by increased acidity, likely as a result of the high GAI.

Key conclusions are as follows:

1. Scaled up leach (accounting for 0.15 million tonne of rock) adjusted for a literature based CSF would be predicted to yield an arsenic concentration less than the current lake water and result in a lake water arsenic concentration around the stock watering criterion for arsenic (similar to now). Predicted concentrations of cobalt and copper are predicted to be less than stock watering criteria after year 1 of recovery.

2. It is possible that arsenic may bind with available ferric oxyhydroxides (FeOH) and therefore have colloidal behaviour. This may result in the arsenic becoming enriched in sediment rather than water column over time.

3. Given the proposed interim in pit storage of PAF rock, if not appropriately managed this may lead to notable generation of acidity and mobile metals/ metalloids during life of mine. When the pit is allowed to flood and contacts the 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). Interim management measures that mitigate oxidation and generation of acidity (and metal release) should be considered with respect to copper and cobalt.

4. The long term management of PAF rock is proposed to be full submergence within POD 3 at the base of the pit upon mine closure. As 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 interim PAF rock drainage may need to be managed and treated in the interim period.

Please note the statement of limitations as Appendix E.

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# 1 INTRODUCTION

## 1.1 OVERVIEW

CDM Smith is currently supporting ERIAS to address the comments received on the Environmental Impact Statement (EIS) for PNX Metal's proposed Fountain Head Gold project in the Northern Territory, Australia. CDM Smith engaged Land & Water Consulting to provide technical support in predicting pit lake water quality in relation to acid rock drainage (ARD) associated with potentially acid forming (PAF) rock that is proposed to be stored in the pit.

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The estimated tonnage of PAF rock at end of mine life is understood to be 0.15 million tonnes. ERIAS has recently confirmed that PAF rock storage will be within the Fountain Head pit comprising a "pod" of rock. The pit lake will be allowed to flood naturally (or be assisted in flooding) with a view to covering the waste PAF rock to exclude oxygen in order to prevent oxidation (or ongoing oxidation) of sulfide in the rock, and mitigate acid generation/ metals solubilisation.

Land & Water Consulting (LWC) undertook a pit lake water quality assessment in October / November 2021, with the released final version being version FR001 released November 2021 which used predictions made on the basis of four kinetic testing time points (weeks 0, 4, 8 and 12) which is insufficient for reasonable prediction of acid metal generation/ leaching from the given material (and only one kinetic column of PAF is established).

LWC was requested to update the study on 6 April 2022 on the following basis:

1. Incorporate a review of the most recent kinetic test dataset (16, 20 and 24 weeks) including investigation of metals and other parameter's response to oxidation.

    a. This review should expand on what was done previously in determining the source term and show visually (i.e. timeseries plots for multiple parameters) that all parameters have been considered by this review.
    b. Comparison of the leachate data against current pit lake water quality and tier 1 criteria
    c. Comment on the level of risk posed from the PAF oxidation regarding specific parameters, i.e. if Mg increases by a factor of 2 could this present as a problem for concern?
    d. Prepare series of plots to demonstrate the Eh/pH relationship which can be used to predict future water quality for given solutes
    e. A brief report/ memo summarising these tasks

## 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:*

$$FeS_2 + 7/2O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+ \qquad \text{Eq. 1}$$

$$or, \quad 2FeS_2 + 7O_2 + 2H_2O \rightarrow 2FeSO_4 + 2H_2SO_4 \qquad \text{Eq. 2}$$

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

$$2\,Fe^{2+} + \tfrac{1}{2}O_2 + 2H^+ \rightarrow 2\,Fe^{3+} + H_2O \qquad \text{Eq. 3}$$

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 ferroxidans* 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:

- limiting access to 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

Assess acid generation, neutralisation, and solute mineral release/ formation due to reactive processes associated with PAF rock to provide input to the CDM Smith Goldsim model used to simulate the pit lake water quality.

## 1.4 SCOPE

The following tasks were agreed as per the scope:

1. Incorporate a review of the most recent kinetic test dataset (16, 20 and 24 weeks) including investigation of metals and other parameter’s response to oxidation.
    a. This review should expand on what was done previously in determining the source term and show visually (i.e. timeseries plots for multiple parameters) that all parameters have been considered by this review.
    b. Comparison of the leachate data against current pit lake water quality and tier 1 criteria
    c. Comment on the level of risk posed from the PAF oxidation regarding specific parameters, i.e. if Mg increases by a factor of 2 could this present as a problem for concern?

d. Prepare series of plots to demonstrate the Eh/pH relationship which can be used to predict future water quality for given solutes

e. A brief report/ memo summarising these tasks.

This report is an update of the LWC 2021 report, using extended kinetic leach data points and accounting for PAF rock management strategy (complete submergence within the pit lake).

# 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.

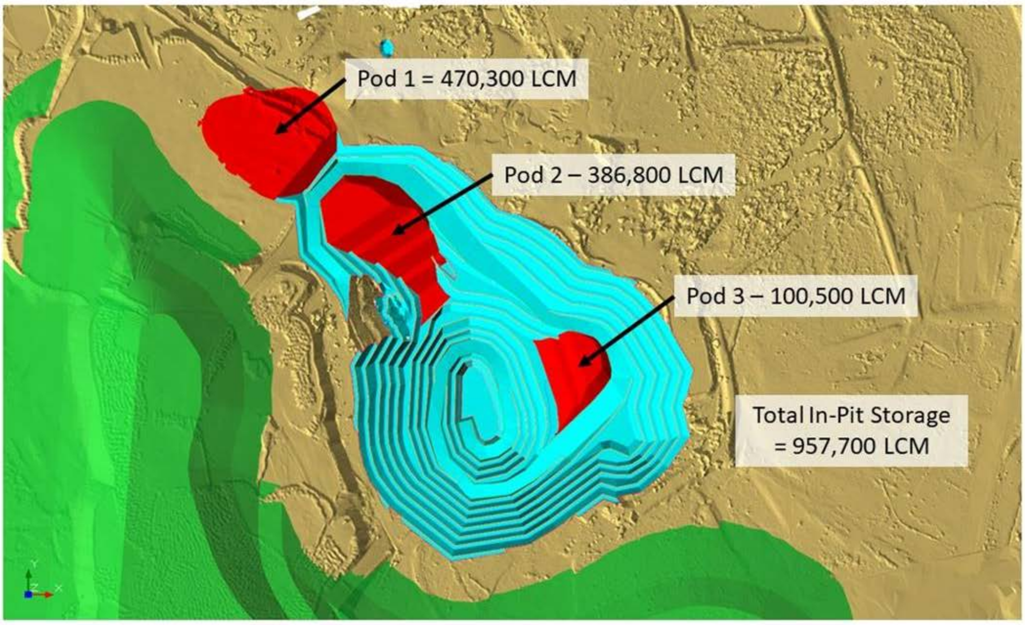
The CSM contributes to an understanding of possible effects posed to environmental values associated in pit storage of acid generating waste materials.

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 PAF STORAGE/ MANAGEMENT CONCEPT

The current proposed PAF management strategy is to store all PAF rock (0.15 mega tonnes) within the pit during mining and then push the material to the bottom (likely pod 3 or below), which is one of three ‘pods’ that have a combined total in-pit storage of 2 mega tonne of PAF rock (Figure 2-1). The PAF rock would then be submerged under the lake water as the water level rises.

*Figure 2-1 Proposed in pit storage of PAF (only POD 3)*



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.

Water table elevation calculations provided by CDM Smith indicate POD 3 would be fully submerged within 5 years.

## 2.3 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 Pit*

| **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 will evapo-concentrate solutes arising from incident rainfall and groundwater discharge. No pit lake is expected to form and the solute will remain on the walls and/ or the base of the Pit. | 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<br>• 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.<br>• 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.<br>• 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) |

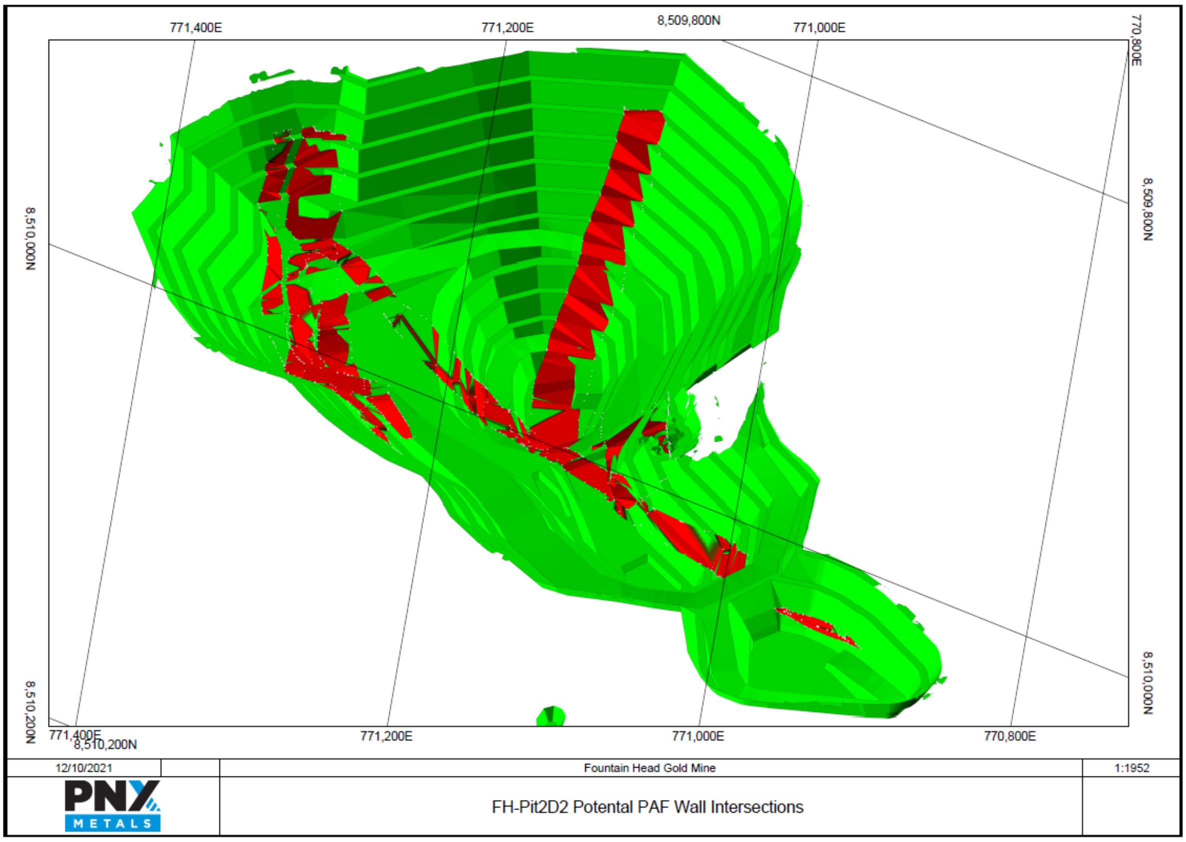
## 2.4 SOURCES

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 (EGi, 2020)) 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 in base of Pit as PODS 1 – 3 (refer Figure 3-1) | 0.15 million tonnes of PAF rock with leach chemistry represented by kinetic sample 21363. | ☑ |
| S2 | Open Pit – rock walls – as per Figure 3-2. | Sulfide oxidation in wall rock – dewatering and excavation exposes wall rock to atmospheric oxygen and solutes released by oxidation of sulfide minerals are flushed into the Pit by rainfall runoff or groundwater seepage through the rock wall.<br>PNX provided an estimation of the PAF wall exposures in the pit (email ERIAS to CDM Smith 13 October 2021).<br>As per Figure 2-2 there is approximately 18.8% of the 295,549 m$^2$ of pit wall which will be ore or PAF in nature (55,563 m$^2$). | X |

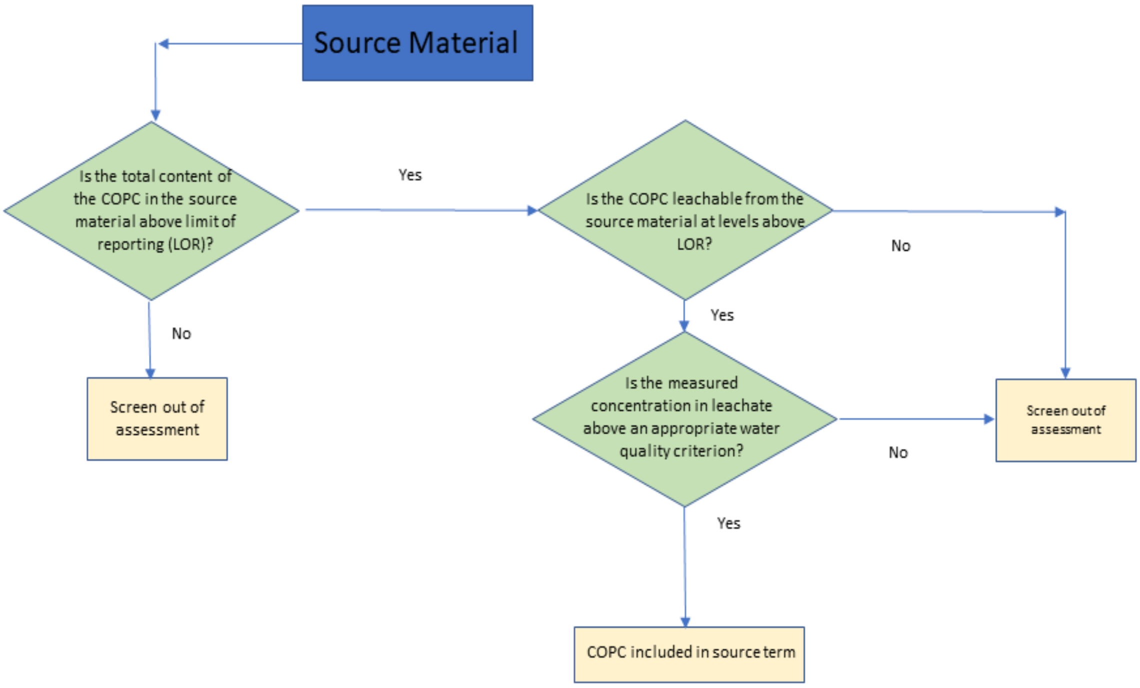
*Figure 2-2 PAF wall rock intersections*



### 2.4.1 Source Term

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 2-3. Refer to Section 4 for further detail.

*Figure 2-3 Source term screening process*



## 2.5 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<br>☑ 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).

# 2.6 Receptors

## 2.6.1 Environment / Ecosystem Health

As per Section 2.6.3 and Table 2-4, migratory birds are considered to be a key ecological receptor. A perennial billabong is known to be located around 2 km to the north east, which is considered to not represent an adjacent receptor. There is some potential for groundwater dependant ecosystems to be present in a unnamed creek approximately 1 km north of the Site.

## 2.6.2 Beneficial use of groundwater

Potential future use of groundwater is understood to be restricted to stock watering supply.

## 2.6.3 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 |
| | Springs and pools | ☑ Perennial billabong approximately 2 km to the north east of the Site.<br>☑ Possible groundwater dependant ecosystems 1 km to the north of the Site in an unnamed creek. |
| | Ecosystems supporting significant flora, vegetation and fauna | ☒ Stygofauna<br>☒ Troglofauna<br>☒ Terrestrial vegetation<br>☑ Migratory aquatic birds |
| | Ecosystems supporting significant amenity, recreation and cultural[4] values | ☒ None identified |

| Environmental value[1] | | Details |
|---|---|---|
| | 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 |
| | Inland waters with high levels of active and passive recreation including multiple use wetlands | ☒ None identified |
| | Inland waters with significant cultural[4] or aesthetic values | ☒ None identified |

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**<br>If a water body were to form such as a transient pit lake, it could potentially contain high levels of selenium (Se) in the water. One pit lake in Wyoming contains over 100 parts per million of selenium.<br>Waterborne selenium concentrations greater than 0.45 mg/L are 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.<br>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).<br>With high selenium as total it is important to speciate the metalloid as the toxicity varies with oxidation state.<br>Se release in acidic water may be to do with dissolution of calcite.<br>Re-precipitation of carbonate can reduce Se content.<br>Mo and Se both affect egg shell production (high concentrations cause softening of the shell) and thus can affect bird reproduction. |

| Receptor (R) | Description |
|---|---|
| R2 | **Future Human Use**<br>Potential treatable water supply - Potential future abstraction for human use. |
| R3 | **Stock Watering**<br>Potential treatable water supply - Potential future abstraction for stock watering. |
| R4 | **Groundwater dependant ecosystems (GDE)**<br>☑ Perennial billabong approximately 2 km to the north east of the Site.<br>☑ Possible groundwater dependant ecosystems 1 km to the north of the Site in an unnamed creek.<br>Groundwater modelling assessments suggest there is no risk to the GDE from site activities. |

## 2.7 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 6 linkages are identified as being potentially relevant / significant (Table 2-7).

*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 (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 |
| **S2**<br>Pit wall rock | P1 - Groundwater inflow and contact with exposed oxidised rock / materials | P2 - direct uptake / contact<br>P3 - Lateral migration of solutes away from the Pit | - | R1 Migratory Birds (contact) | L4 |
| | | | P4 - Abstraction | R2 Future Human Use | L5 |
| | | | P4 - Abstraction | R3 Stock watering | L6 |
| | | | (Direct contact) | R4 GDE | Modelling suggest no risk |

# 3 SOURCE TERM

## 3.1 CONTEXT

The geochemical data made available to LWC for version FR001 is summed in:

- Environmental Geochemistry International (Egi) (2020). Geochemical Characterisation of Waste Rock & Ore - FOUNTAIN HEAD. DOCUMENT NUMBER: 1316 / J000373 / REPORT # 1369 prepared for ERIAS Group Pty Ltd; and

The additional geochemical data made available to LWC for version FR002 was provided as:

- Extended Fountain Head Leach Column Results (excel file), provided by Egi to ERIAS
- Excel file “all PNX WQ Data” 20220218

Egi (2020) reports that the Project will involve a cutback of the existing pit. Approximately 15 Mt of waste rock and 3 Mt of ore will be mined over the 2.5 year operation. Waste rock will be placed in the existing waste rock stockpile (WRS). The existing WRS encroaches onto the proposed pit cutback and therefore a section of the waste stockpile will need to be relocated prior to cutting back in this region.

Egi (2020) reports that the geochemical testing included waste rock that will be removed from the pit during the cutback, waste rock from the existing WRS, including material that will be removed to allow pit development, and ore samples.

In order to obtain rock samples which would satisfactorily represent the distribution of waste rock types to be mined during the expansion of the existing Fountain Head pit, a number of drill holes were selected by Egi from the many drilled during resource definition drilling. Samples from these drill holes were selected to cover variation in lithology, oxidation and chemical composition of the waste rock, while also achieving appropriate spatial coverage of the proposed expanded pit. A value of 1 ppm Au (fire assay results) was used in most instances to delineate between ore (Au >1 ppm) and waste rock.

In total 111 drill hole samples, 18 WRS samples and 3 ore and 3 cyanide leached samples were tested for the following:

- Total sulphur (S);
- Paste (1:2) pH and EC;
- single addition net acid generation (NAG) test; and
- acid neutralising capacity (ANC)

For a number of samples, additional geochemical testing was conducted to provide better definition of their geochemical properties including:

- acid buffering characteristic curve (ABCC) testing to define the relative availability of the measured ANC;
- carbon speciation analysis (Total C, organic C and inorganic C) to determine carbonate content; and
- chromium reducible sulphur (CRS) to quantify the amount of sulphide sulphur.

In addition to the above tests, leach tests were conducted on a number of samples to provide information on the leaching characteristics of various metals and other elements of concern. Testing included:

- Multi-element testing of the sample solid (19 drill hole samples, multi-element assay results were available for WRS and metallurgical samples)
- Peroxide extraction testing including multi-element assay of the extract (9 drill hole samples)
- Water extraction testing including multi-element assay of the extract (19 drill hole samples, 3 WRS samples and 2 metallurgical samples)

## 3.2 ELEMENTAL SPECIATION

Multi element composition of Fountain Head pit waste rock and ore was undertaken by EGI (2020) and is presented as Table H1 in their document.

Arsenic concentrations are very noticeable in terms of magnitude compared to other elements, reporting concentrations in excess of 10,000 mg/kg (for context general crustal concentration would be in the range 5 – 30 mg/kg). Arsenopyrite (an iron arsenic sulfide (FeAsS)) is present at the Site. Arsenic has a calculated geochemical abundance indices of over 10. Anything of 3 or above is generally counted as being heavily mineralised. Other elements reporting with a GAI at or >3 are (as per Table H2 of the Egi report):

- Silver (Ag)
- Beryllium (Be)
- Bismuth (Bi)
- Cobalt (Co) (in the ore only)
- Copper (in the ore only)
- Manganese (Mn)
- Lead (Pb)
- Sulfur (S)
- Selenium (Se)
- Uranium (U)
- Tungsten (W)

## 3.3 STATIC TESTING

The Egi (2020) results of geochemical testing of samples obtained from drilling in the Fountain Head pit show:

- There is no immediately available acidity and low salinity in these samples when contacted with water, indicating that freshly mined rock is unlikely to provide low pH or saline drainage.

- Total S analysis showed a broad range up to 3%S, but with the vast majority (90%) having a relatively low S value of 0.5%S or less, suggesting the occurrence of pyritic rock is not widespread.
- ANC was relatively low, ranging up to 33 kg $H_2SO_4$/t, indicating a general lack of excess buffering.
- Carbon speciation analysis indicates carbonate content is negligible, with the total carbon content of these samples generally low. This is consistent with ABCC test results which also suggest little carbonate content, and that the small amount of carbonate present in these samples is predominantly iron carbonates (ferroan dolomite, siderite), which will react relatively slowly.
- Most samples were NAPP negative, with the majority of these having ANC/MPA ratios of 2 or more, indicating a high factor of safety.
- The majority (70%) of NAGpH values were 4.5 or greater, corroborating the ABA results which indicated most samples are likely to be NAF.
- CRS measurements show that greater than 90% of Total S is contained in sulphide minerals, suggesting that Total S measurements can be used as suitable guide to the sulphide (pyrite) content of these materials.
- Test results were used to classify samples as NAF, PAF, PAF-LC or UC. Around 80% of samples tested were classified NAF (including UC equivalents), 15% PAF-LC (including UC equivalents) and 5% PAF. Overall results indicate most waste materials to be mined will be NAF, with a minor proportion of PAF.

Given the relatively low ANC and poor reactivity, criteria based on Total S was selected as the best potential option for routine classification of ARD rock types. Using the results from detailed geochemical testing, sulphur distributions were determined for each of NAF, PAF-LC or PAF ARD classifications. The results show:

- NAF samples can be differentiated from PAF/PAF-LC samples by applying a Total S cut-off of 0.2%S
- 95% of samples classified NAF have a Total S value of 0.2% or less, and all PAF samples and 60% of PAF-LC samples have a Total S value of greater than 0.2%S.
- Although using a ≤0.2%S criteria for NAF waste rock includes 40% PAF-LC material, these have low acid potential and operational blending with NAF materials would be expected to account for any minor acidity generated.

## 3.4 SINGLE ADDITION LEACH TESTING

In addition to the above testing, water and peroxide extractions were conducted on selected samples to understand the likely quality of drainage from freshly mined and oxidised waste rock respectively. EGI (2020) reported the results of these tests show:

- All water extracts produced circum-neutral to mildly alkaline solutions with low salinity. Metal concentrations in water extracts were also very low to non-detectable.
- These results suggest leachates from freshly mined waste rock from the Fountain Head pit will, in general, be of reasonable quality. However, segregation of the PAF waste rock using a Total

S value of 0.2% may improve leachate quality for the majority of fresh waste rock containing ≤0.2%S.

- Water extracts for WRS samples had neutral pH and low salinity. Metal/metalloid concentrations were also very low or non-detectable.
- Water extractions conducted on an ore sample and the same sample following cyanidation showed that cyanide leaching has significantly increased arsenic mobility in this sample.
- Arsenic is significantly enriched in the majority of samples tested relative to average crustal and soil abundance.
- Iron, copper, cobalt, nickel and arsenic concentrations in peroxide leachates correlated with Total S content of the samples, indicating that segregation of samples with significant sulphur content is likely to reduce the concentration of these heavy metals/ metalloids in drainage from oxidised waste rock in the WRS.
- Peroxide leachates suggest drainage from oxidised waste rock containing more than 0.2% sulphur may contain substantial concentrations of Al, Co, Mn, Ni, Pb, Zn and waste rock with Total S concentrations above this value should be managed to minimise oxidation and release of heavy metals.

Consequently, the following were recommended with respect to geochemical investigations:

1. Although the proportion of PAF materials is likely to be minor, quantification of the distribution of PAF materials will be required ahead of mining and selective handling and management carried out during mining to ensure PAF materials are not a source of ARD during operations and at closure. Quantifying the proportion of PAF will require more extensive testing and it is recommended that any further drilling for resource definition, should include Total S analysis (high temperature combustion method e.g. LECO method, or ICP MS analysis) as a part of the suite of analyses conducted on the samples tested.
2. Only a limited number of WRS samples were tested, and more widespread follow up testing (S only required initially) is recommended for rock from the WRS.
3. It is expected that some ore processed at Fountain Head may have higher sulphide content associated with pyrite than the samples tested during this study. Such materials could potentially generate ARD, depending on the balance between the acid generating potential of the sulphide and the ANC in the material and the alkalinity added through lime addition. It is therefore recommended that ore samples with higher sulphur content should be tested for ARD generating potential.
4. Currently available geological information is not sufficient to calibrate reliable geological criteria for waste handling and management. Definition of geological criteria would require inspection of representative drill core through the deposit to better understand controls on sulphide and carbonate distribution, including the oxidation profile to check for the presences of residual sulphides in oxide and transition zones..
5. If a ≤0.2%S criteria for NAF waste rock is to be utilised as a waste segregation and handling criterium, it is recognised that the NAF rock will likely contain a small portion of PAF-LC rock. While these materials have low acid potential and operational blending with NAF materials could be expected to account for any minor acidity generated, this assumption should be validated. It was recommended that kinetic leach column testing be undertaken on samples of

PAF-LC material and mixtures of NAF and PAF-LC materials to determine the likely nature of drainage of such materials stored permanently in the WRS (this was completed)

6. Because of the elevated concentrations of several metals (Al, Co, Mn, Ni, Pb, Zn) in peroxide extracts of samples containing relatively low Total S (<0.35%), it was recommended that further testing of the leaching behaviour of these types of samples should be investigated further.

## 3.5 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) through the sample for a specified period. Leachate samples can be collected at any desired frequency and analyzed 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)
- Leachant composition (water or other reagent, sparged to remove $O_2$, 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.

The column leach data initially provided to LWC spanned weeks 0 – 12 (12 July 2021 to 5 October 2021). A total of five columns are understood to be in progress:

1. PAF Rock
2. PAF (low confidence (LC)) Rock
3. NAF Rock
4. Blend of PAF and NAF rock (10/90)
5. Tailings

Data for weeks 16, 20 and 24 was provided to LWC in April 2022.

For the purposes of pit lake water quality prediction, the PAF data is of interest in the first instance The kinetic test for PAF uses sample 21363. Sample characteristics are summed in Table 3-1.

*Table 3-1 Sample 21363 characteristics*

| Sulphur | ANC | NAPP | $NAG_{4.5}$ | $NAG_{7.0}$ | NAGpH | Weight | Start | Sample |
|---|---|---|---|---|---|---|---|---|
| %S | $kgH_2SO_4/t$ | $kgH_2SO_4/t$ | $kgH_2SO_4/t$ | $kgH_2SO_4/t$ | | g | Date | Code |
| 0.67 | 9 | 12 | 4 | 10 | 3.3 | 2001 | 09/01/21 | FH/21363 |

General trends observable from sample 21363 in the duration of data initially available (weeks 0 – 12):

- In line with elemental speciation, arsenic is by far the predominant element (metalloid) in terms of metal/ metalloid magnitude.
- No alkalinity is recorded.
- Acidity had doubled in 12 weeks with a concomitant decrease in pH from 5.9 to 4.8.
- Sulfate has decreased three to four-fold.
- All metals generally in steady state other than copper which has ~doubled.

General trends observable from sample 21363 in the duration of data initially available (weeks 16 - 24):

- pH is relatively stable around 4.6 (4.8 in week 12)
- acidity is relatively stable at week 24 relative to week 12 (38 mg/L versus 59 mg/L)

Egi provided the following commentary to Egi on 1 February 2022:

- *As expected, leachate from the NAF material remained slightly alkaline (pH 7.5 – 8) throughout the test. PAF-LC leachate was circum-neutral (pH 6.5 – 7) across the testing period, while PAF leachate decreased from around 6 to about 4.6 across 6 months of leaching. Leachate pH from the blended NAF/PAF-LC/PAF column leachate was the same as for the NAF column.*
- *Intrinsic oxidation rates (IOR) calculated from sulphate release followed the order NAF≈Blend<PAF-LC<PAF<Tailings, which roughly follows the S content of these materials with the exception of the tailings where the high IOR probably reflects both S content and reduced particle size (increased surface area).*
- *Heavy metal concentrations were low in leachates from all the materials tested with the exception of the* ***PAF waste where leachates contained elevated concentrations of Co, Ni, Mn and Zn across the 24 weeks of testing****.*
- *Copper concentrations appear to be pH controlled and as the pH dropped in the leachate from the PAF material, the concentration increased significantly.*
- *Al, Fe and Si concentrations in the leachates from the NAF and blended columns appear to be significantly higher than could be expected in solutions with slightly alkaline pH. Measurement of organic C in the leachates showed elevated concentrations of organics in the leachates, but these did not correlate with the higher Al and Fe concentrations, so the complexation of the metals with organic species does not appear to explain the higher than expected concentrations.*
- *Ultrafiltration of a leachate sample with high Al, Fe and Si showed that all of the Al and Fe and about 30% of the Si was present as species >20nm (nominal size of the UF membrane) i.e., present as very fine colloids, and not true solution species. Solution modelling calculations showed that if iron was allowed to precipitate as ferrihydrite and Al and Si as kaolinite, modelled solution concentrations matched those of the UF filtered leachate. This suggests that the elevated concentrations of Al, Fe and Si in the leachates from the NAF waste rock was probably due to very fine (20 – 450 nm) colloidal iron oxyhydroxides and kaolinite (the NAF materials contains ~10% kaolinite) in equilibrium with the solution. These calculations suggest that true solution concentrations of Al and Fe are likely to be below the detection limit and the measured concentrations in leachates should not be considered as the true solution concentrations. As colloidal species of Al in particular are not likely to have the same toxicity as dissolved Al species, Al should not be regarded as a potential toxic species present in waste rock drainage.*

*It should be noted however, that for the PAF sample, calculated solution concentrations of Al and measured concentrations matched from week 12 onwards. This coincides with a decrease in leachate pH to below 5, where Al solubility would be expected to increase. Dominant solution species predicted from solution modelling include* $AlSO_4^+$ *and* $AlF^{2+}$ *at lower pH which may contribute to toxicity of PAF leachates.*

- *Concentrations of As were elevated in leachate from the PAF-LC column, increasing as leaching continued,* ***without any obvious correlation to leachate pH or sulphate release****. Leachate concentrations of As appear to reflect the amount of As in the sample in the order PAF-LC>PAF>NAF≈Blend. Leaching of As from the cyanide leached ore was significantly higher than from waste rock, probably reflecting both the relatively high concentration of As in the ore and the reduced particle size compared to waste rock. While As concentrations in leachates from the PAF-LC sample might suggest a potential issue with leaching from PAF-LC rock in the IWL, As concentrations in leachates from the blended sample were very low throughout testing. If dilution of the PAF-LC waste in the blended sample was taken into account, leachate concentrations from the blended sample were slightly lower than would be expected from dilution alone. This may suggest retention of As in the blended column, perhaps as a result of sorption processes.*
- *The results of leach column tests suggest that NAF waste rock stored in the IWL is unlikely to produce seepage that would pose any significant risk to surface or groundwater.*
- *Further, co-disposal of PAF-LC waste with NAF waste would seem unlikely to impact seepage water quality. Even if As in seepage from the IWL were occur at concentrations slightly higher than those measured in leachates from leach column tests, the impact on groundwater and pit water would likely be minimal, given the elevated background As concentrations in groundwater at the site.*
- *The predicted small volume (≈2%) of PAF waste expected during the pit expansion at Fountain Head is likely to produce low quality drainage if exposed to atmospheric conditions. This could include elevated concentrations of a number of metals including Al, Co, Cu, Mn, Ni and Zn. Based on the results of the leach column tests, the lag time to increased concentrations of metals in pore water could be as short as 2 – 3 months and, depending on rainfall, drainage containing elevated levels of metals potentially shortly after this. Although the pH may remain above 4.5 for some considerable time, this does not appear to preclude significant increases in metal concentrations.*
- *Whether this PAF waste is deposited in the Fountain Head pit or in the IWL, it would appear that drainage from the stored waste rock should be captured and monitored and potentially treated before discharge. Alternatively, the small volume of PAF waste might be treated with lime or limestone to delay the onset of metal release until a closure strategy (e.g., encapsulation of the PAF waste in the IWL, inundation in the final pit) can be put into place.*
- *It would be useful to continue operation of the PAF and blended leach columns to provide an estimate of potential acidity and metal loads from the PAF waste and to examine how long the blended waste can maintain low metal/metalloid loads in leachates, both of which may help inform options for PAF waste disposal. It is suggested that these columns be continued for a further 6 months.*

EGI considered that concentrations of As were elevated in leachate from the PAF-LC column, increasing as leaching continued, without any obvious correlation to leachate pH or sulphate release. Leachate concentrations of As appear to reflect the amount of As in the sample in the order PAF-LC>PAF>NAF≈Blend.

LWC plotted relevant data using ACT 2 software of Geochemists Work Bench (GWB, version 11.06.0) to create an Eh/pH diagram for arsenic in the leach test system (Figure 3-1). Such diagram shows arsenic to be relatively stable as aqueous specie regardless of pH or redox (blue colouration = in solution, brown colouration = solid phase – Eh represents the redox condition of the system with higher numbers indicating a more oxidised system and lower numbers indicating a more reducing system. The broad existence of arsenic in the solution phase supports EGi's conclusion that As can be elevated in leachate from the PAF-LC column without any obvious correlation to leachate pH (or inferring sulfate release and generation of sulfuric acid).

Conversely, EGI considered copper increase was likely to be associated with pH (acidity) and speciation of the specific system as per column test week 24. The Eh/ pH diagram matched to the specific kinetic test environment would support this (refer Figure 3-2; aqueous copper species <pH 5.2 – blue zones). Copper is predicted to be largely in the solid phase unless the pH begins to decrease and the system becomes more acidic (see the blue $Cu^{++}$ triangle to the left of the image). This would infer that copper is mostly within the solid phase within the current pit as observed from low copper concentrations in the pit lake water. Cobalt demonstrates a similar distribution between solid and solution under decreasing pH (Figure 3-3).

*Figure 3-1 Eh/ pH diagram for arsenic as per kinetic column 24 week time point*

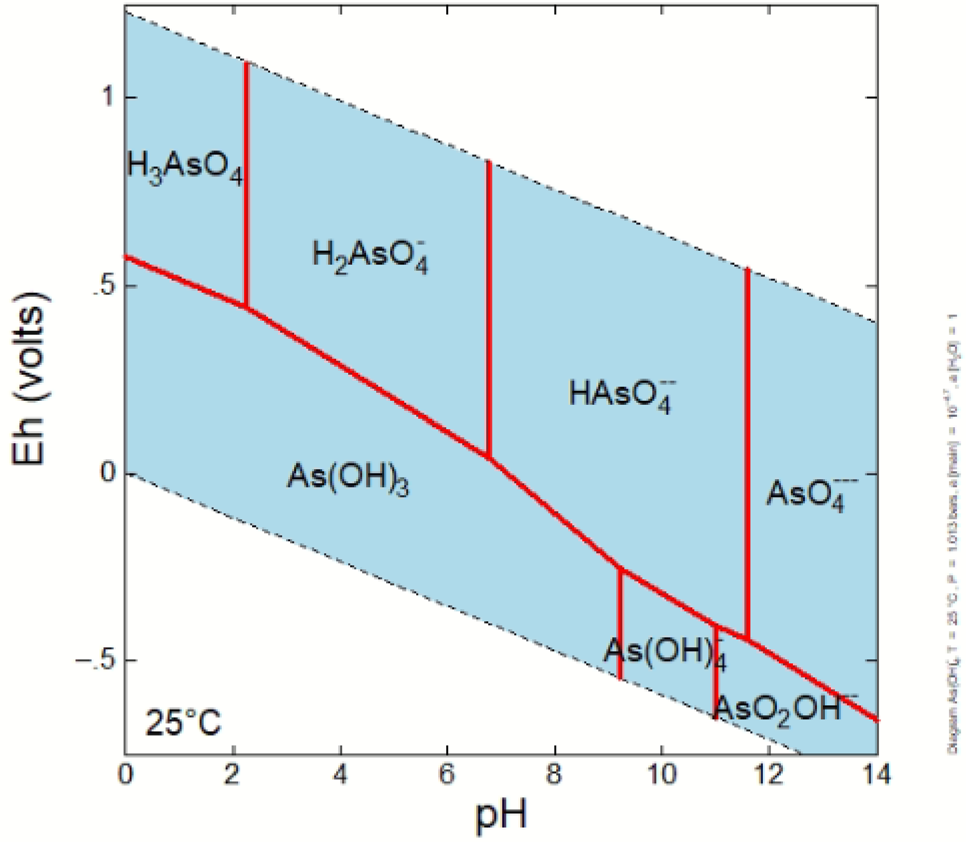


*Figure 3-2 Eh/ pH diagram for cobalt as per kinetic column 24 week time point*

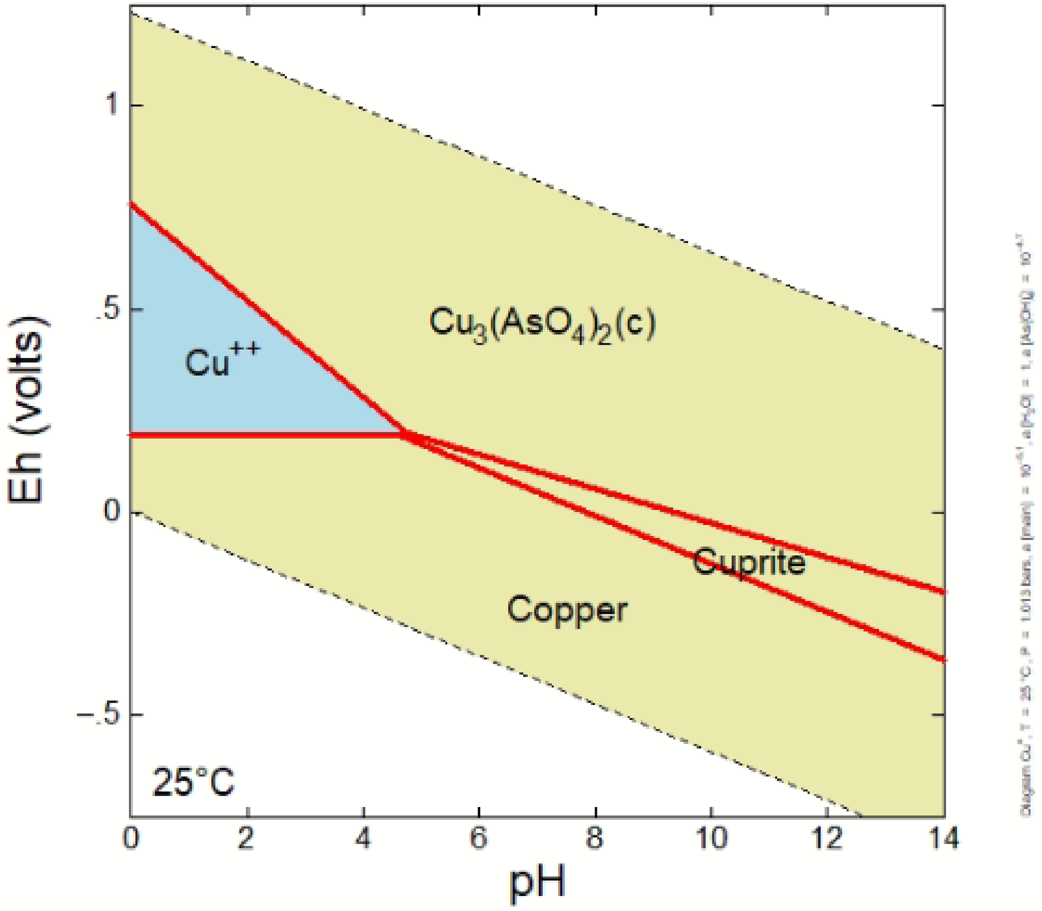
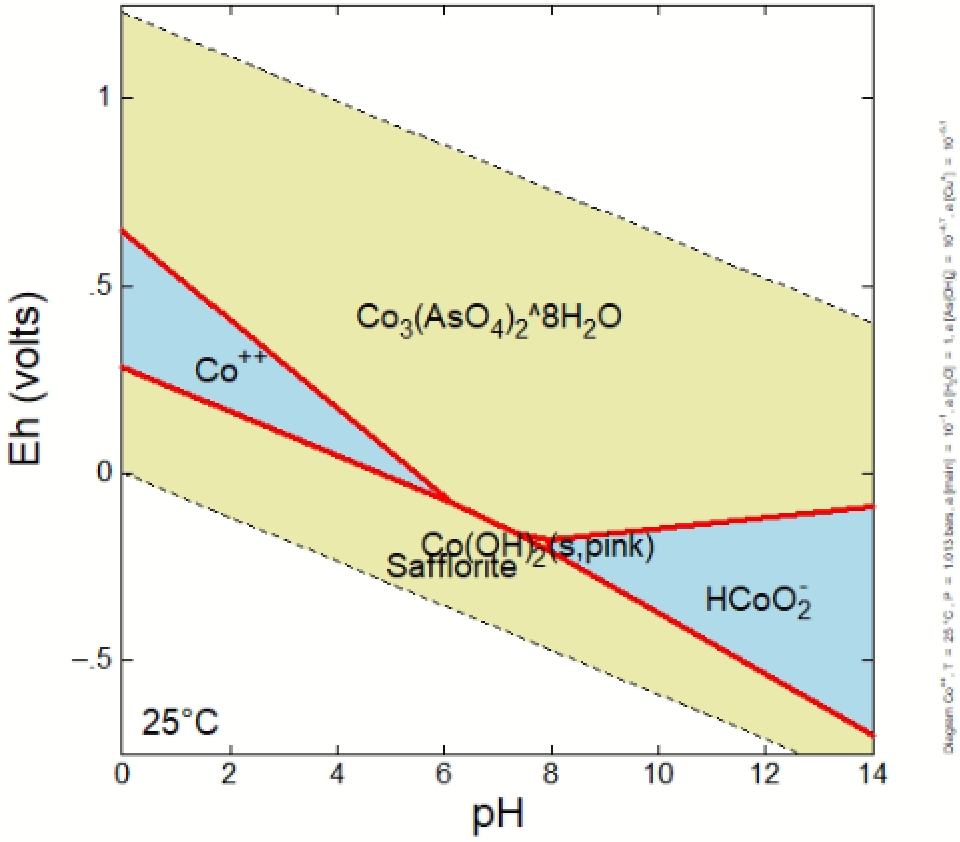


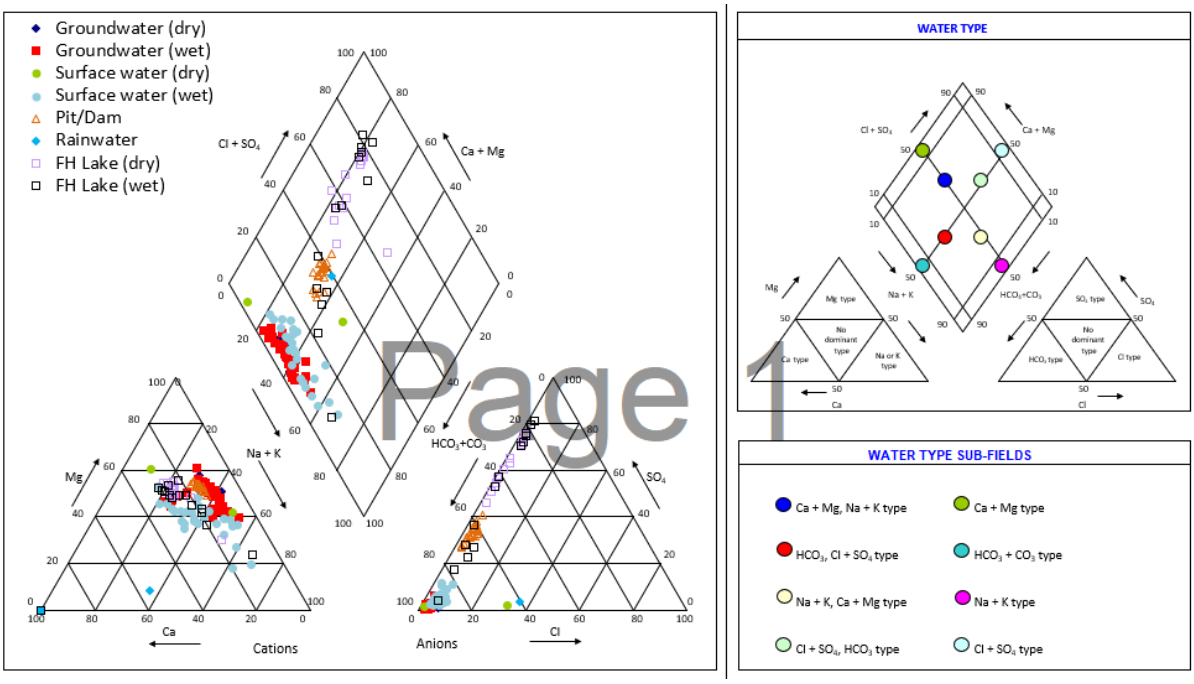
Figure 3-3 Eh/ pH diagram for cobalt as per kinetic column 24 week time point



## 3.6 PROJECT WATER QUALITY

Piper diagram of various waters associated with the project is presented as Figure 3-4.

*Figure 3-4 Piper diagram of project area water types (CDM Smith 2021)*



Groundwater monitoring wells FHMB01, FHMB02 and FHMB03 generally have elevated metal concentrations compared to other groundwater samples and are located on the northern and eastern sides of the pit, while FHMB04, FHMB05 and FHMB06 for example, have lower metal concentrations and are located to the south of the pit.

Pit lake water currently has higher arsenic concentrations than the groundwater (Table 3-3 and Table 3-4), and the lake arsenic concentrations exceed the stock watering guideline value.

Since there is uncertainty about the spatial extent and volume of groundwater with different chemical signatures, and because all of this groundwater is expected to be drawn into the pit and mixed together (CDM Smith, 2021), geometric mean concentrations were adopted to compare water composition (Table 3-4).

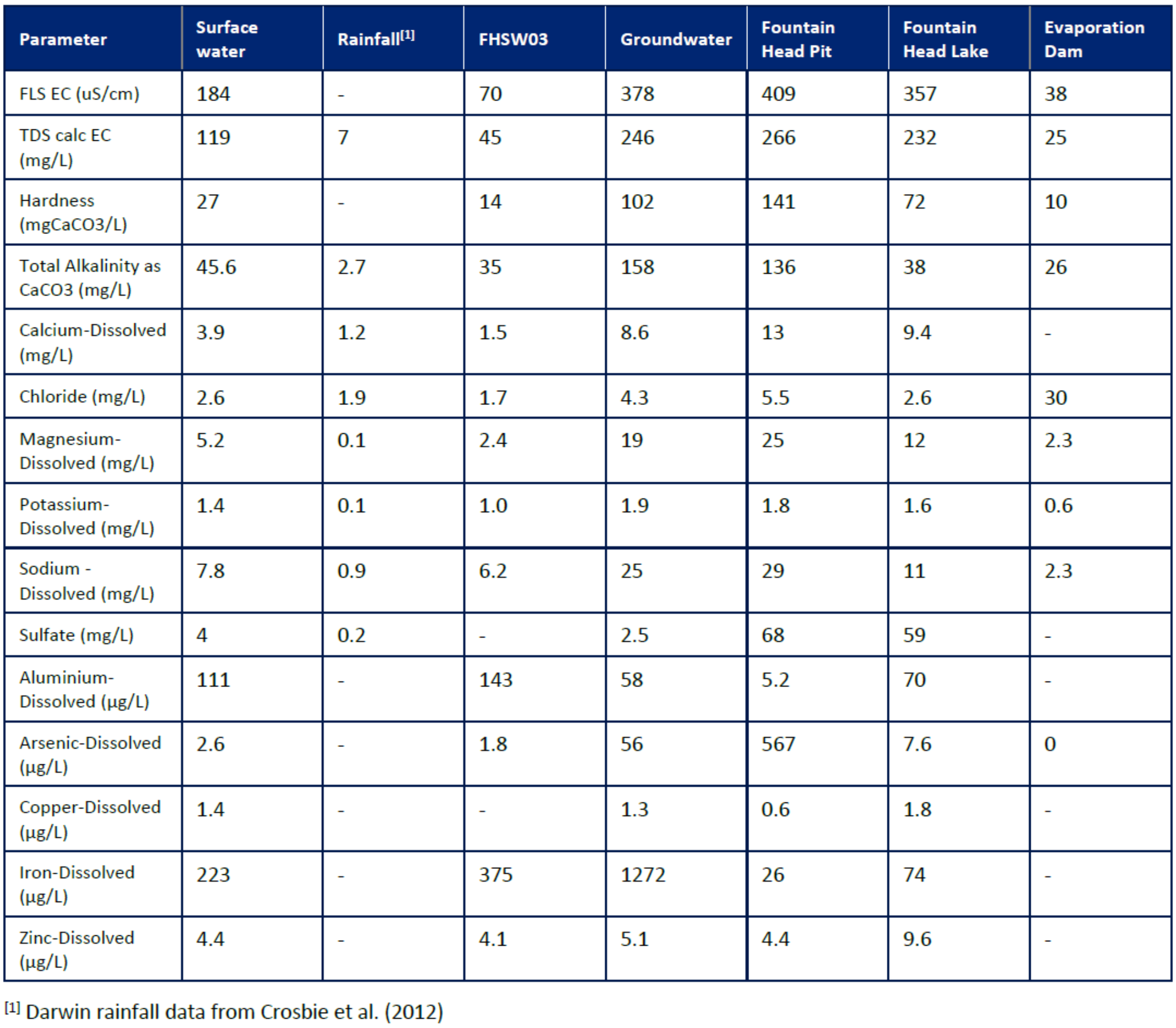
## Table 3-2 Groundwater chemistry summary – irrigation and stock water

| | | | General Parameters | | | | Major Ions (mg/L) | | | | | | Total Metals (µg/L) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SWL (m below top of casing) | Conductivity (uS/cm) | pH | Hardness (mg CaCO$_3$/L) | Total Alkalinity as CaCO$_3$ (mg/L) | Calcium | Chloride | Magnesium | Potassium | Sodium | Sulphate | Aluminium | Arsenic | Cadmium | Chromium | Cobalt | Copper | Iron | Lead | Manganese | Nickel | Zinc |
| Long-term trigger value – Irrigation and General Water Use (ANZECC, 2000) | | | see below | 6–8.5 | | | | see below | | | see below | | 5,000 | 100 | 10 | 100 | 50 | 200 | 200 | 2,000 | 1,000 | 200 | 2000 |
| Short-term trigger value – Irrigation and General Water Use (ANZECC, 2000) | | | | | | | | | | | | | 20,000 | 2,000 | 50 | 1000 | 100 | 5,000 | 10,000 | 5,000 | | 2000 | 5000 |
| Stock Drinking Water (ANZECC, 2000) | | | 7460† | 5–9 | | | 1000 | | | | | 1,000 | 5,000 | 500 (5000) | 10 | 1,000 | 1,000 | 1,000 | | 100 | 10000 | 1,000 | 20,000 |
| Average | | | 376 | 7 | 108 | 163 | 10 | 5 | 20 | 2 | 26 | 1131 | 655 | 101 | 0 | 5 | 2 | 6 | 5,316 | 6 | 171 | 3 | 10 |
| Mean | | | 335 | 7 | 89 | 140 | 7 | 4 | 17 | 2 | 24 | 5 | 87 | 50 | 0 | 2 | 1 | 3 | 650 | 4 | 113 | 2 | 6 |
| s.d. | | | 167 | 1 | 60 | 77 | 9 | 2 | 9 | 1 | 10 | 3707 | 2,074 | 115 | 0 | 12 | 1 | 9 | 7,595 | 7 | 152 | 6 | 13 |
| Median | | | 360 | 7 | 102 | 168 | 8 | 5 | 21 | 2 | 28 | 2 | 47 | 72 | 0 | 2 | 1 | 3 | 1,400 | 3 | 130 | 2 | 7 |
| 90% | | | 648 | 7.521 | 209 | 290 | 28.7 | 7 | 34 | 3.5 | 34.9 | 3000 | 2,230 | 320 | - | 10 | 3 | 14.1 | 18,200 | 21.6 | 354 | 5 | 19.6 |
| **Max** | | | **844** | **8.63** | **270** | **380** | **44** | **16** | **40** | **5** | **64** | **15000** | 13,000 | **450** | **0.3** | **53** | **3** | **40** | **32,000** | **26** | **860** | **35** | **86** |
| Count | | | 72 | 72 | 70 | 69 | 70 | 69 | 70 | 69 | 70 | 39 | 46 | 69 | 3 | 19 | 16 | 22 | 67 | 21 | 67 | 33 | 55 |

## Table 3-3 Pit lake chemistry summary

| | | General Parameters | | | | Major Ions (mg/L) | | | | | | Total Metals (µg/L) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | pH | Conductivity (uS/cm) | Hardness (mg CaCO$_3$/L) | Total Alkalinity as CaCO$_3$ (mg/L) | Calcium | Chloride | Magnesium | Potassium | Sodium | Sulphate | Aluminium | Arsenic | Boron | Cadmium | Chromium | Cobalt | Copper | Iron | Lead | Lithium | Manganese | Molybdenum | Nickel | Selenium | Uranium | Vanadium | Zinc |
| Long-term trigger value – Irrigation and General Water Use (ANZECC, 2000) | | 6–9 | see below | | | | see below | | | see below | | 5,000 | 100 | 500 | 10 | 100 | 50 | 200 | 200 | 2,000 | 2500 | 1,000 | 10 | 200 | 20 | 10 | 100 | 2000 |
| Short-term trigger value – Irrigation and General Water Use (ANZECC, 2000) | | | | | | | | | | | | 20,000 | 2,000 | 4000-6000 for sorghum | 50 | 1000 | 100 | 5,000 | 10,000 | 5,000 | 2500 | | 50 | 2000 | 50 | 100 | 500 | 5000 |
| Stock Drinking Water (ANZECC, 2000) | | 5–9 | 7460† | | | 1000 | | | | | 1,000 | 5,000 | 500 (5000) | 5000 | 10 | 1,000 | 1,000 | 1000* | | 100 | | 10000 | 150 | 1,000 | 20 | 200 | | 20,000 |
| Average | | 8.1 | 526 | | 138 | 12.3 | 5.6 | 27.2 | 1.7 | 29.8 | 3549.3 | 50.4 | 618 | 15.6 | 0.0 | 0.9 | 0.2 | 2.8 | 82.2 | 1.4 | 18.0 | 124.5 | 7.3 | 0.8 | 0.2 | 5.0 | 0.5 | 8.2 |
| Mean | | 8.0 | 433 | | 137 | 12.2 | 5.5 | 27.2 | 1.7 | 29.7 | 99.0 | 15.0 | 547 | 15.5 | 0.0 | 0.9 | 0.1 | 0.6 | 35.3 | 0.3 | 18.0 | 30.0 | 6.9 | 0.4 | 0.2 | 4.6 | 0.4 | 4.5 |
| s.d. | | 0.8 | 617 | | 15 | 1.4 | 1.3 | 1.3 | 0.3 | 2.4 | 14351.9 | 169 | 156.1 | 1.6 | - | - | 0.1 | 9.5 | 175.3 | 2.8 | 0.0 | 172.8 | 2.9 | 1.2 | 0.0 | 2.1 | 0.3 | 10.3 |
| Median | | 8.3 | 415 | | 142 | 12.7 | 5.5 | 27.6 | 1.7 | 29.4 | 66.1 | 11.6 | 620 | 15.0 | 0.0 | 0.9 | 0.1 | 0.6 | 28.0 | 0.2 | 18.0 | 14.6 | 9.0 | 0.2 | 0.2 | 5.9 | 0.4 | 3.6 |
| 90% | | 9.0 | 509.5 | | 154.6 | 14.1 | 7.7 | 28.8 | 2.0 | 33.3 | 84.0 | 55.0 | 770 | 18.6 | - | - | 0.4 | 2.0 | 239.0 | 7.5 | - | 426.0 | - | 2.5 | - | - | 1.1 | 28.4 |
| Max | | 9.4 | 3991.4 | | 170 | 14.9 | 7.9 | 29.1 | 2.4 | 34 | 62000 | 906 | 784 | 20 | 0.04 | 0.9 | 0.4 | 43 | 852 | 9.7 | 18 | 437 | 9 | 4.691 | 0.2 | 6.4 | 1.25 | 40 |
| Count | | 34 | 34 | | 32 | 36 | 33 | 36 | 36 | 36 | 35 | 28 | 35 | 13 | 1 | 1 | 13 | 20 | 26 | 13 | 2 | 32 | 3 | 17 | 2 | 4 | 12 | 26 |

*Table 3-4 Geometric mean parameters for Fountain Head water sources (CDM Smith (2021))*



| Parameter | Surface water | Rainfall[1] | FHSW03 | Groundwater | Fountain Head Pit | Fountain Head Lake | Evaporation Dam |
|---|---|---|---|---|---|---|---|
| FLS EC (uS/cm) | 184 | - | 70 | 378 | 409 | 357 | 38 |
| TDS calc EC (mg/L) | 119 | 7 | 45 | 246 | 266 | 232 | 25 |
| Hardness (mgCaCO3/L) | 27 | - | 14 | 102 | 141 | 72 | 10 |
| Total Alkalinity as CaCO3 (mg/L) | 45.6 | 2.7 | 35 | 158 | 136 | 38 | 26 |
| Calcium-Dissolved (mg/L) | 3.9 | 1.2 | 1.5 | 8.6 | 13 | 9.4 | - |
| Chloride (mg/L) | 2.6 | 1.9 | 1.7 | 4.3 | 5.5 | 2.6 | 30 |
| Magnesium-Dissolved (mg/L) | 5.2 | 0.1 | 2.4 | 19 | 25 | 12 | 2.3 |
| Potassium-Dissolved (mg/L) | 1.4 | 0.1 | 1.0 | 1.9 | 1.8 | 1.6 | 0.6 |
| Sodium - Dissolved (mg/L) | 7.8 | 0.9 | 6.2 | 25 | 29 | 11 | 2.3 |
| Sulfate (mg/L) | 4 | 0.2 | - | 2.5 | 68 | 59 | - |
| Aluminium-Dissolved (µg/L) | 111 | - | 143 | 58 | 5.2 | 70 | - |
| Arsenic-Dissolved (µg/L) | 2.6 | - | 1.8 | 56 | 567 | 7.6 | 0 |
| Copper-Dissolved (µg/L) | 1.4 | - | - | 1.3 | 0.6 | 1.8 | - |
| Iron-Dissolved (µg/L) | 223 | - | 375 | 1272 | 26 | 74 | - |
| Zinc-Dissolved (µg/L) | 4.4 | - | 4.1 | 5.1 | 4.4 | 9.6 | - |

[1] Darwin rainfall data from Crosbie et al. (2012)

## 3.7 DERIVATION OF SOURCE TERM

Existing groundwater, Fountain Head Lake and pit lake water quality were compared to the following water quality criteria with respect to the screening process summarised in the process flow diagram in Figure 3-1[1]:

- NTMO Short-term trigger value  Irrigation and General Water Use (ANZECC, 2000)
- NTMO Stock Drinking Water (ANZECC, 2000)
- NHMRC 2011 Australian Drinking Water Guidelines (Health)
- NTMO 80% Aquatic Ecosystem (ANZG 2018 at 80% protection)
- NTMO 90% Aquatic Ecosystem (ANZG 2018 at 90% protection)
- NTMO 95% Aquatic Ecosystem (ANZG 2018 at 95% protection)
- NTMO 99% Aquatic Ecosystem (ANZG 2018 at 99% protection)

As per previous study (LWC, 2021) it is understood that NTMO Stock Drinking Water (ANZECC, 2000) is the likely only potential beneficial use noting that groundwater exceeds NTMO 80% Aquatic Ecosystem (ANZG 2018 at 80% protection) and groundwater would flow into the pit – i.e. future pit lake water quality is unlikely to be suitable based on the current composition of groundwater in the first instance.

Adopting NTMO Stock Drinking Water (ANZECC, 2000) then, the kinetic testing weeks 0 – 24 indicate the following elements to be above such criteria:

- Cobalt (maximum of 1.7 mg/L versus criterion of 1 mg/L (mean of 1,2 mg/L)); and
- Copper (maximum of 4.9 mg/L versus criterion of 1 mg/L (mean of 1.7 mg/L))

This is based on increase in the concentrations of these elements from week 16 onwards (i.e. the new data) – refer Appendix A.

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[1] Note that all source term elements exceed ANZG 2018 80% protection so >90% protection not shown.

# 4 PIT LAKE WATER QUALITY PREDICTIONS

## 4.1 SOURCE S1 – PAF ROCK IN PIT

### 4.1.1 COLUMN LEACH TESTING EXTRAPOLATION

The original assessment (LWC, 2021) had four data points from the 0 – 12 week kinetic test of PAF material. A trend line was applied to the existing data points to formulate a regression equation. This was done for fitting through 0 intercept and also ignoring such intercept. The regression equations were used to extrapolate the potential concentration of the key parameters of acidity and arsenic over a 52 week period. The extrapolations were re-done to incorporate the new kinetic data (Appendix B) – note that fitting through 0 intercept did not seem appropriate for the extended data as in some cases (arsenic, copper, acidity) the trend had flattened off – only copper appeared to be increasing.

### 4.1.2 ALKALINITY

Non-acid forming (NAF) sample 21365 was submitted for column leaching. The sample produced 84 to 99 mg/L over weeks 0 – 12 which then decreased to 41 mg/L at week 24.

Note that in terms of pit wall loading, unlike acidity and metals, alkalinity will not accumulate on mineral surfaces, hence, a stored alkalinity load cannot be calculated as alkalinity associated with pit wall rock is stored in carbonate minerals and associated ANC available on the wall rock surfaces. During subaerially exposure pit wall ANC will be consumed in response to acid production.

### 4.1.3 BULK SCALE DRAINAGE

As noted, a major 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 (Kirchner and Mattson, 2015):

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

The assumptions used to calculate the total scaled up predicted concentration are presented in Table 4-1. The resulting values are presented as Table 4-2 based on the calculations in Appendix B. Note that mg of solute was adjusted for an average leach column volume of 0.503L.

*Table 4-1 Scale up parameters*

| Parameter | Value | Source/ Reference/ Rationale |
|---|---|---|
| Time (weeks) | 52 – refer value for 52 weeks in Appendix B, which mimics 1 year of oxidation. | Arbitrary extrapolation – can be extended forward to any week value. |
| Mass of Waste PAF Rock | 0.15 million tonnes | As advised by ERIAS via CDM Smith |
| Volume of infiltrating water | 0 - 7500 ML + run off and rainfall | Rainfall influx modelled reported in CDM Smith (2021) |
| HC Load | Kinetic data from sample 21363. | Kinetic data from sample 21363. |

A similar approach was undertaken for alkalinity in NAF wall rock - assumed to be primary source of alkalinity - noting however unlike acidity and metals, alkalinity will not accumulate on mineral surfaces, hence, a stored alkalinity load cannot be calculated as alkalinity associated with pit wall rock is stored in carbonate minerals and associated ANC available on the wall rock surfaces.

Rationale for wall rock surface area is presented in Section 5.2. Assuming ~81.2% of the surface area is NAF rock (3.6 mega tonne), then assuming a 2000 ML lake the resulting concentration (ignoring groundwater, which is an average alkalinity of 163 mg/L, then resulting alkalinity from wall rock could be ~30 mg/L (Appendix B), for a cumulative of close to 200 mg/L.

Assuming a total mass of acidity as mg/L $CaCO_3$ is $6.89 \times 10^{10}$, divided by lake volume, this would result in an acidity of ~34 mg/L $CaCO_3$. Therefore depending on groundwater throughflow and NAF rock kinetics, alkalinity (based on data to date) would appear to be buffered to around 15 – 160 mg/L, which is around the current alkalinity (assuming some PAF from previous mining has influenced the water chemistry to a similar degree).

Sample 21363 has a net acid producing potential of 12 kg $H_2SO_4$ per tonne of rock with a 24 week time point acidity of 0.36 kg of $H^+$ per tonne of rock, or a total of 54 tonne of acidity (as $H^+$) for 0.15 million tonne of PAF rock.

Residual S in the same sample is given as 6,600 mg/kg. Harries et al., 1981 report a median weathering rate of 0.26 g S per kg rock per year (mixed rock ~3wt% Rum Jungle NT). Using the Total S concentration, this would assume an exhaustion of S oxidation in 25 years and a sulfate release of 9 mg/kg per week.

### 4.1.4 EXTRAPOLATION RESULTS / RATES

Calculations are presented in Appendix B and are summarised in Table 4-2 for average extrapolated rates and Table 4-3 for maximum rates.

*Table 4-2 Average of extrapolated results*

| **Element / parameter** | **Average 52 week extrapolated leach concentration (mg/L)** | **Average 52 week extrapolated release mg/kg$_{rock}$ week$^{-1}$** |
|---|---|---|
| arsenic | 0.35 | 0.023 |
| cobalt | 1.17 | 0.072 |
| copper | 4.49 | 0.31 |

*Table 4-3 Maximum of extrapolated results*

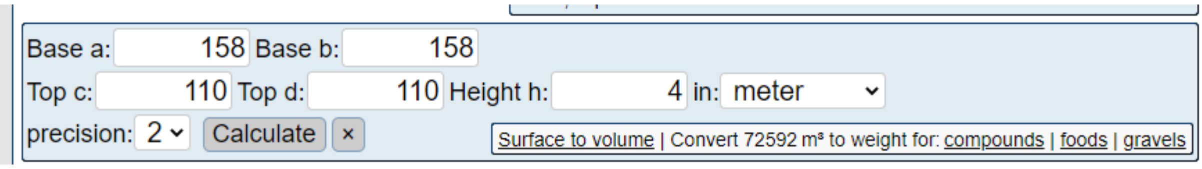
| **Element / parameter** | **Maximum 52 week extrapolated leach concentration (mg/L)** | **Maximum 52 week extrapolated release mg/kg$_{rock}$ week$^{-1}$** |
|---|---|---|
| arsenic | 0.49 | 0.03 |
| cobalt | 1.68 | 0.09 |
| copper | 9.64 | 0.62 |

### 4.1.5 PREDICTING PAF PILE LEACH CONCENTRATIONS

The average release rates (Table 4-2) are used to estimate concentrations of the source term elements in leach from the stored PAF pile in the base of the Pit.

The following assumptions are made:

1. The PAF pile has a volume of ~75,000 m$^3$ based on tonnage of 0.15 million tonne and a bulk density of 2 tonne per m$^3$ (rock).
2. The PAF rock is stored as a truncated pyramid rather than a 'stockpile', thus with a presumed height of 4 m (seems operationally manageable) and a volume of 75,000 m$^3$, such pile could have a footprint of 25,000 m$^2$ as per example dimensions below:



Base a: 158 Base b: 158
Top c: 110 Top d: 110 Height h: 4 in: meter
precision: 2

3. Precipitation is 1250 mm annual which translates to 1250 L per m$^{2.}$ For an area of 25,000 m$^2$ the direct precipitation falling on the pile in any given week would then be 6 x $10^{-5}$ L.
4. 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 3.0 x $10^7$ kg of rock in the pile may be saturated by infiltration and generate leach.
5. 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 may result in the concentrations of source term elements shown in Table 4-4. Refer calculations in Appendix B.

Note that weekly single event leach concentrations exceed the Stock Watering Criterion for arsenic, cobalt and copper (0.5 mg/L, 1.0 mg/L and 1.0 mg/L respectively).

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

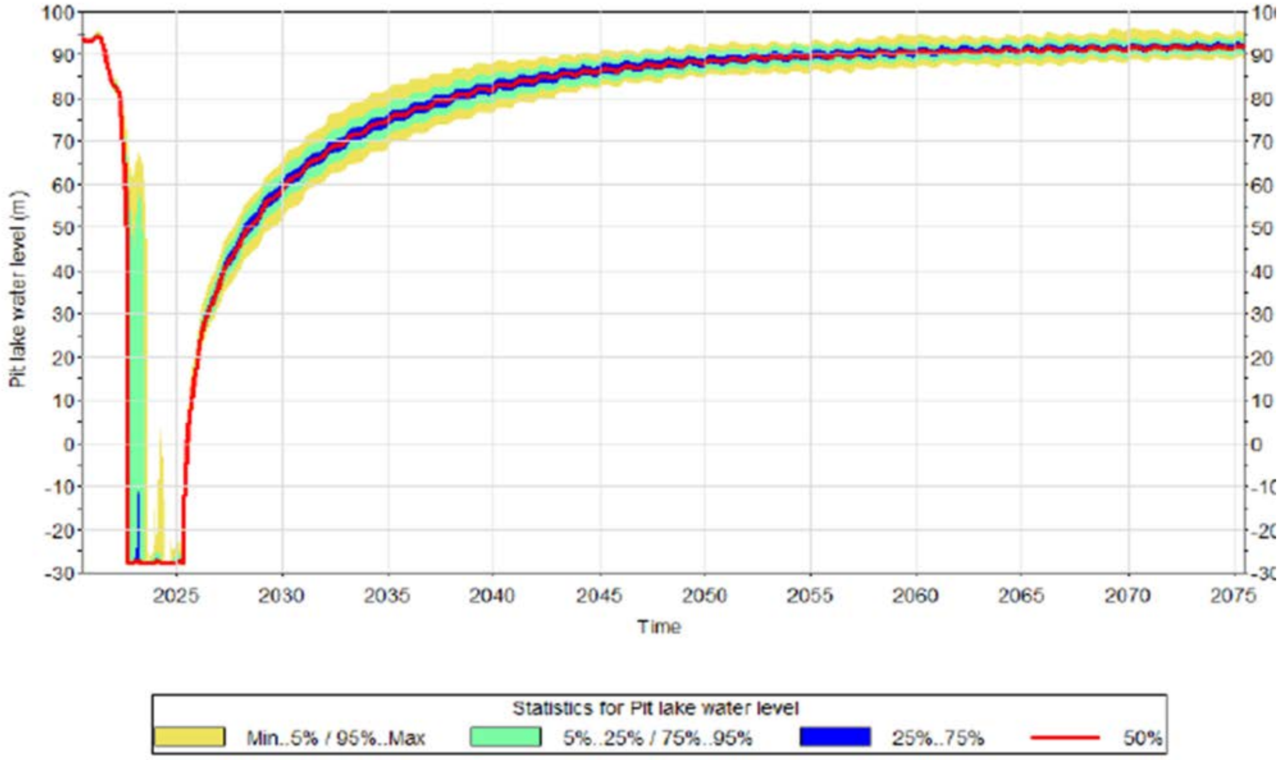
| | | Rock | | | | Pile | Precipitation | | | | Leach |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average Release | Kg rock | mg | Bulk Density t/m$^3$ | m$^3$ | Possible Footprint (m$^2$) | Rainfall (mm) | L per m2 | Litres per footprint | Weekly | mg/L |
| Arsenic | 0.023 | 3.00E+07 | 6.90E+05 | 2.00E+00 | 7.50E+04 | 2.50E+04 | 1250 | 1250 | 3.13E+07 | 6.01E+05 | **1.1** |
| Cobalt | 0.072 | 3.00E+07 | 2.16E+06 | 2.00E+00 | 7.50E+04 | 2.50E+04 | 1250 | 1250 | 3.13E+07 | 6.01E+05 | **3.6** |
| Copper | 0.126 | 3.00E+07 | 3.78E+06 | 2.00E+00 | 7.50E+04 | 2.50E+04 | 1250 | 1250 | 3.13E+07 | 6.01E+05 | **6.3** |

In terms of acidity and alkalinity, the column testing indicates the generation of alkalinity outstrips acidity generation based on the data available to week 12, though then alkalinity becomes progressively diminished until exhausted (week 24).

### 4.1.6 SOURCE S1 MIXING

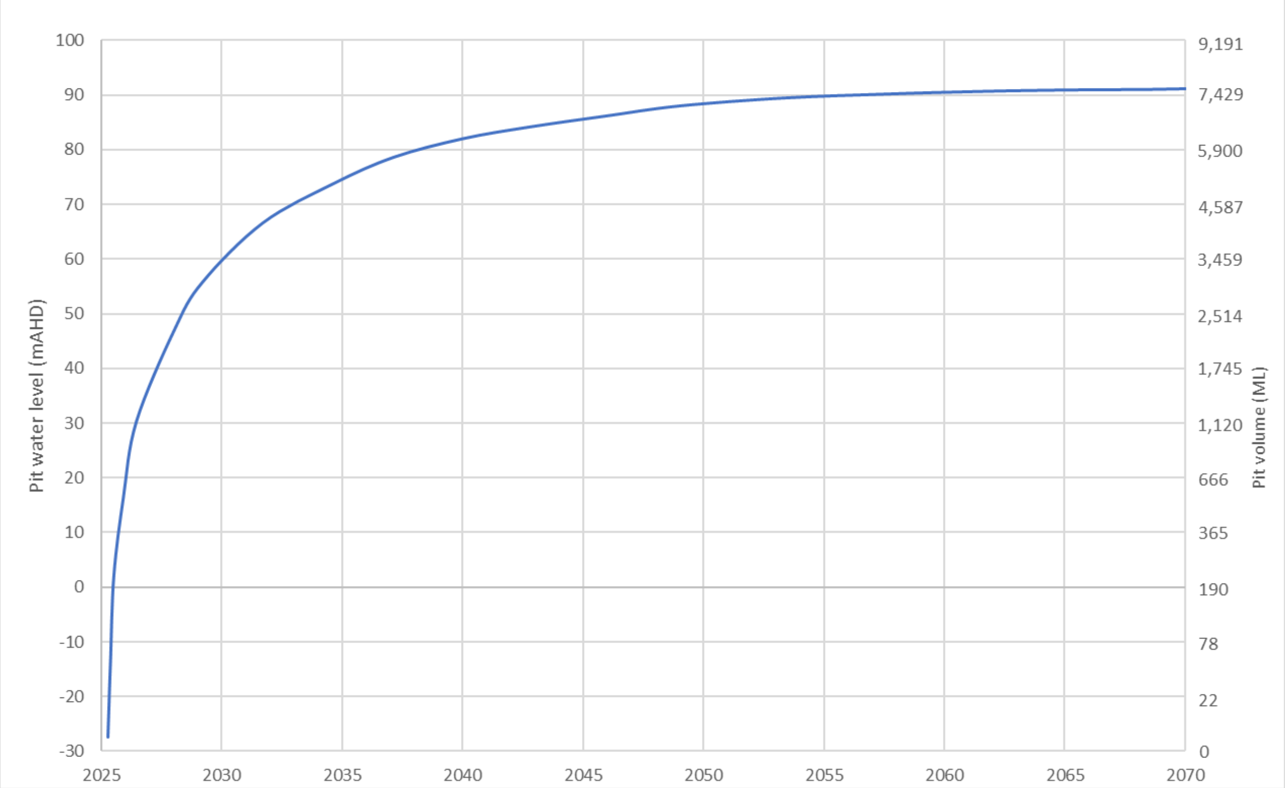
It is understood that the Lake will progressively fill to around 7,500 ML volume, with full recovery taking around 50 years (Figure 4-10 of CDM Smith, 2021 – reproduced as Figure 4-1). Pit lake volume is expected to increase from ~0 ML to ~7,500 ML over this period (observed surface water level at 90 m AHD), though the pit is predicted to fill relatively rapidly in the first twenty years (see Figure 4-1, CDM Smith 2021). It is estimated in CDM Smith (2021) that approximately 116 ML of run-off will be recovered by the Pit per annum until steady state (through flow) occurs). Rainfall is estimated at ~92 ML per annum.

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



Predicted pit volume is reproduced here as Figure 4-2. As noted, the largest contribution by far is groundwater, with rainfall and run-off also contributing, with rainfall being a more dominant contributor after ~year 3 post closure.

*Figure 4-2 Modelled pit lake volume (CDM Smith (2021)) – not adjusted for evaporation*



The source term S1 will therefore be progressively covered (with respect to mitigation of oxidation and ongoing generation of cobalt and copper) by (predominantly) groundwater in ~Year 1 (around 500 ML). Arsenic associated with source term S1 will also be flushed and mixed predominantly with groundwater.

Assuming the above water balance values, the contribution to lake development is estimated to occur as per Table 4-5, using ~5 year increments and taking predicted volumes from Figure 4-3 cross referenced with Figure 4-2.

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 a 20% reduction per 5 year increment until the steady state volume of ~7500 ML is reached (with corresponding elevation of water level presumed to cover PAF wall rock such that contribution of such wall rock to run-off composition is zero in Year 20).

The predicted scaled up Source term S1 concentrations are presented in Table 4-6, scaled for 0.15 million tonne PAF using 52 week mean release rates. The values for copper and cobalt are given as zero after year 1 presuming that water level covers POD 3 (>500 ML) and mitigates significant ongoing oxidation and release of elements. Arsenic uses 52 weeks release rate at each time point to represent steady state release un-related to pH.

The potential elemental composition (contribution) of pit wall rock run-off is presented in Section 4.2. Source S1 and S2 are considered in terms of the contribution of groundwater and run-off to lake development in Section 4.3.

*Table 4-5 Estimated volumes of rainfall, run-off, and groundwater per year post closure to ~7,500 ML*

| | | **(2026)** | **(2031)** | **(2039)** | **(2044)** | **(2061)** |
|---|---|---|---|---|---|---|
| Parameter | Stock Watering Criterion (mg/L) | 500 ML | 3500 ML | 6000 ML | 6500 ML | 7500 ML (SWL) |
| Time (weeks) | | 52 | 52 | 52 | 52 | 52 |
| Mass of Waste PAF Rock (kg) | | 1.50E+08 | 1.50E+08 | 1.50E+08 | 1.50E+08 | 1.50E+08 |
| Rainfall (L) | | 9.20E+07 | 9.20E+07 | 9.20E+07 | 9.20E+07 | 9.20E+07 |
| Run-off Volume (L) | | 1.16E+08 | 1.16E+08 | 1.16E+08 | 1.16E+08 | 1.16E+08 |
| Groundwater Influx (L) | | 5.00E+08 | 3.50E+09 | 6.00E+09 | 6.50E+09 | 7.50E+09 |
| Cumulative Rainfall & Groundwater (L) | | 5.92E+08 | 3.59E+09 | 6.09E+09 | 6.59E+09 | 7.59E+09 |
| Ratio Run-off: Lake | | 1.96E-01 | 3.23E-02 | 1.90E-02 | 1.76E-02 | 1.53E-02 |
| Run-off Contribution | | 0.8 | 0.6 | 0.4 | 0.2 | 0 |

*Table 4-6 Predicted source S1 concentrations scaled (based on 52 weeks mean release rates from Table 4-2)*

| Element | Parameter | Stock Criterion (mg/L) | (2026) | (2031) | (2039) | (2044) | (2061) |
|---|---|---|---|---|---|---|---|
| arsenic | (mg/kg/rock per week) | | 0.023 | 0.023 | 0.023 | 0.023 | 0.023 |
| arsenic | mg/L | **0.5** | 0.303 | 0.050 | 0.029 | 0.027 | 0.024 |
| cobalt | (mg/kg/rock per week) | | 0.073 | 0 | 0 | 0 | 0 |
| cobalt | mg/L | **1** | 0.96 | 0.00 | 0.00 | 0.00 | 0.00 |
| copper | (mg/kg/rock per week) | | 0.311 | 0 | 0 | 0 | 0 |
| copper | mg/L | **1** | **4.10** | 0.00 | 0.00 | 0.00 | 0.00 |

## 4.2 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 ANFO (ammonium nitrate and fuel oil) 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 $m^2$ (1 $m^3$) is increased by a factor of 1.41 to account for an assumed average pit wall slope of 45 degrees, i.e. 1.41 $m^3$. Finally, the mass of rock is determined by multiplying the effective volume by average waste density of 2.7 $t/m^3$ 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).

The full parameters and values are presented in Appendix C.

The mass of arsenic which may accumulate on PAF rock pit wall surfaces per year is 0.52 mg per kg of rock (no CSF).

This represents:

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

The proportion of exposed rock throughout the life or mine and post closure will be governed by the elevation of the water table.

For simplicity, this calculation assumes that all PAF wall rock is exposed. When the water table rebounds the loading will decrease due to less exposed surface area.

The final calculations carry a cumulative scaling factor of 0.4 (refer section 6.1.3) to account for mass loading correction factors between laboratory and field scale calculations (e.g. grains size, seasonality, temperature, water contact etc.)

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.

The calculations for arsenic, cobalt and copper loading as well as acidity (as $CaCO_3$) are presented in Appendix C. Unlike acidity and metals, alkalinity will not accumulate on mineral surfaces, hence, a stored alkalinity load cannot be calculated as alkalinity associated with pit wall rock is stored in carbonate minerals and associated ANC available on the wall rock surfaces. During subaerially exposure pit wall ANC will be consumed in response to acid production. However, for indicative purposes the alkalinity data acquired from the kinetic testing was used to calculate an annual loading. Groundwater reports an alkalinity of 178 mg/L $CaCO_3$ and this is presented for comparison against predictive pit wall loading with respect to acid base assessment.

*Table 4-7 Pit wall contribution predictions based on 52 week kinetic testing (mg/l) – refer Appendix C*

| Chemical/ Parameter | Predicted pit wall run-off concentrations scaled for area and rainfall/ run-off |
|---|---|
| arsenic | 3.8 |
| cobalt | 15.2 |
| copper | 26.6 |
| acidity (mg/L $CaCO_3$) | 109 |
| alkalinity (mg/L $CaCO_3$) - predicted | 129 |
| Nett alkalinity (predicted from loading) | 20 |
| Groundwater alkalinity (mg/L $CaCO_3$) | 178 |
| Fountain Head Lake average 2011 – 2021 alkalinity (mg/L $CaCO_3$) | 29 |
| Pit (mg/L $CaCO_3$) | 154 |

## 4.3 COMBINED S1 + S2

Combining the two sources S1 and S2 gives predicted lake concentrations at each increment as per Table 4-7 using both mean and 90th percentile groundwater concentration was used in S1 mixing calculations. Under such scenario arsenic, cobalt and copper are predicted to exceed stock watering criteria in year 1, driven largely by run-off from PAF wall rock (oxidation and leach: Source S2). The concentration at Year >5 represents rebound and cessation of most oxidation and leaching of wall rock and or dilution effects of rainfall and lake volume coupled to the increase in lake volume.

*Table 4-8 Predicted concentrations in lake water years 1 – 20 (includes S1 and S2) using mean release values from Table 4-2 and source terms S1 and S2 (refer Appendix D)*

| Element | Units | Mean or 90th percentile groundwater concentration | **Stock Watering Criteria** | (2026) | (2031) | (2039) | (2044) | (2061) |
|---|---|---|---|---|---|---|---|---|
| arsenic | mg/L | Mean - groundwater | **0.5** | **0.9** | 0.17 | 0.11 | 0.09 | 0.07 |
| arsenic | mg/L | 90th percentile - groundwater | **0.5** | **1.2** | 0.44 | 0.38 | 0.36 | 0.34 |
| cobalt | mg/L | Mean - groundwater | **1** | **3.3** | 0.30 | 0.12 | 0.05 | 0.001 |
| cobalt | mg/L | 90th percentile - groundwater | **1** | **3.3** | 0.30 | 0.12 | 0.06 | 0.003 |
| copper | mg/L | Mean - groundwater | **1** | **8.2** | 0.5 | 0.2 | 0.10 | 0.003 |
| copper | mg/L | 90th percentile - groundwater | **1** | **8.2** | 0.5 | 0.2 | 0.13 | 0.04 |

# 5 DISCUSSION

## 5.1 SOURCE S1 – PAF ROCK IN PIT

### 5.1.1 PREDICTION OUTCOMES

1. Results of kinetic tests were extrapolated to identify a 52 week average and 52 week potential maximum for the source term elements. These results were converted to release rates as mg per kg of rock per week. The results are shown in Table 4-2 and

### 5.1.2 SCALING FACTORS

There are of course discrepancies in geochemical and physical conditions between laboratory kinetic reactors and full-scale waste dumps, including but 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 is missing.

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 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.

### 5.1.3 CSF 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 calculations for acidity using the cumulative probability 1 CSF of 0.4 from Lapakko and Olsen (2015) - Table 5-1, 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.

Application of the CSF to both Source term 1 and 2 predicts lower concentrations than no CSF (as would be expected), with concentration of arsenic below the criterion in Year 1 onwards (no CSF predicts arsenic above criterion in Year 1 (Table 5-2).

*Table 5-1 Predicted acidity in lake water concentrations with 0.4 CSF applied to release rates (>Year 2)*

| | Without CSF – maximum extrapolated release rate | | With CSF – maximum extrapolated release rate | |
|---|---|---|---|---|
| Parameter | Mean groundwater concentration | 90th percentile groundwater concentration | Mean groundwater concentration | 90th percentile groundwater concentration |
| acidity<br>(mg/L $CaCO_3$) | 29 | 285 | 12 | 114 |

*Table 5-2 Predicted concentrations of source term elements in lake water concentrations with 0.4 CSF applied to release rates (mg/L) (average release rates, Table 4-2)*

| Element | Units | Mean or 90th percentile groundwater concentration | **Stock Watering Criteria** | (2026) | (2031) | (2039) | (2044) | (2061) |
|---|---|---|---|---|---|---|---|---|
| arsenic | mg/L | Mean - groundwater | **0.5** | 0.41 | 0.10 | 0.07 | 0.07 | 0.06 |
| arsenic | mg/L | 90th percentile - groundwater | **0.5** | **0.7** | 0.37 | 0.34 | 0.34 | 0.33 |
| cobalt | mg/L | Mean - groundwater | **1** | **1.3** | 0.12 | 0.05 | 0.02 | 0.001 |
| cobalt | mg/L | 90th percentile - groundwater | **1** | **1.3** | 0.12 | 0.05 | 0.02 | 0.003 |
| copper | mg/L | Mean - groundwater | **1** | **3.3** | 0.2 | 0.1 | 0.04 | 0.003 |
| copper | mg/L | 90th percentile - groundwater | **1** | **3.3** | 0.2 | 0.1 | 0.08 | 0.04 |

The effect of CSF and also mean and 90th percentile of arsenic in groundwater (background) is shown in Figure 5-1, noting the stock watering criterion is 0.5 mg/L.

Cobalt is shown in Figure 5-2, and copper in Figure 5-3 – both have criterion of 1 mg/L.

*Figure 5-1 Predicted arsenic in lake water during recovery (source S1 and S2 combined, with and without CSF and showing contribution of mean and 90th percentile groundwater arsenic)*

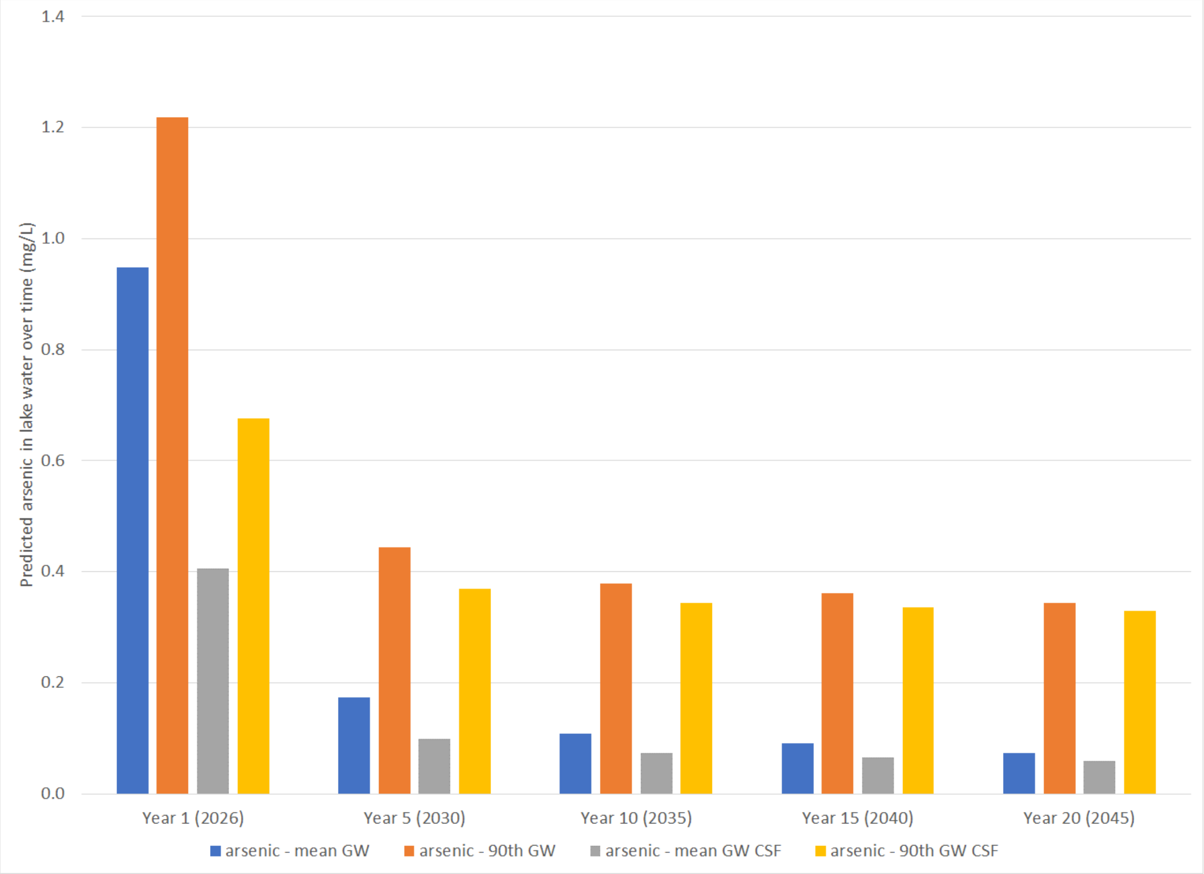


*Figure 5-2 Predicted cobalt in lake water during recovery (source S1 and S2 combined, with and without CSF and showing contribution of mean and 90th percentile groundwater cobalt (no significant difference in mean and 90th percentile))*

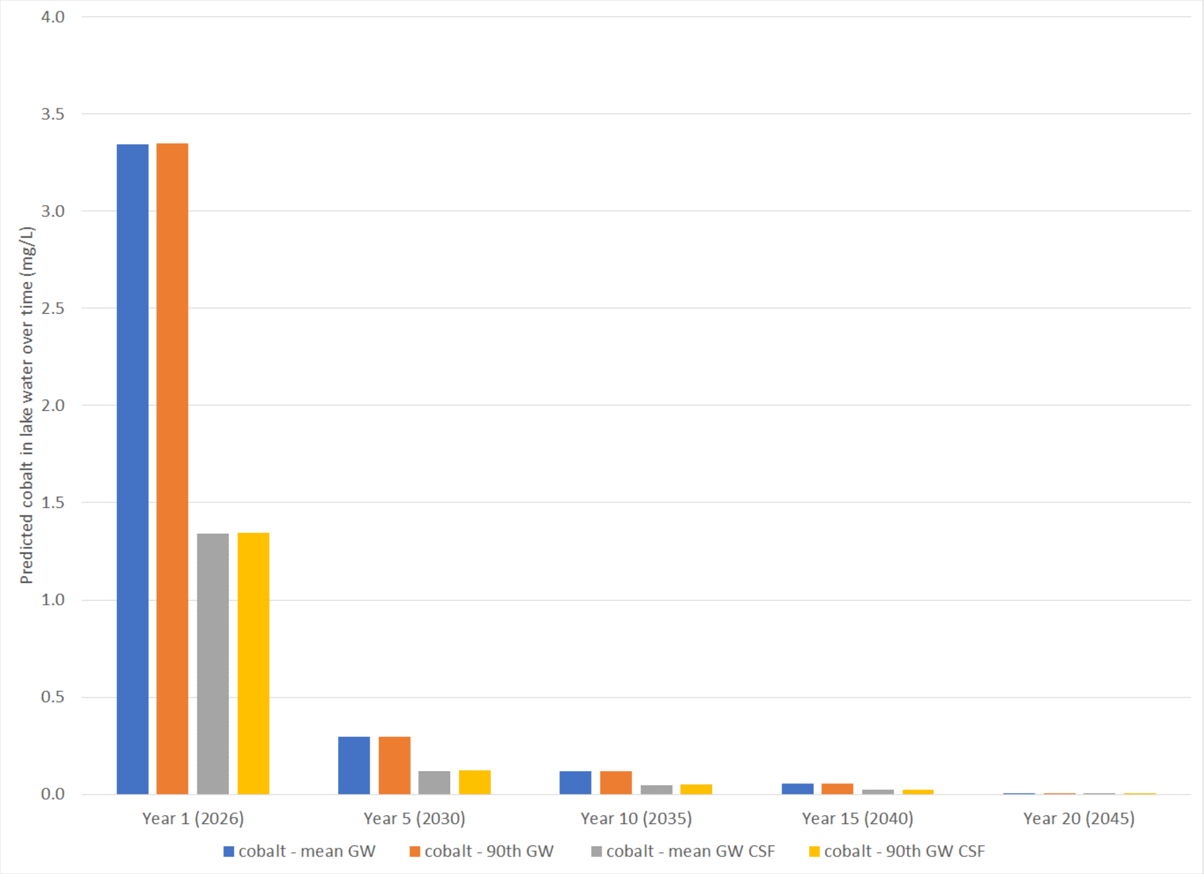
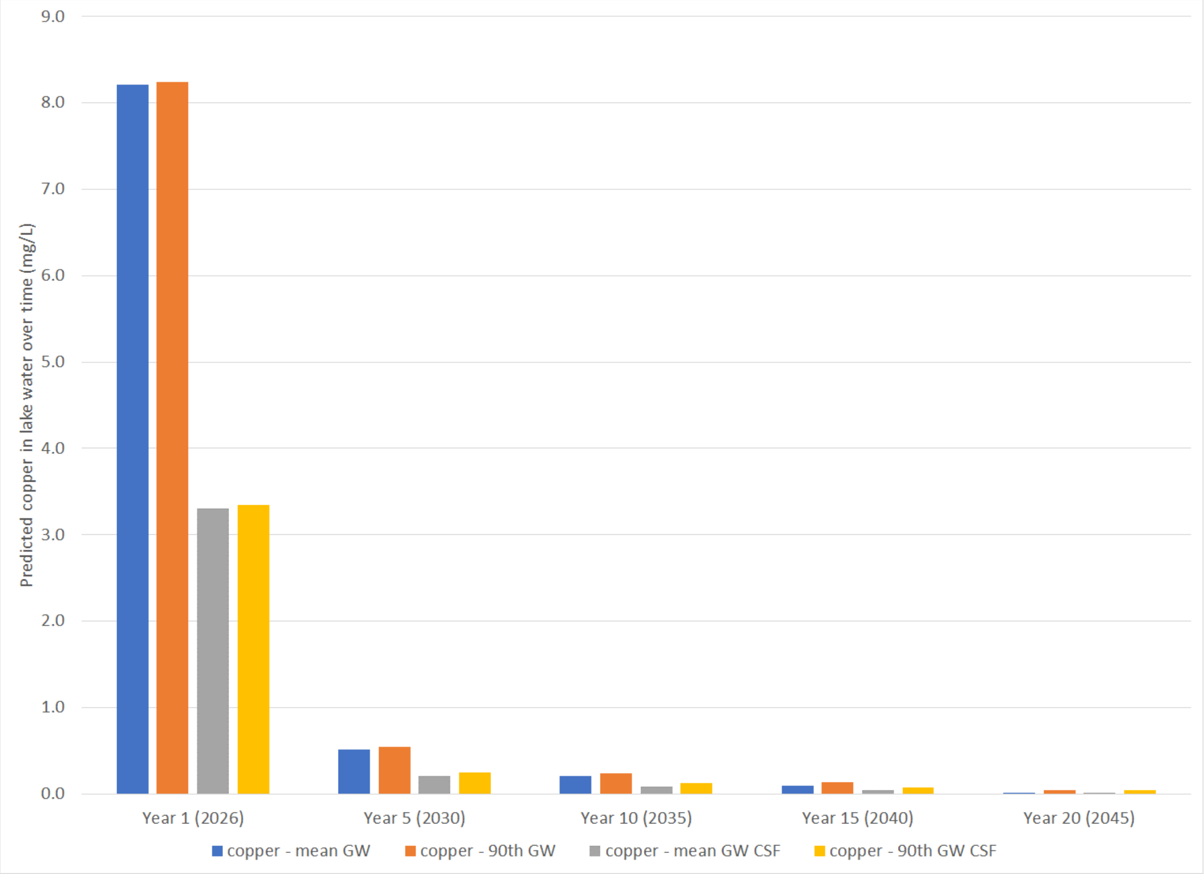


*Figure 5-3 Predicted copper in lake water during recovery (source S1 and S2 combined, with and without CSF and showing contribution of mean and 90th percentile groundwater copper (no significant difference in mean and 90th percentile))*



## 5.2 METALS & METALLOID LIMNOLOGICAL DISTRIBUTION

It is possible that arsenic, cobalt and copper may bind with available ferric oxyhydroxides (FeOH) and therefore have colloidal behaviour. This may result in the arsenic becoming enriched in sediment rather than water column over time.

## 5.3 PIT CHARACTERISTICS

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.).

**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 PREDICTIONS & CSM

The CSM set out in Section 2 is revisited with the outcomes of the predictive calculations. Six linkages were identified, and these are considered below noting predicted estimated concentrations of arsenic, cobalt and copper as per Tables 5-2 – 5-4 (various assumptions in predictions – all predictions less than adopted criterion at year 5 when Lake is progressively filing).

| Source (S) | Primary Pathway (P) [2] | Secondary Pathway (P) | Tertiary Pathway (P) | Receptor (R) | Linkage # (L) | Discussion |
|---|---|---|---|---|---|---|
| **S1 –** PAF rock in the pit | P1 - Groundwater inflow and contact with exposed oxidised rock / materials | P2 - direct uptake / contact | - | R1 Migratory Birds (contact) | L1 | Bioaccumulation of heavy metals becomes a concern for fauna when the capacity of species to regulate the internal concentration of metals is lost. This can occur through direct ingestion of heavy metals or ingestion of contaminated organisms. This results in the impairment of physiological functions required for normal growth and survival, with documented effects on development and survival of species.<br>Accumulation of heavy metals can seriously alter the aquatic environment, affecting the survival of some fauna.<br>The bioaccumulation of toxic chemicals could occur if waters within the Pit are considered productive enough to support algal growth, aquatic vegetation, and associated organisms such as zooplankton which could provide foraging opportunities for visiting fauna.<br>The acidity generated and arsenic generated and metals may be significant and indicate this is a potentially significant linkage if rok is left unmanaged.<br>Estimations of alkalinity from wall rock coupled to groundwater inflow suggest however that there is a potential for an excess of alkalinity in the lake water, with calculations indicating an alkalinity close to existing depending on groundwater dynamics and wall rock kinetics. |
|  | P1 - Groundwater inflow (and/ or rainfall) and contact with exposed oxidised rock / materials | P3 -<br>Lateral migration of solutes away from the Pit | P4 - Abstraction | R2 Future Human Use | L2 | Abstraction of groundwater along the flow path away from the Pit – key species are currently above drinking water criteria in groundwater but not above stock watering criteria according to predictions when accounting for scaling. |
|  |  |  | P4 - Abstraction | R3 Stock watering | L3 |  |
| **S2**<br>Pit wall rock | P1 - Groundwater inflow and contact with exposed oxidised rock / materials | P2 - direct uptake / contact<br>P3 - Lateral migration of solutes away from the Pit | - | R1 Migratory Birds (contact) | L4 | The wall rock alkalinity may outstrip the acidity generated from the 18.8% of wall rock that is PAF (based on current data and several assumptions). There will be an interim loading of metals from the PAF wall sections.<br>These are predicted to mix with lake water and produce a final concentration below stock watering criteria. |

| Source (S) | Primary Pathway (P) [2] | Secondary Pathway (P) | Tertiary Pathway (P) | Receptor (R) | Linkage # (L) | Discussion |
|---|---|---|---|---|---|---|
| | | | P4 - Abstraction | R2 Future Human Use | L5 | |
| | | | P4 - Abstraction | R3 Stock watering | L6 | |

# 6 CONCLUSIONS

The following conclusions are drawn in relation to this assessment in the context of the proposed full submergence of PAF rock in the pit as a disposal option post mining.

This assessment used available kinetic data for PAF rock and extrapolated forward using linear trend analysis and bulk scaling factors. A cumulative scaling factor (CSF) was adopted for consideration from literature, and this reduces the predicted rates and leach concentrations, though scaling factors that are not site specific are problematic.

Arsenic concentrations are very noticeable in terms of magnitude compared to other elements, where concentrations in excess of 10,000 mg/kg (for context general crustal concentration would be in the range 5 – 30 mg/kg) have been reported. Arsenopyrite (an iron arsenic sulfide (FeAsS)) is present in project rock. Arsenic has a calculated geochemical abundance index (GAI) of over 10.

Arsenic and acidity are thus considered to be the key parameters, along with cobalt and copper (i.e. these form the source term).

Current pit lake water has an arsenic concentration above the stock watering guideline value of 0.5 mg/L.

It is understood the PAF rock would be left unmanaged within the pit for ~3 years and so further oxidation of sulfidic materials may occur, leading to a higher leach concentration of copper and cobalt, which appear to be pH sensitive (higher in concentration under more acidic conditions). Arsenic does not appear to be unduly driven by increased acidity, likely as a result of the high GAI.

Key conclusions are as follows:

1. Scaled up leach (accounting for 0.15 million tonne of rock) adjusted for a literature based CSF would be predicted to yield an arsenic concentration less than the current lake water and result in a lake water arsenic concentration around the stock watering criterion for arsenic (similar to now) depending on whether adopting mean or 90th percentile groundwater concentration for arsenic, at Year 4. Predicted concentrations of cobalt and copper are predicted to be less than stock watering criteria at Year 4.

2. It is possible that arsenic may bind with available ferric oxyhydroxides (FeOH) and therefore have colloidal behaviour. This may result in the arsenic becoming enriched in sediment rather than water column over time. Further partition and speciation modelling could be undertaken on receipt of further kinetic data.

3. Given the proposed interim in pit storage of PAF rock, if not appropriately managed this may lead to notable generation of acidity and mobile metals/ metalloids during life of mine. When the pit is allowed to flood and contacts the 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). Interim management measures that mitigate oxidation and generation of acidity (and metal release) should be considered with respect to copper and cobalt.

4. The long term management of PAF rock is proposed to be full submergence within POD 3 at the base of the pit upon mine closure. As 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 interim PAF rock drainage may need to be managed and treated in the interim period.

Please note the statement of limitations as Appendix E.

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# APPENDIX A – SOURCE TERM DERIVATION

# Appendix A Source Term Derivation

Column leach test results: PAF Waste

| Sample Characteristics | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sulphur<br>%S | ANC<br>kg$H_2SO_4$/t | NAPP<br>kg$H_2SO_4$/t | NAG$_{4.5}$<br>kg$H_2SO_4$/t | NAG$_{7.0}$<br>kg$H_2SO_4$/t | NAGpH | Weight<br>g | Start<br>Date | Sample<br>Code |
| 0.67 | 9 | 12 | 4 | 10 | 3.3 | 2001 | 09/01/21 | FH/21363 |

### NTMO Stock Drinking Water (ANZECC, 2000)

| | | NTMO Short-term trigger value Irrigation and General Water Use (ANZECC, 2000) | NTMO Stock Drinking Water (ANZECC, 2000) | NHMRC 2011 Australian Drinking Water Guidelines (Health) | NTMO 80% Aquatic Ecosystem (ANZECC, 2000 at 80% protection) | NTMO 90% Aquatic Ecosystem (ANZECC, 2000 at 90% protection) | NTMO 95% Aquatic Ecosystem (ANZECC, 2000 at 95% protection) | NTMO 99% Aquatic Ecosystem (ANZECC, 2000 at 99% protection) | Background Pit | | | | | | Background Lake | | | | | | Background Groundwater | | | | | | | | | | New | New | New | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameters** | | | | | | | | | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum | **Week** | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 4 | 8 | 12 | 16 | 20 | 24 | Maximum | Mean |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | 12-Jul-21 | 9-Aug-21 | 6-Sep-21 | 5-Oct-21 | 1-Nov-21 | 29-Nov-21 | 29-Dec-21 | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | **21363-Initial** | **21363-1** | **21363-2** | **21363-3** | **21363-4** | **21363-5** | **21363-6** | | |
| As | mg/l | 2 | 0.5 | 0.01 | 0.14 | 0.042 | 0.013 | 0.0008 | 0.604 | 0.526 | 0.164 | 0.583 | 0.77 | 0.784 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.05 | 0.10 | 0.05 | 0.12 | 0.072 | 0.32 | 0.45 | 0.188 | 0.142 | 0.296 | 0.300 | 0.391 | 0.323 | 0.245 | 0.391 | 0.269 |
| Cd | mg/l | 0.05 | 0.01 | 0.002 | 0.0008 | 0.0004 | 0.0002 | 0.00006 | | | | | | 0 | | | | | | 0 | | | | | | 0.3 | 0.0991 | 0.0637 | 0.0590 | 0.0533 | 0.0717 | 0.0738 | 0.0602 | 0.099 | 0.069 |
| Co | mg/l | 0.1 | 1.0 | | | | | | | | | | | 0 | | | | | | 0.01 | 0.002 | 0.001 | 0.001 | 0.001 | 0.003 | 0.003 | 1.68 | 0.988 | 0.992 | 0.754 | 1.30 | 1.38 | 1.25 | 1.7 | 1.192 |
| Cu | mg/l | 5 | 1.0 | 2 | 0.0025 | 0.0018 | 0.0014 | 0.001 | 0.003 | 0.001 | 0.009 | 0.001 | 0.002 | 0.043 | | | | | | 0.03 | 0.006 | 0.003 | 0.009 | 0.003 | 0.014 | 0.04 | 0.325 | 0.202 | 0.350 | 0.671 | 2.00 | 3.55 | 4.94 | 4.9 | 1.720 |
| Mn | mg/l | 10 | | 0.5 | 3.6 | 2.5 | 1.9 | 1.2 | 0.142 | 0.041 | 0.178 | 0.026 | 0.427 | 0.437 | 0.03 | 0.02 | 0.04 | 0.01 | 0.07 | 0.26 | 0.171 | 0.113 | 0.152 | 0.13 | 0.354 | 0.86 | 2.37 | 6.84 | 5.26 | 3.24 | 5.81 | 6.18 | 5.18 | 6.840 | 4.983 |
| Ni | mg/l | 2 | 1.0 | 0.02 | 0.017 | 0.013 | 0.011 | 0.008 | 0.001 | 0.001 | 0.001 | 0.001 | 0.003 | 0.005 | 0 | 0 | 0.01 | 0 | 0.02 | 0.02 | 0.003 | 0.002 | 0.006 | 0.002 | 0.005 | 0.035 | 0.61 | 0.35 | 0.35 | 0.31 | 0.45 | 0.50 | 0.45 | 0.607 | 0.431 |
| Pb | mg/l | 5 | 0.1 | 0.01 | 0.0094 | 0.0056 | 0.0034 | 0.001 | | | | | | 0.01 | | | | | | 0 | 0.006 | 0.004 | 0.007 | 0.003 | 0.0216 | 0.026 | 0.008 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.04 | 0.039 | 0.015 |
| Zn | mg/l | 5 | 20 | | 0.031 | 0.015 | 0.008 | 0.002 | 0.008 | 0.004 | 0.01 | 0.004 | 0.028 | 0.04 | 0.02 | 0.01 | 0.03 | 0.01 | 0.07 | 0.1 | 0.01 | 0.006 | 0.013 | 0.007 | 0.02 | 0.086 | 1.01 | 0.50 | 0.64 | 0.73 | 1.25 | 1.44 | 1.30 | 1.440 | 0.982 |

### NTMO Short-term trigger value Irrigation and General Water Use (ANZECC, 2000)

| | | NTMO Short-term trigger value Irrigation and General Water Use (ANZECC, 2000) | NTMO Stock Drinking Water (ANZECC, 2000) | NHMRC 2011 Australian Drinking Water Guidelines (Health) | NTMO 80% Aquatic Ecosystem (ANZECC, 2000 at 80% protection) | NTMO 90% Aquatic Ecosystem (ANZECC, 2000 at 90% protection) | NTMO 95% Aquatic Ecosystem (ANZECC, 2000 at 95% protection) | NTMO 99% Aquatic Ecosystem (ANZECC, 2000 at 99% protection) | Background Pit | | | | | | Background Lake | | | | | | Background Groundwater | | | | | | | | | | New | New | New | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameters** | | | | | | | | | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum | **Week** | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 4 | 8 | 12 | 16 | 20 | 24 | Maximum | Mean |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | 12-Jul-21 | 9-Aug-21 | 6-Sep-21 | 5-Oct-21 | 1-Nov-21 | 29-Nov-21 | 29-Dec-21 | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | **21363-Initial** | **21363-1** | **21363-2** | **21363-3** | **21363-4** | **21363-5** | **21363-6** | | |
| As | mg/l | 2 | 0.5 | 0.01 | 0.14 | 0.042 | 0.013 | 0.0008 | 0.604 | 0.526 | 0.164 | 0.583 | 0.772 | 0.784 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.05 | 0.10 | 0.05 | 0.12 | 0.072 | 0.32 | 0.45 | 0.188 | 0.142 | 0.296 | 0.300 | 0.391 | 0.323 | 0.245 | 0.391 | 0.269 |
| Cd | mg/l | 0.05 | 0.01 | 0.002 | 0.0008 | 0.0004 | 0.0002 | 0.00006 | | | | | | 0 | | | | | | 0 | | | | | | 0.3 | 0.0991 | 0.0637 | 0.0590 | 0.0533 | 0.0717 | 0.0738 | 0.0602 | 0.0991 | 0.069 |
| Co | mg/l | 0.1 | 1.0 | | | | | | | | | | | 0 | | | | | | 0.01 | 0.002 | 0.001 | 0.001 | 0.001 | 0.003 | 0.003 | 1.68 | 0.988 | 0.992 | 0.754 | 1.30 | 1.38 | 1.25 | 1.68 | 1.192 |
| Cu | mg/l | 5 | 1.0 | 2 | 0.0025 | 0.0018 | 0.0014 | 0.001 | 0.003 | 0.001 | 0.009 | 0.001 | 0.002 | 0.043 | | | | | | 0.03 | 0.006 | 0.003 | 0.009 | 0.003 | 0.014 | 0.04 | 0.325 | 0.202 | 0.350 | 0.671 | 2.00 | 3.55 | 4.94 | 4.940 | 1.720 |
| Mn | mg/l | 10 | | 0.5 | 3.6 | 2.5 | 1.9 | 1.2 | 0.142 | 0.041 | 0.178 | 0.026 | 0.427 | 0.437 | 0.03 | 0.02 | 0.04 | 0.01 | 0.07 | 0.26 | 0.171 | 0.113 | 0.152 | 0.13 | 0.354 | 0.86 | 2.37 | 6.84 | 5.26 | 3.24 | 5.81 | 6.18 | 5.18 | 6.840 | 4.983 |
| Ni | mg/l | 2 | 1.0 | 0.02 | 0.017 | 0.013 | 0.011 | 0.008 | 0.001 | 0.001 | 0.001 | 0.001 | 0.003 | 0.005 | 0 | 0 | 0.01 | 0 | 0.02 | 0.02 | 0.003 | 0.002 | 0.006 | 0.002 | 0.005 | 0.035 | 0.61 | 0.35 | 0.35 | 0.31 | 0.45 | 0.50 | 0.45 | 0.607 | 0.431 |
| Pb | mg/l | 5 | 0.1 | 0.01 | 0.0094 | 0.0056 | 0.0034 | 0.001 | | | | | | 0.01 | | | | | | 0 | 0.006 | 0.004 | 0.007 | 0.003 | 0.0216 | 0.026 | 0.008 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.04 | 0.039 | 0.015 |
| Zn | mg/l | 5 | 20 | | 0.031 | 0.015 | 0.008 | 0.002 | 0.008 | 0.004 | 0.01 | 0.004 | 0.028 | 0.0 | 0.02 | 0.01 | 0.03 | 0.01 | 0.07 | 0.1 | 0.01 | 0.006 | 0.013 | 0.007 | 0.02 | 0.086 | 1.01 | 0.50 | 0.64 | 0.73 | 1.25 | 1.44 | 1.30 | 1.440 | 0.982 |

### NTMO S NHMRC 2011 Australian Drinking Water Guidelines (Health)

| | | NTMO Short-term trigger value Irrigation and General Water Use (ANZECC, 2000) | NTMO Stock Drinking Water (ANZECC, 2000) | NHMRC 2011 Australian Drinking Water Guidelines (Health) | NTMO 80% Aquatic Ecosystem (ANZECC, 2000 at 80% protection) | NTMO 90% Aquatic Ecosystem (ANZECC, 2000 at 90% protection) | NTMO 95% Aquatic Ecosystem (ANZECC, 2000 at 95% protection) | NTMO 99% Aquatic Ecosystem (ANZECC, 2000 at 99% protection) | Background Pit | | | | | | Background Lake | | | | | | Background Groundwater | | | | | | | | | | New | New | New | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameters** | | | | | | | | | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum | **Week** | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 4 | 8 | 12 | 16 | 20 | 24 | Maximum | Mean |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | 12-Jul-21 | 9-Aug-21 | 6-Sep-21 | 5-Oct-21 | 1-Nov-21 | 29-Nov-21 | 29-Dec-21 | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | **21363-Initial** | **21363-1** | **21363-2** | **21363-3** | **21363-4** | **21363-5** | **21363-6** | | |
| As | mg/l | 2 | 0.5 | 0.01 | 0.14 | 0.042 | 0.013 | 0.0008 | 0.604 | 0.526 | 0.164 | 0.583 | 0.772 | 0.784 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.05 | 0.10 | 0.05 | 0.12 | 0.072 | 0.32 | 0.45 | 0.188 | 0.142 | 0.296 | 0.300 | 0.391 | 0.323 | 0.245 | 0.391 | 0.269 |
| Cd | mg/l | 0.05 | 0.01 | 0.002 | 0.0008 | 0.0004 | 0.0002 | 0.00006 | | | | | | 0 | | | | | | 0 | | | | | | 0.3 | 0.0991 | 0.0637 | 0.0590 | 0.0533 | 0.0717 | 0.0738 | 0.0602 | 0.0991 | 0.069 |
| Co | mg/l | 0.1 | 1.0 | | | | | | | | | | | 0 | | | | | | 0.01 | 0.002 | 0.001 | 0.001 | 0.001 | 0.003 | 0.003 | 1.68 | 0.988 | 0.992 | 0.754 | 1.30 | 1.38 | 1.25 | 1.68 | 1.192 |
| Cu | mg/l | 5 | 1.0 | 2 | 0.0025 | 0.0018 | 0.0014 | 0.001 | 0.003 | 0.001 | 0.009 | 0.001 | 0.002 | 0.043 | | | | | | 0.03 | 0.006 | 0.003 | 0.009 | 0.003 | 0.014 | 0.04 | 0.325 | 0.202 | 0.350 | 0.671 | 2.00 | 3.55 | 4.94 | 4.94 | 1.720 |
| Mn | mg/l | 10 | | 0.5 | 3.6 | 2.5 | 1.9 | 1.2 | 0.142 | 0.041 | 0.178 | 0.026 | 0.427 | 0.437 | 0.03 | 0.02 | 0.04 | 0.01 | 0.07 | 0.26 | 0.171 | 0.113 | 0.152 | 0.13 | 0.354 | 0.86 | 2.37 | 6.84 | 5.26 | 3.24 | 5.81 | 6.18 | 5.18 | 6.84 | 4.983 |
| Ni | mg/l | 2 | 1.0 | 0.02 | 0.017 | 0.013 | 0.011 | 0.008 | 0.001 | 0.001 | 0.001 | 0.001 | 0.003 | 0.005 | 0 | 0 | 0.01 | 0 | 0.02 | 0.02 | 0.003 | 0.002 | 0.006 | 0.002 | 0.005 | 0.035 | 0.61 | 0.35 | 0.35 | 0.31 | 0.45 | 0.50 | 0.45 | 0.607 | 0.431 |
| Pb | mg/l | 5 | 0.1 | 0.01 | 0.0094 | 0.0056 | 0.0034 | 0.001 | | | | | | 0.01 | | | | | | 0 | 0.006 | 0.004 | 0.007 | 0.003 | 0.0216 | 0.026 | 0.008 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.04 | 0.039 | 0.015 |
| Zn | mg/l | 5 | 20 | | 0.031 | 0.015 | 0.008 | 0.002 | 0.008 | 0.004 | 0.01 | 0.004 | 0.028 | 0.0 | 0.02 | 0.01 | 0.03 | 0.01 | 0.07 | 0.1 | 0.01 | 0.006 | 0.013 | 0.007 | 0.02 | 0.086 | 1.01 | 0.50 | 0.64 | 0.73 | 1.25 | 1.44 | 1.30 | 1.440 | 0.982 |

### NTMO S NHMRC NTMO 80% Aquatic Ecosystem (ANZECC, 2000 at 80% protection)

| | | NTMO Short-term trigger value Irrigation and General Water Use (ANZECC, 2000) | NTMO Stock Drinking Water (ANZECC, 2000) | NHMRC 2011 Australian Drinking Water Guidelines (Health) | NTMO 80% Aquatic Ecosystem (ANZECC, 2000 at 80% protection) | NTMO 90% Aquatic Ecosystem (ANZECC, 2000 at 90% protection) | NTMO 95% Aquatic Ecosystem (ANZECC, 2000 at 95% protection) | NTMO 99% Aquatic Ecosystem (ANZECC, 2000 at 99% protection) | Background Pit | | | | | | Background Lake | | | | | | Background Groundwater | | | | | | | | | | New | New | New | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameters** | | | | | | | | | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum | **Week** | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 4 | 8 | 12 | 16 | 20 | 24 | Maximum | Mean |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | 12-Jul-21 | 9-Aug-21 | 6-Sep-21 | 5-Oct-21 | 1-Nov-21 | 29-Nov-21 | 29-Dec-21 | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | **21363-Initial** | **21363-1** | **21363-2** | **21363-3** | **21363-4** | **21363-5** | **21363-6** | | |
| As | mg/l | 2 | 0.5 | 0.01 | 0.14 | 0.042 | 0.013 | 0.0008 | 0.604 | 0.526 | 0.164 | 0.583 | 0.772 | 0.784 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.05 | 0.10 | 0.05 | 0.12 | 0.072 | 0.32 | 0.45 | 0.188 | 0.142 | 0.296 | 0.300 | 0.391 | 0.323 | 0.245 | 0.391 | 0.269 |
| Cd | mg/l | 0.05 | 0.01 | 0.002 | 0.0008 | 0.0004 | 0.0002 | 0.00006 | | | | | | 0 | | | | | | 0 | | | | | | 0.3 | 0.0991 | 0.0637 | 0.0590 | 0.0533 | 0.0717 | 0.0738 | 0.0602 | 0.0991 | 0.069 |
| Co | mg/l | 0.1 | 1.0 | | | | | | | | | | | 0 | | | | | | 0.01 | 0.002 | 0.001 | 0.001 | 0.001 | 0.003 | 0.003 | 1.68 | 0.988 | 0.992 | 0.754 | 1.30 | 1.38 | 1.25 | 1.68 | 1.192 |
| Cu | mg/l | 5 | 1.0 | 2 | 0.0025 | 0.0018 | 0.0014 | 0.001 | 0.003 | 0.001 | 0.009 | 0.001 | 0.002 | 0.043 | | | | | | 0.03 | 0.006 | 0.003 | 0.009 | 0.003 | 0.014 | 0.04 | 0.325 | 0.202 | 0.350 | 0.671 | 2.00 | 3.55 | 4.94 | 4.94 | 1.720 |
| Mn | mg/l | 10 | | 0.5 | 3.6 | 2.5 | 1.9 | 1.2 | 0.142 | 0.041 | 0.178 | 0.026 | 0.427 | 0.437 | 0.03 | 0.02 | 0.04 | 0.01 | 0.07 | 0.26 | 0.171 | 0.113 | 0.152 | 0.13 | 0.354 | 0.86 | 2.37 | 6.84 | 5.26 | 3.24 | 5.81 | 6.18 | 5.18 | 6.84 | 4.983 |
| Ni | mg/l | 2 | 1.0 | 0.02 | 0.017 | 0.013 | 0.011 | 0.008 | 0.001 | 0.001 | 0.001 | 0.001 | 0.003 | 0.005 | 0 | 0 | 0.01 | 0 | 0.02 | 0.02 | 0.003 | 0.002 | 0.006 | 0.002 | 0.005 | 0.035 | 0.61 | 0.35 | 0.35 | 0.31 | 0.45 | 0.50 | 0.45 | 0.607 | 0.431 |
| Pb | mg/l | 5 | 0.1 | 0.01 | 0.0094 | 0.0056 | 0.0034 | 0.001 | | | | | | 0.01 | | | | | | 0 | 0.006 | 0.004 | 0.007 | 0.003 | 0.0216 | 0.026 | 0.008 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.04 | 0.039 | 0.015 |
| Zn | mg/l | 5 | 20 | | 0.031 | 0.015 | 0.008 | 0.002 | 0.008 | 0.004 | 0.01 | 0.004 | 0.028 | 0.0 | 0.02 | 0.01 | 0.03 | 0.01 | 0.07 | 0.1 | 0.01 | 0.006 | 0.013 | 0.007 | 0.02 | 0.086 | 1.01 | 0.50 | 0.64 | 0.73 | 1.25 | 1.44 | 1.30 | 1.44 | 0.982 |

# APPENDIX B – EXTRAPOLATIONS

# Appendix B - Extrapolations and Release Rates

†McPherson et al., 2014
‡RIVM 2020

Column leach test results: PAF Waste

| Sample Characteristics | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sulphur %S | ANC kgH$_2$SO$_4$/t | NAPP kgH$_2$SO$_4$/t | NAG$_{4.5}$ kgH$_2$SO$_4$/t | NAG$_{7.0}$ kgH$_2$SO$_4$/t | NAGpH | Weight g | Start Date | Sample Code |
| 0.67 | 9 | 12 | 4 | 10 | 3.3 | 2 | 09/01/21 | FH/21363 |

| Parameters | | NTMO Short-term trigger value Irrigation and General Water Use (ANZECC, 2000) | NTMO Stock Drinking Water (ANZECC, 2000) | NHMRC 2011 Australian Drinking Water Guidelines (Health) | NTMO 80% Aquatic Ecosystem (ANZECC, 2000 at 80% protection) | NTMO 90% Aquatic Ecosystem (ANZECC, 2000 at 90% protection) | NTMO 95% Aquatic Ecosystem (ANZECC, 2000 at 95% protection) | NTMO 99% Aquatic Ecosystem (ANZECC, 2000 at 95% protection) |
|---|---|---|---|---|---|---|---|---|
| Volume | ml | | | | | | | |
| pH | - | | | | | | | |
| EC | dS/m | | | | | | | |
| Alkalinity | mg/l | | | | | | | |
| Acidity | mg/l | | | | | | | |
| DOC | | | | | | | | |
| Total CN | | | | | | | | |
| Ag | mg/l | | | 0.1 | 0.0002 | 0.0001 | 0.00005 | 0.00002 |
| Al | mg/l | 20 | 5 | 0 | 0.15 | 0.08 | 0.055 | 0.027 |
| As | mg/l | 2 | 0.5 | 0.01 | 0.14 | 0.042 | 0.013 | 0.0008 |
| B | mg/l | 0.5 - 1.0 | 5 | 4 | 1.3 | 0.68 | 0.37 | 0.09 |
| Ba | mg/l | | | | | | | 0.093† |
| Be | mg/l | 0.5 | | 0.06 | | | | |
| Ca | mg/l | | | | | | | |
| Cd | mg/l | 0.05 | 0 | 0.002 | 0.0008 | 0.0004 | 0.0002 | 0.00006 |
| Cl | mg/l | | | | | | | |
| Co | mg/l | 0.1 | 1 | | | | | |
| Cr | mg/l | 1 | 1 | | 0.04 | 0.006 | 0.001 | 0.00001 |
| Cu | mg/l | 5 | 1 | 2 | 0.0025 | 0.0018 | 0.0014 | 0.001 |
| F | mg/l | | | | | | | |
| Fe | mg/l | 10 | | | | | | |
| Hg | mg/l | 0.002 | 0 | 0.001 | 0.0054 | 0.0019 | 0.0006 | 0.00006 |
| K | mg/l | | | | | | | |
| Mg | mg/l | | | | | | | |
| Mn | mg/l | 10 | 0.00000 | 0.5 | 3.6 | 2.5 | 1.9 | 1.2 |
| Mo | mg/l | 0.05 | 0.15 | 0.05 | 0 | 0 | 0 | |
| Na | mg/l | | | | | | | |
| Ni | mg/l | 2 | 1 | 0.02 | 0.017 | 0.013 | 0.011 | 0.008 |
| P | mg/l | | | | | | | |
| Pb | mg/l | 5 | 0 | 0.01 | 0.0094 | 0.0056 | 0.0034 | 0.001 |
| Sb | mg/l | | | | | | | |
| Se | mg/l | 0.05 | 0 | 0.01 | 0 | 0 | 0 | 0 |
| Si | mg/l | | | | | | | |
| Sn | mg/l | | | | | | | |
| SO$_4$ | mg/l | | | | | | | |
| Sr | mg/l | | | | | | | 10.7‡ |
| Th | mg/l | | | | | | | |
| Tl | mg/l | | | | | | | |
| U | mg/l | 0.1 | 0.2 | 0.017 | | | | |
| Zn | mg/l | 5.000 | 20.000 | 0.000 | 0.031 | 0.015 | 0.008 | 0.002 |

| Parameters | Background Pit | | | | | | Background Lake | | | | | | Background Groundwater | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum | Average | Mean | SD | Median | 90%tile | Maximum |
| Volume | | | | | | | | | | | | | | | | | | |
| pH | | | | | | | | | | | | | | | | | | |
| EC | | | | | | | | | | | | | | | | | | |
| Alkalinity | | | | | | | | | | | | | | | | | | |
| Acidity | | | | | | | | | | | | | | | | | | |
| DOC | | | | | | | | | | | | | | | | | | |
| Total CN | | | | | | | | | | | | | | | | | | |
| Ag | | | | | | | | | | | | | | | | | | |
| Al | 0.05 | 0.015 | 0.169 | 0.012 | 0.055 | 0.906 | 0.98 | 0.2 | 3.38 | 0.12 | 0.87 | 20 | 0.655130435 | 0.086579 | 2.074198 | 0.046 | 2.23 | 13 |
| As | 0.604 | 0.526 | 0.164 | 0.583 | 0.77 | 0.784 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.05 | 0.100550725 | 0.04985 | 0.115298 | 0.072 | 0.32 | 0.45 |
| B | 0.016 | 0.016 | 0.002 | 0.015 | 0.019 | 0.02 | | | | | | 0.02 | | | | | | |
| Ba | | | | | | | | | | | | | | | | | | |
| Be | | | | | | 0 | | | | | | 0 | | | | | | |
| Ca | | | | | | | | | | | | | | | | | | |
| Cd | | | | | | 0 | | | | | | 0 | | | | | | 0.3 |
| Cl | | | | | | | | | | | | | | | | | | |
| Co | | | | | | 0 | | | | | | 0.01 | 0.002 | 0.001 | 0.001 | 0.001 | 0.003 | 0.003 |
| Cr | | | | | | 0.001 | | | | | | 0.04 | 0.005 | 0.002 | 0.012 | 0.002 | 0.01 | 0.053 |
| Cu | 0.003 | 0.001 | 0.009 | 0.001 | 0.002 | 0.043 | | | | | | 0.03 | 0.006 | 0.003 | 0.009 | 0.003 | 0.014 | 0.04 |
| F | | | | | | | | | | | | | | | | | | |
| Fe | 0.082 | 0.035 | 0.175 | 0.028 | 0.239 | 0.852 | | | | | | 26 | 5.3 | 0.65 | 7.6 | 1.4 | 18.2 | 32 |
| Hg | | | | | | 0 | | | | | | 0 | | | | | | |
| K | | | | | | | | | | | | | | | | | | |
| Mg | | | | | | | | | | | | | | | | | | |
| Mn | 0.142 | 0.041 | 0.178 | 0.026 | 0.427 | 0.437 | 0.03 | 0.02 | 0.04 | 0.01 | 0.07 | 0.26 | 0.171 | 0.113 | 0.152 | 0.13 | 0.354 | 0.86 |
| Mo | | | | | | 0.009 | | | | | | 0 | | | | | | |
| Na | | | | | | | | | | | | | | | | | | |
| Ni | 0.001 | 0.001 | 0.001 | 0.001 | 0.003 | 0.005 | 0 | 0 | 0.01 | 0 | 0.02 | 0.02 | 0.003 | 0.002 | 0.006 | 0.002 | 0.005 | 0.035 |
| P | | | | | | | | | | | | | | | | | | |
| Pb | | | | | | 0.01 | | | | | | 0 | 0.006 | 0.004 | 0.007 | 0.003 | 0.0216 | 0.026 |
| Sb | | | | | | | | | | | | | | | | | | |
| Se | | | | | | 0 | | | | | | 0 | | | | | | |
| Si | | | | | | | | | | | | | | | | | | |
| Sn | | | | | | | | | | | | | | | | | | |
| SO$_4$ | | | | | | | | | | | | | | | | | | |
| Sr | | | | | | | | | | | | | | | | | | |
| Th | | | | | | | | | | | | | | | | | | |
| Tl | | | | | | | | | | | | | | | | | | |
| U | | | | | | 0.006 | | | | | | 0 | | | | | | |
| Zn | 0.008 | 0.004 | 0.01 | 0.004 | 0.028 | 0.040 | 0.02 | 0.01 | 0.03 | 0.01 | 0.07 | 0.1 | 0.01 | 0.006 | 0.013 | 0.007 | 0.02 | 0.086 |

| Week | 0 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 | 52 | *Average* | *maximum* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 12-Jul-21 | 9-Aug-21 | 6-Sep-21 | 5-Oct-21 | 1-Nov-21 | 29-Nov-21 | 29-Dec-21 | *Extrapolation* | | | | | | | | |
| | **21363-Initial** | **21363-1** | **21363-2** | **21363-3** | **21363-4** | **21363-5** | **21363-6** | **21363-7** | **21363-8** | **21363-9** | **21363-10** | **21363-11** | **21363-12** | **21363-13** | | |
| Volume | 0.463 | 0.522 | 0.512 | 0.516 | 0.511 | 0.515 | 0.523 | 0.517 | 0.517 | 0.517 | 0.517 | 0.517 | 0.517 | 0.517 | | |
| pH | 5.9 | 5.9 | 5.1 | 4.8 | 4.9 | 4.7 | 4.6 | | | | | | | | | |
| EC | 0.816 | 0.74 | 0.62 | 0.43 | 0.35 | 0.36 | 0.38 | | | | | | | | | |
| Alkalinity | - | - | - | - | - | - | - | | | | | | | | | |
| Acidity | 29 | 20 | 21 | 59 | 33 | 39 | 38 | | | | | | | | | |
| DOC | - | - | 1 | 1 | 1 | <1 | <1 | | | | | | | | | |
| Total CN | - | - | - | - | - | - | - | | | | | | | | | |
| Ag | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | | | | | | | | | |
| Al | 0.07 | 0.07 | 0.13 | 0.16 | 0.34 | 0.47 | 0.58 | | | | | | | | | |
| As | 0.188 | 0.142 | 0.296 | 0.300 | 0.391 | 0.323 | 0.245 | 0.359 | 0.381 | 0.404 | 0.426 | 0.448 | 0.471 | 0.493 | 0.35 | 0.49 |
| B | 0.09 | 0.06 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | | | | | | | | | |
| Ba | 0.03 | 0.01 | 0.02 | 0.01 | 0.02 | 0.03 | 0.02 | | | | | | | | | |
| Be | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.003 | 0.003 | | | | | | | | | |
| Ca | 31 | 22 | 16 | 15 | 11 | 13 | 11 | | | | | | | | | |
| Cd | 0.0991 | 0.0637 | 0.0590 | 0.0533 | 0.0717 | 0.0738 | 0.0602 | | | | | | | | | |
| Cl | 13 | 4 | 2 | 1 | 2 | <1 | <1 | | | | | | | | | |
| Co | 1.68 | 0.988 | 0.992 | 0.754 | 1.30 | 1.38 | 1.25 | 1.16 | 1.16 | 1.15 | 1.14 | 1.13 | 1.13 | 1.12 | 1.17 | 1.68 |
| Cr | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | | | | | | | | | |
| Cu | 0.325 | 0.202 | 0.350 | 0.671 | 2.00 | 3.55 | 4.94 | 4.89 | 5.68 | 6.47 | 7.27 | 8.06 | 8.85 | 9.64 | 4.49 | 9.64 |
| F | 0.1 | 0.2 | 0.1 | <0.1 | 0.2 | 0.1 | 0.2 | | | | | | | | | |
| Fe | 0.24 | 0.08 | 0.20 | 0.30 | 0.43 | 0.60 | 0.53 | | | | | | | | | |
| Hg | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | | | | | | | | | |
| K | 25 | 17 | 13 | 14 | 10 | 10 | 7 | | | | | | | | | |
| Mg | 88 | 73 | 42 | 27 | 29 | 29 | 21 | | | | | | | | | |
| Mn | 2.37 | 6.84 | 5.26 | 3.24 | 5.81 | 6.18 | 5.18 | | | | | | | | | |
| Mo | 0.002 | <0.001 | 0.002 | <0.001 | <0.001 | 0.001 | <0.001 | | | | | | | | | |
| Na | 16 | 8 | 5 | 4 | 4 | 9 | 5 | | | | | | | | | |
| Ni | 0.61 | 0.35 | 0.35 | 0.31 | 0.45 | 0.50 | 0.45 | | | | | | | | | |
| P | <1 | <1 | <1 | <1 | <1 | <1 | <1 | | | | | | | | | |
| Pb | 0.008 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.04 | | | | | | | | | |
| Sb | <0.001 | <0.001 | 0.002 | <0.001 | 0.001 | 0.001 | <0.001 | | | | | | | | | |
| Se | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | | | | | | | | | |
| Si | 1.4 | 2.7 | 1.2 | 1.3 | 1.1 | 1.0 | 0.9 | | | | | | | | | |
| Sn | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | | | | | | | | | |
| SO$_4$ | 448 | 327 | 209 | 131 | 136 | 166 | 136 | 142 | 142 | 142 | 142 | 142 | 142 | 142 | | |
| Sr | 0.07 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | | | | | | | | | |
| Th | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | | | | | | | | | |
| Tl | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | | | | | | | | | |
| U | 0.009 | 0.003 | 0.004 | 0.004 | 0.007 | 0.010 | 0.012 | | | | | | | | | |
| Zn | 1.01 | 0.50 | 0.64 | 0.73 | 1.25 | 1.44 | 1.30 | | | | | | | | | |

### Calculated Parameters

| | | 0 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 | 52 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SO$_4$ Release | mg/kg/wk | - | 21 | 13 | 8 | 9 | 11 | 9 | 11.904 | 9 | 9 | 9 | 9 | 9 | 9 |
| IOR | kg O2/m3/s | - | 1.37E-08 | 8.59E-09 | 5.42E-09 | 5.58E-09 | 6.86E-09 | 5.71E-09 | 0.000 | | | | | | |
| Cumulative SO$_4$ | mg/kg | 104 | 189 | 243 | 276 | 311 | 354 | 389 | 266.582 | 303 | 340 | 377 | 413 | 450 | 487 |
| PAF | kg H2SO4/t | 0.11 | 0.19 | 0.25 | 0.28 | 0.32 | 0.36 | 0.40 | 0.272 | | | | | | |
| Cumulative ANC | kg H2SO4/t | 0.11 | 0.10 | 0.06 | 0.04 | 0.04 | 0.05 | 0.03 | 0.062 | | | | | | |
| Nett Acidity | kg H2SO4/t | 0.00 | 0.09 | 0.19 | 0.24 | 0.28 | 0.31 | 0.36 | 0.210 | | | | | | |
| Acidity | mg CaCO3/L | 467 | 341 | 218 | 136 | 142 | 173 | 142 | 148 | 148 | 148 | 148 | 148 | 148 | 148 |
| Alkalinity | mg CaCO3/L | 488 | 389 | 238 | 174 | 166 | 184 | 133 | | | | | | | |
| Nett Alkalinity | mg CaCO3/L | 21 | 48 | 20 | 37 | 24 | 11 | -9 | | | | | | | |
| Titrated Alkalinity | mg CaCO3/L | -29 | -20 | -21 | -59 | -33 | -39 | -38 | | | | | | | |
| Residual S | %S | 0.67 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.65 | 0.65 |
| CaCO$_3$ Consumption | mg/kg/wk | - | 23 | 14 | 10 | 9 | 10 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cumulative CaCO$_3$ | mg/kg | 102 | 195 | 249 | 288 | 325 | 364 | 394 | 394 | 394 | 394 | 394 | 394 | 394 | 394 |
| Residual ANC | kg H$_2$SO$_4$/t | 8.9 | 8.8 | 8.8 | 8.7 | 8.7 | 8.6 | 8.6 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| CO$_3$/SO$_4$ molar ratio | - | 0.9 | 1.0 | 1.0 | 1.1 | 1.0 | 0.9 | 0.8 | | | | | | | |

| | | |
|---|---|---|
| As Release (Cumulative) | mg/kg | 3720 |
| | % | |
| | mg/kg/week | |
| | | |
| Cobalt | mg/kg | 50.3 |
| Release | % | |
| Cum | mg/kg/week | |
| | | |
| Copper | mg/kg | 426 |
| Release | % | |
| Cum | mg/kg/week | |
| | | |
| Acidity | mg/kg | 110 |
| Release | % | |
| Cum | mg/kg/week | |

### Leach Concentrations from Rock Pile

| | A Release | Kg rock | mg | Bulk Density t/m3 | m3 | Possible Footprint (m2) | Rainfall (mm) | L per m2 | Litres per footprint | Weekly | mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Arsenic | 0.023 | 3.00E+07 | 6.90E+05 | 2.00E+00 | 7.50E+04 | 2.50E+04 | 1250 | 1250 | 3.13E+07 | 6.01E+05 | **1.1** |
| Cobalt | 0.072 | 3.00E+07 | 2.16E+06 | 2.00E+00 | 7.50E+04 | 2.50E+04 | 1250 | 1250 | 3.13E+07 | 6.01E+05 | **3.6** |
| Copper | 0.126 | 3.00E+07 | 3.78E+06 | 2.00E+00 | 7.50E+04 | 2.50E+04 | 1250 | 1250 | 3.13E+07 | 6.01E+05 | **6.3** |

### Release Rates

| **As** | | | 0 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 | 52 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cumul. | mg/kg | 3720 | 0.04 | 0.08 | 0.16 | 0.23 | 0.33 | 0.42 | 0.48 | 0.57 | 0.67 | 0.78 | 0.89 | 1.00 | 1.12 | 1.25 | | |
| Percent | % | | 0.001% | 0.002% | 0.004% | 0.006% | 0.009% | 0.011% | 0.013% | 0.015% | 0.018% | 0.021% | 0.024% | 0.027% | 0.030% | 0.034% | | |
| Per week | mg/kg/week | | - | 0.009 | 0.019 | 0.019 | 0.025 | 0.021 | 0.016 | 0.023 | 0.025 | 0.026 | 0.028 | 0.029 | 0.030 | 0.032 | 0.02 | 0.03 |
| **Cobalt** | | | | | | | | | | | | | | | | | | |
| Cumul. | mg/kg | 50.3 | 0.39 | 0.65 | 0.90 | 1.10 | 1.43 | 1.78 | 2.11 | 2.41 | 2.71 | 3.01 | 3.30 | 3.59 | 3.89 | 4.17 | | |
| Percent | % | | 0.773% | 1.286% | 1.791% | 2.177% | 2.838% | 3.544% | 4.194% | 4.792% | 5.386% | 5.976% | 6.562% | 7.145% | 7.724% | 8.299% | | |
| Per week | mg/kg/week | | | 0.064 | 0.063 | 0.049 | 0.083 | 0.089 | 0.082 | 0.075 | 0.075 | 0.074 | 0.074 | 0.073 | 0.073 | 0.072 | 0.07 | 0.09 |
| **Copper** | | | | | | | | | | | | | | | | | | |
| Cumul. | mg/kg | 426 | 0.08 | 0.13 | 0.22 | 0.39 | 0.90 | 1.82 | 3.11 | 4.37 | 5.84 | 7.51 | 9.39 | 11.47 | 13.76 | 16.26 | | |
| Percent | % | | 0.018% | 0.030% | 0.051% | 0.092% | 0.212% | 0.426% | 0.729% | 1.026% | 1.371% | 1.764% | 2.205% | 2.694% | 3.231% | 3.816% | | |
| Per week | mg/kg/week | | | 0.013 | 0.022 | 0.043 | 0.128 | 0.229 | 0.323 | 0.316 | 0.367 | 0.418 | 0.470 | 0.521 | 0.572 | 0.623 | 0.31 | 0.62 |

# APPENDIX C – PIT WALL ROCK PREDICTIONS

## Appendix C Rock Wall Loading Estimates - no CSF

| | | arsenic | cobalt | copper | acidity as mg/L CaCO3 | Alkalinity as mg/L CaCO3 |
|---|---|---|---|---|---|---|
| Parameter | Unit | Value | Value | Value | Value | Value |
| Area of exposed wall rock | m$^2$ | 1 | 1 | 1 | 1 | 1 |
| Average assumed pit wall side slope angle | Degrees | 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 |
| Density of pit wall rock | Tonne/m$^3$ | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 |
| Depth of blast fractured zone | m | 1 | 1 | 1 | 1 | 1 |
| Depth of blast influenced zone | m | 3 | 3 | 3 | 3 | 3 |
| Mass of rock in blast fractured zone | tonne | 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 |
| Total mass of wall rock in the 4 m deep blast affected zone | tonne | 15.228 | 15.228 | 15.228 | 15.228 | 15.228 |
| | kg | 15,228 | 15,228 | 15,228 | 15,228 | 15,228 |
| Mean annual precipitation | mm/year | 1245 | 1245 | 1245 | 1245 | 1245 |
| Mean annual precipitation volume (per 1m$^2$ of exposed unsubmerged wall rock) | m$^3$ | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 |
| **Mass loading rates** | | | | | | |
| Mass loading rate - week | mg/kg/wk | 0.018 | 0.072 | 0.126 | 12.4 | 13.8 |
| Mass loading rate - annual | mg/kg/yr | 0.9 | 3.7 | 6.6 | 644.8 | 717.6 |
| Wall rock loading rate (from Table 5-4) with CSF of 0.4 | mg/kg/yr | 0.4 | 1.5 | 2.6 | 257.9 | 287.0 |
| **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 | 16.2 |
| | kg | 15200 | 15200 | 15200 | 15200 | 16200 |
| Area of PAF rock | m$^2$ | 55,563 | 55,563 | 55,563 | 55,563 | 55,564 |
| Total mass of PAF rock available | tonnes | 844558 | 844558 | 844558 | 844558 | 900137 |
| Total mass of PAF rock available | kg | 844557600 | 844557600 | 844557600 | 844557600 | 900136800 |
| Annual mass loading per 1m$^2$ of unsubmerged rock | mg/yr per m$^2$ | 14227 | 56909 | 99590 | 3920384 | 4650048 |
| | kg/yr per m$^2$ | 0.0142 | 0.0569 | 0.0996 | 4 | 5 |
| Total annual contact water available per 1 m$^2$ of unsubmerged rock (per 1m$^2$) | L per year | 1,250 | 1,250 | 1,250 | 1,250 | 1,251 |
| Annual average wall rock runoff concentration (calculated/ predicted) per 1m$^2$ | mg/L per m$^2$ | 11.4 | 45.5 | 79.7 | 3136.3 | 3717.1 |
| Annual mass loading from the pit walls to the pit lake for PAF unsubmerged rock | mg/yr | 7.91E+08 | 3.16E+09 | 5.53E+09 | 2.18E+11 | 2.58E+11 |
| Rainfall | L per year | 9.20E+07 | 9.20E+07 | 9.20E+07 | 9.20E+07 | 9.20E+07 |
| Total annual contact water available per PAF unsubmerged rock | L per year | 1.16E+08 | 1.16E+08 | 1.16E+08 | 6.95E+07 | 6.95E+07 |
| Cumulative | L per year | 2.08E+08 | 2.08E+08 | 2.08E+08 | 1.61E+08 | 1.62E+08 |
| Annual average wall rock runoff concentration for PAF - arsenic | flux mg/L | 3.8 | 15.2 | 26.6 | 1349.2 | 1599.7 |
| Lake Volume | L | 2.00E+09 | 2.00E+09 | 2.00E+09 | 2.00E+09 | 2.00E+09 |
| Dilution factor | (Total annual contact water available per PAF unsubmerged rock / Lake Volume, fraction) | 5.80E-02 | 5.80E-02 | 5.80E-02 | 3.47E-02 | 3.48E-02 |
| Predicted lake water concentration from PAF rock post dilution in lake volume. | mg/L | 0.22 | 0.88 | 1.54 | 46.85 | 55.60 |
| Nett Alkalinity | mg/L | | | | 8.75 | |

## Appendix C - Rock Wall Loading Estimates - with CSF

| | | arsenic | cobalt | copper | acidity as mg/L CaCO3 | Alkalinity as mg/L CaCO3 |
|---|---|---|---|---|---|---|
| Parameter | Unit | Value | Value | Value | Value | Value |
| Area of exposed wall rock | $m^2$ | 1 | 1 | 1 | 1 | 1 |
| Average assumed pit wall side slope angle | Degrees | 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 |
| Density of pit wall rock | Tonne/$m^3$ | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 |
| Depth of blast fractured zone | m | 1 | 1 | 1 | 1 | 1 |
| Depth of blast influenced zone | m | 3 | 3 | 3 | 3 | 3 |
| Mass of rock in blast fractured zone | tonne | 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 |
| Total mass of wall rock in the 4 m deep blast affected zone | tonne | 15.228 | 15.228 | 15.228 | 15.228 | 15.228 |
| | kg | 15,228 | 15,228 | 15,228 | 15,228 | 15,228 |
| Mean annual precipitation | mm/year | 1245 | 1245 | 1245 | 1245 | 1245 |
| Mean annual precipitation volume (per $1m^2$ of exposed unsubmerged wall rock) | $m^3$ | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 |
| **Mass loading rates** | | | | | | |
| Mass loading rate - week | mg/kg/wk | 0.018 | 0.072 | 0.126 | 12.4 | 13.8 |
| Mass loading rate - annual | mg/kg/yr | 0.9 | 3.7 | 6.6 | 644.8 | 717.6 |
| Wall rock loading rate (from Table 5-4) with CSF of 0.4 | mg/kg/yr | 0.4 | 1.5 | 2.6 | 257.9 | 287.0 |
| **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 | 16.2 |
| | kg | 15200 | 15200 | 15200 | 15200 | 16200 |
| Area of PAF rock | $m^2$ | 55,563 | 55,563 | 55,563 | 55,563 | 55,564 |
| Total mass of PAF rock available | tonnes | 844558 | 844558 | 844558 | 844558 | 900137 |
| Total mass of PAF rock available | kg | 844557600 | 844557600 | 844557600 | 844557600 | 900136800 |
| Annual mass loading per $1m^2$ of unsubmerged rock | mg/yr per $m^2$ | 5691 | 22764 | 39836 | 3920384 | 4650048 |
| | kg/yr per $m^2$ | 0.0057 | 0.0228 | 0.0398 | 4 | 5 |
| Total annual contact water available per 1 $m^2$ of unsubmerged rock (per $1m^2$) | L per year | 1,250 | 1,250 | 1,250 | 1,250 | 1,251 |
| Annual <u>average</u> wall rock runoff concentration (calculated/ predicted) per $1m^2$ | mg/L per $m^2$ | 4.6 | 18.2 | 31.9 | 3136.3 | 3717.1 |
| Annual mass loading from the pit walls to the pit lake for PAF unsubmerged rock | mg/yr | 3.16E+08 | 1.26E+09 | 2.21E+09 | 2.18E+11 | 2.58E+11 |
| Rainfall | L per year | 9.20E+07 | 9.20E+07 | 9.20E+07 | 9.20E+07 | 9.20E+07 |
| Total annual contact water available per PAF unsubmerged rock | L per year | 1.16E+08 | 1.16E+08 | 1.16E+08 | 6.95E+07 | 6.95E+07 |
| Cumulative | L per year | 2.08E+08 | 2.08E+08 | 2.08E+08 | 1.61E+08 | 1.62E+08 |
| Annual average wall rock runoff concentration for PAF - arsenic | flux mg/L | 1.5 | 6.1 | 10.6 | 1349.2 | 1599.7 |
| Lake Volume | L | 2.00E+09 | 2.00E+09 | 2.00E+09 | 2.00E+09 | 2.00E+09 |
| Dilution factor | (Total annual contact water available per PAF unsubmerged rock / Lake Volume, fraction) | 5.80E-02 | 5.80E-02 | 5.80E-02 | 3.47E-02 | 3.48E-02 |
| Predicted lake water concentration from PAF rock post dilution in lake volume. | mg/L | 0.09 | 0.35 | 0.62 | 46.85 | 55.60 |
| Nett Alkalinity | mg/L | | | | 8.75 | |

# APPENDIX D –
MIXING OF S1 + S2

## Appendix D - Combined S1 and S2 Predictions (Scaled) - with no CSF

*Increments mimic the period 2025 - 2045*

| | | | | | **Source S2** | **Year 1 (2026)** | **Year 5 (2030)** | **Year 10 (2035)** | **Year 15 (2040)** | **Year 20 (2045)** |
|---|---|---|---|---|---|---|---|---|---|---|
| | Parameter | Value | Source/ Reference/ Rationale | Stock Watering Criterion (mg/L) | Runoff | 500 ML | 3500 ML | 6000 ML | 6500 ML | 7500 ML (SWL) |
| Sources | Time (weeks) | 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) | 1.50E+08 | As advised by ERIAS via CDM Smith | | | 1.50E+08 | 1.50E+08 | 1.50E+08 | 1.50E+08 | 1.50E+08 |
| | Rainfall (L) | | | | | 9.20E+07 | 9.20E+07 | 9.20E+07 | 9.20E+07 | 9.20E+07 |
| | Run-off Volume (L) | | | | 1.16E+08 | 1.16E+08 | 1.16E+08 | 1.16E+08 | 1.16E+08 | 1.16E+08 |
| | Groundwater Influx (L) | Variable per stage of recovery | CDM Smith (2021) | | - | 5.00E+08 | 3.50E+09 | 6.00E+09 | 6.50E+09 | 7.50E+09 |
| | Cumulative Rainfall & Groundwater (L) | | | | | 5.92E+08 | 3.59E+09 | 6.09E+09 | 6.59E+09 | 7.59E+09 |
| | Ratio Run-off: Lake | | | | | 1.96E-01 | 3.23E-02 | 1.90E-02 | 1.76E-02 | 1.53E-02 |
| | Run-off Contribution | Fraction | | | | 0.8 | 0.6 | 0.4 | 0.2 | 0 |
| | arsenic | (mg/kg/rock per week) | | | | 0.023 | 0.023 | 0.023 | 0.023 | 0.023 |
| | arsenic | mg/L | | 0.5 | 3.8 | 0.303 | 0.050 | 0.029 | 0.027 | 0.024 |
| | cobalt | (mg/kg/rock per week) | | | | 0.073 | 0 | 0 | 0 | 0 |
| | cobalt | mg/L | | 1 | 15.2 | 0.96 | 0.00 | 0.00 | 0.00 | 0.00 |
| | copper | (mg/kg/rock per week) | | | | 0.311 | 0 | 0 | 0 | 0 |
| | copper | mg/L | | 1 | 26.2 | 4.10 | 0.00 | 0.00 | 0.00 | 0.00 |
| Groundwater | arsenic | mg/L | Mean | 0.5 | | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| | arsenic | mg/L | 90th percentile | 0.5 | | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 |
| | cobalt | mg/L | Mean | 1 | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| | cobalt | mg/L | 90th percentile | 1 | | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| | copper | mg/L | Mean | 1 | | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| | copper | mg/L | 90th percentile | 1 | | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Combined | arsenic - mean GW | mg/L | Mean - groundwater | 0.5 | | 0.9 | 0.17 | 0.11 | 0.09 | 0.07 |
| | arsenic - 90th GW | mg/L | 90th percentile - groundwater | 0.5 | | 1.2 | 0.44 | 0.38 | 0.36 | 0.34 |
| | cobalt - mean GW | mg/L | Mean - groundwater | 1 | | 3.3 | 0.30 | 0.12 | 0.05 | 0.001 |
| | cobalt - 90th GW | mg/L | 90th percentile - groundwater | 1 | | 3.3 | 0.30 | 0.12 | 0.06 | 0.003 |
| | copper - mean GW | mg/L | Mean - groundwater | 1 | | 8.2 | 0.5 | 0.2 | 0.10 | 0.003 |
| | copper - 90th GW | mg/L | 90th percentile - groundwater | 1 | | 8.2 | 0.5 | 0.2 | 0.13 | 0.04 |

# Appendix D Combined S1 and S2 Predictions (Scaled) - with CSF

*Increments mimic the period 2025 - 2045*

Sources

| | | | | Source S2 | Year 1 (2026) | Year 5 (2030) | Year 10 (2035) | Year 15 (2040) | Year 20 (2045) |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | Value | Source/ Reference/ Rationale | Stock Watering Criterion (mg/L) | Runoff | 500 ML | 3500 ML | 6000 ML | 6500 ML | 7500 ML (SWL) |
| Time (weeks) | 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) | 1.50E+08 | As advised by ERIAS via CDM Smith | | | 1.50E+08 | 1.50E+08 | 1.50E+08 | 1.50E+08 | 1.50E+08 |
| Rainfall (L) | | | | | 9.20E+07 | 9.20E+07 | 9.20E+07 | 9.20E+07 | 9.20E+07 |
| Run-off Volume (L) | | | | 1.16E+08 | 1.16E+08 | 1.16E+08 | 1.16E+08 | 1.16E+08 | 1.16E+08 |
| Groundwater Influx (L) | Variable per stage of recovery | CDM Smith (2021) | | - | 5.00E+08 | 3.50E+09 | 6.00E+09 | 6.50E+09 | 7.50E+09 |
| Cumulative Rainfall & Groundwater (L) | | | | | 5.92E+08 | 3.59E+09 | 6.09E+09 | 6.59E+09 | 7.59E+09 |
| Ratio Run-off: Lake | | | | | 1.96E-01 | 3.23E-02 | 1.90E-02 | 1.76E-02 | 1.53E-02 |
| Run-off Contribution | Fraction | | | | 0.8 | 0.6 | 0.4 | 0.2 | 0 |
| arsenic | (mg/kg/rock per week) | 0.023 | | | 0.0092 | 0.0092 | 0.0092 | 0.0092 | 0.0092 |
| arsenic | mg/L | | 0.5 | 1.5 | 0.121 | 0.020 | 0.012 | 0.011 | 0.009 |
| cobalt | (mg/kg/rock per week) | 0.073 | | | 0.02920 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| cobalt | mg/L | | 1 | 6.1 | 0.38 | 0.00 | 0.00 | 0.00 | 0.00 |
| copper | (mg/kg/rock per week) | 0.311 | | | 0.1244 | 0 | 0 | 0 | 0 |
| copper | mg/L | | 1 | 10.6 | 1.64 | 0.00 | 0.00 | 0.00 | 0.00 |

Groundwater

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| arsenic | mg/L | Mean | 0.5 | | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| arsenic | mg/L | 90th percentile | 0.5 | | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 |
| cobalt | mg/L | Mean | 1 | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| cobalt | mg/L | 90th percentile | 1 | | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| copper | mg/L | Mean | 1 | | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| copper | mg/L | 90th percentile | 1 | | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |

Combined

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| arsenic - mean GW CSF | mg/L | Mean - groundwater | 0.5 | | 0.41 | 0.10 | 0.07 | 0.07 | 0.06 |
| arsenic - 90th GW CSF | mg/L | 90th percentile - groundwater | 0.5 | | 0.7 | 0.37 | 0.34 | 0.34 | 0.33 |
| cobalt - mean GW CSF | mg/L | Mean - groundwater | 1 | | 1.3 | 0.12 | 0.05 | 0.02 | 0.001 |
| cobalt - 90th GW CSF | mg/L | 90th percentile - groundwater | 1 | | 1.3 | 0.12 | 0.05 | 0.02 | 0.003 |
| copper - mean GW CSF | mg/L | Mean - groundwater | 1 | | 3.3 | 0.2 | 0.1 | 0.04 | 0.003 |
| copper - 90th GW CSF | mg/L | 90th percentile - groundwater | 1 | | 3.3 | 0.2 | 0.1 | 0.08 | 0.04 |

# APPENDIX E – STATEMENT OF 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 statues 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 though 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 appraised 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.

# Appendix C Goldsim Water Balance Model Parameters

Table 8-1 Summary of the model parameters

| Model component / Parameter | unit | Value (median value for Monte Carlo parameter) | | | | | | Standard Deviation | Minimum value | Maximum value | note |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | For the Monte Carlo parameters only | | | |
| Climate data | | | | | | | | | | | |
| Rainfall | | Time series of historical rainfall | | | | | | Rainfall series is stochastically generated from historical rainfall data. | | | Rainfall is applied at 100% over the Pond wet surface. |
| Natural evaporation | | Use monthly average of pan ET | | | | | | - | - | - | ET is applied over the wet surface of the Pond. |
| Evaporation Pond | | | | | | | | | | | |
| Evaporation Pond catchment | $m^2$ | 570,400 | | | | | | - | - | - | - |
| Evaporation Pond spill level | m AHD | 98.6 | | | | | | - | - | - | Any volume after the Evaporation Pond reaches 98.8 m AHD is reported as overflow. |
| Evaporation Pond full capacity | ML | 1,074 | | | | | | - | - | - | The full capacity is the total volume in the Evaporation Pond before the Pond overflow is triggered. |
| Evaporation Pond maximum wall elevation | m AHD | 98.8 | | | | | | - | - | - | - |
| Evaporation Pond area at full capacity | $m^2$ | 281,000 | | | | | | - | - | - | - |
| Evaporation Pond maximum operational level | m AHD | 97.4 | | | | | | - | - | - | Stop the dewatering to the Evaporation Pond when this elevation is reached to keep a reserve for large rainfall. |
| Evaporation Pond minimum level | m AHD | 93 | | | | | | - | - | - | Stop the evaporators to keep a reserve of water in the Pond. |
| Evaporation Pond operational volume | ML | 709 | | | | | | - | - | - | Volume between the minimum and maximum operational level. |
| AWBM Runoff coefficient over Evaporation Pond catchment | [] | A1 | A2 | A3 | C1 | C2 | C3 | - | - | - | Runoff is applied over the catchment (less the wet surface). |
| | | 0.134 | 0.433 | 0.433 | 3 | 27 | 53 | | | | |
| Pan to lake factor | [] | 0.75 | | | | | | - | - | - | To account for vapour saturation over large lake. |
| Groundwater seepage | | | | | | | | | | | |
| Soil thickness | m | 3 | | | | | | - | - | - | - |
| Kv soil | m/d | 0.0034 | | | | | | 0.002 | 0.0005 | 0.05 | This parameter has a large control on the amount of water infiltrating from the Evaporation Pond. Groundwater seepage is calculated by a Darcy flux equation applied over the wet surface area and the average depth of the Evaporation Pond. |
| Evaporators | | | | | | | | | | | |
| Quantity of evaporators | unit | 3 | | | | | | - | - | - | The evaporators are initially installed over the Fountain Head Pit and then moved in June 2021 to the Evaporation Pond. |
| Pumping rate | $m^3/h$ | 135 | | | | | | - | - | - | - |
| Working period per day | h/d | 20.3 | | | | | | - | - | - | - |
| Monthly evaporators efficiency | [] | Jan | Feb | Mar | Apr | May | Jun | - | - | - | Those factors provided by PNX accounts for average monthly climatic conditions (rainfall, pan evaporation and winds). |
| | | 0.27 | 0.24 | 0.33 | 0.42 | 0.48 | 0.5 | | | | |
| | | Jul | Aug | Sep | Oct | Nov | Dec | | | | |
| | | 0.52 | 0.55 | 0.54 | 0.5 | 0.42 | 0.33 | | | | |
| Fountain Head Pit parameters | | | | | | | | | | | |
| K aquifer | m/d | 0.09 | | | | | | 0.01 | 0.06 | 0.12 | This parameter is relatively poorly characterised (and is a surrogate for the more complex hydrostratigraphy not represented in the model). However, this parameter is constrained by the historical pit water level recovery. The current Monte Carlo analysis does not assess the range of resulting groundwater inflows from this altered K value. |

| Model component / Parameter | unit | Value (median value for Monte Carlo parameter) | Standard Deviation | Minimum value | Maximum value | note |
|---|---|---|---|---|---|---|
| | | | For the Monte Carlo parameters only | | | |
| Water table elevation near the pit | m AHD | 95 | 0.5 | 93 | 97 | This parameter accounts for the uncertainty in defining the average water level condition around the pit. It has some control over the long-term pit stabilisation water level. |
| Max pumping rate | ML/d | 9 | - | - | - | Pumping from the pit to maintain the pit dry during LOM. |
| Base of pit diameter | m | 175 | - | - | - | From previous calibrated analytical solution of pit inflow. |
| Initial Fountain Head Pit Lake volume | ML | 2064 | - | - | - | - |
| Fountain Head Lake parameter | | | | | | |
| Catchment area | - | Cf. Table 4-1 (CDM Smith, 2021) | - | - | - | - |
| Runoff. AWBM | - | Cf. Table 4-1 (CDM Smith, 2021) | - | - | - | - |
| Pan to lake | - | 0.75 | - | - | - | To account for vapour saturation over the lake. |

# Appendix D Calculated PAF storage loading rates

|  |  |  |  | BE1A - Arsenic | BE1B - Arsenic | BE1A - Arsenic | BE1A - Arsenic | BE1A - Arsenic | BE1B - Arsenic | BE2A - Arsenic | BE2B - Arsenic |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  | As |  |  |  |  |  |  |  |  |  |
|  |  |  |  | Extrapolation using 0 intercept | Extrapolation using un-forced intercept |  |  |  |  | mg total (150,000 t rock) | mg total (150,000 t rock) |  |  |
|  |  |  | time in mo | mg/l | mg/l | mg in solution given volume | mg per kg of sample | mg per tonne of rock | mg per tonne of rock |  |  | **BE2B - PAF release kg/d (input)** | **Post 52 week PAF release kg/d (input)** |
| Measured | 11-Jul-21 | **21363-Initia** | 0 | 0.188 | 0.188 | 0.095 | 0.047 | 47 | 47 | 7.10E+06 | 7.09E+06 | 0.23 |  |
| Measured | 8-Aug-21 | **21363-1** | 4 | 0.142 | 0.142 | 0.071 | 0.036 | 36 | 36 | 5.36E+06 | 5.35E+06 | 0.18 |  |
| Measured | 5-Sep-21 | **21363-2** | 8 | 0.296 | 0.296 | 0.149 | 0.074 | 74 | 74 | 1.12E+07 | 1.12E+07 | 0.37 |  |
| Measured | 4-Oct-21 | **21363-3** | 12 | 0.300 | 0.300 | 0.151 | 0.075 | 75 | 75 | 1.13E+07 | 1.13E+07 | 0.37 |  |
| Measured | 31-Oct-21 | **21363-4** | 16 | 0.47 | 0.39 | 0.235 | 0.118 | 118 | 98 | 1.76E+07 | 1.47E+07 | 0.49 |  |
| Measured | 28-Nov-21 | **21363-5** | 20 | 0.58 | 0.32 | 0.294 | 0.147 | 147 | 81 | 2.20E+07 | 1.22E+07 | 0.40 |  |
| Measured | 28-Dec-21 | **21363-6** | 24 | 0.70 | 0.25 | 0.353 | 0.176 | 176 | 62 | 2.64E+07 | 9.24E+06 | 0.30 |  |
| Extrapolated | 25-Jan-22 | **21363-7** | 28 | 0.82 | 0.36 | 0.412 | 0.206 | 206 | 90 | 3.09E+07 | 1.35E+07 | 0.45 |  |
| Extrapolated | 22-Feb-22 | **21363-8** | 32 | 0.93 | 0.38 | 0.470 | 0.235 | 235 | 96 | 3.53E+07 | 1.44E+07 | 0.47 |  |
| Extrapolated | 22-Mar-22 | **21363-9** | 36 | 1.05 | 0.40 | 0.529 | 0.264 | 264 | 102 | 3.97E+07 | 1.52E+07 | 0.50 |  |
| Extrapolated | 19-Apr-22 | **21363-10** | 40 | 1.17 | 0.43 | 0.588 | 0.294 | 294 | 107 | 4.41E+07 | 1.61E+07 | 0.53 |  |
| Extrapolated | 17-May-22 | **21363-11** | 44 | 1.28 | 0.45 | 0.647 | 0.323 | 323 | 113 | 4.85E+07 | 1.69E+07 | 0.56 |  |
| Extrapolated | 14-Jun-22 | **21363-12** | 48 | 1.40 | 0.47 | 0.706 | 0.353 | 353 | 118 | 5.29E+07 | 1.78E+07 | 0.59 |  |
| Extrapolated | 12-Jul-22 | **21363-13** | 52 | 1.52 | 0.50 | 0.764 | 0.382 | 382 | 126 | 5.73E+07 | 1.89E+07 | 0.62 | **0.62** |