Macraes Phase IV

Stage 3 – Surface and Groundwater Assessment

Oceana Gold New Zealand Ltd.

26 March 2024

→ **The Power of Commitment**

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The Power of Commitment

Executive Summary

OceanaGold New Zealand Limited (OGNZL) operate the Macraes Gold Project (MGP) in east Otago, situated approximately 56 km north of Dunedin. The MGP began operations in 1990 and currently comprises two operational open cast pits (Frasers and Coronation Pits) and two underground mines - Frasers Underground (FRUG) and Golden Point Underground (GPUG), and a processing plant. Waste rock is placed both in pit and at a number of waste rock stacks (WRSs) located around the open pit margins. Tailings from processed ore is currently stored at the Top Tipperary Tailings Storage Facility (TTTSF). There are also two decommissioned Tailings Storage Facilities (TSFs) the Mixed Tailings Impoundment (MTI) and the SP11 Tailings Storage Facility (SP11).

The Macraes Phase IV (MPIV) project is the next major phase of proposed development at the site which aims to extend the life of mine (LOM) to approximately 2030. Consenting MPIV has been undertaken in stages. So far the MPIV project has involved increasing the capacity of the existing TTTSF to a height of 570 m RL allowing an additional 3.2 Mm^3 of tailings storage, a minor expansion of the existing Innes Mills Open Pit (IMOP) and the placement of an embankment structure and wet tailings disposal within the existing Fraser's Pit (FROP) (Frasers Co-disposal / Continuity Consents Project). Expansion and extension of the Golden Point Underground mine (GPUG Ext) has also been subject to a standalone consent application. Surface water and groundwater assessments for these components of MPIV have previously been undertaken by GHD (GHD New Zealand Limited). In addition, MPIV consists of three open pit extensions and further tailings storage in Frasers Pit (Frasers Tailings Facility (FTSF), comprising:

1. The central area comprising life of mine tailings storage in FROP and development of the open pit mining extensions in the IMOP;
2. An expansion of the Coronation Pit with waste infilling of the Coronation North Open Pit (situated approximately 4 km to the northwest of IMOP);
3. An expansion of the Golden Bar Pit and the associated Golden Bar WRS (situated approximately 6 km to the southeast of IMOP); and
4. Rehandle of ~5.4Mtones of waste rock from the rehabilitated Northern Gully Waste Rock Stack to the Golden Point Pit

The focus of this assessment is surface water and groundwater cumulative effects of the proposed IMOP extension, Golden Point Pit filling and FTSF developments within the Deepdell and the Waikouaiti River North Branch (NBWR) catchments including the separately reported effects from the MPIV GPUG Expansion and Extension, Coronation and Golden Bar pit developments and associated waste rock disposal. The effects of the MPIV Coronation extension and Coronation Pit infilling to the Mare Burn are reported separately in the Coronation surface and groundwater assessment. As a cumulative assessment, it includes consideration of all the aforementioned mine elements that have been reported on separately for MPIV and includes consideration of activities both consented and under application where it is likely that those consents will be given effect as part of the MPIV development. Cumulative water quality effects further down catchment within the Shag River are also considered..

A 3D numerical groundwater model has been developed using MODFLOW-USG (flow modelling code) and MODFLOW-USG-TRANSPORT (for solute transport modelling code). The 3D model has been used to assess groundwater inflow into the existing and proposed expanded pit during dewatering as well as during groundwater recovery for 400 years. The model was calibrated to reflect the current mine status before undertaking model predictions.

The majority of seepages are expected to move laterally within the weathered schist and be captured in silt ponds, pit sumps and/or report to the receiving surface water catchment. The groundwater contaminant plume (conservatively illustrated using sulphate due to its low potential for attenuation within the groundwater system and existing elevated nature in some receiving surface water bodies as a result of past mining activity associated with MGP) is modelled to primarily impact Deepdell Creek (from a combination of WRS seepage and Pit Lake overflow) with an estimated sulphate seepage flux of between 24 and 861 kg/day (20 and 200 years post closure respectively). The Waikouaiti River North Branch (NBWR) is modelled to receive an estimated sulphate seepage flux of between 5 and 116 kg/day (20 and 200 years post closure respectively) with the majority of the mass sourced directly from WRS seepage.

An existing sitewide Goldsim Water Balance Model (WBM) has been utilised to estimate future impacts on the receiving water quality as a result of mining and rehabilitation activities. Key updates to the WBM include revised WRS seepage and pit lake filling and water quality estimates, recalibration of key monitoring and compliance points utilising revised catchment boundaries and water quality and revised groundwater inflow / outflow estimates from the groundwater mode. Mitigation options to manage the receiving water quality to meet compliance criteria are also outlined and modelled where appropriate.

A pit lake filling assessment of the FROP and IMOP Pits was undertaken utilising the WBM and groundwater recharge rates from the groundwater model. Sensitivity to climate and climate change variables applicable to the area has also been applied. The assessment suggests that the resulting pit lake water level could reach the Frasers Backfill embankment (FRBF) level of 480 m RL (separating the two pits) approximately 51 years post closure (year 2081), upon which the lake levels would combine to form a single combined pit lake – Frasers / Innes Mills Pit Lake (FRIM). Long-term (>200 years) lake level projections suggest that FRIM lake levels are expected to reach a water level of between approximately 486 and 494 m RL when taking conservative climate change scenarios into consideration. These levels are below the north west pit rim spill point of 497 m RL and therefore no direct surface water discharge from the lake to the receiving surface water bodies is predicted.

A higher volume of seepage reporting to the Murphys Silt Pond through waste stored in the south of the Frasers Pit is considered possible (for pit lake waters in excess of 487 mRL above which waste is stored on the southern pit crest). In this event it is recommended that this increase in seepage be captured and treated in the same manner as currently occurs (captured prior to Murphys Silt Pond and pumped back to FRIM) with provision for increased pumping capacity considered if required.

Modelling results indicate that the development of the Macraes Phase IV project will potentially result in a predicted increase in sulphate concentrations associated with WRS development and seepage through the underlying schist into Deepdell Creek. These effects could be mitigated (if required) by augmentation of the flow from the Camp Creek reservoir (by up to 20 L/s) or an alternate low flow augmentation source. The construction of the Camp Creek reservoir would offer contingency against elevated concentrations of contaminants within Deepdell Creek during low flow periods and remove reliance on operational control of spill waters from the Maori Tommy Silt Pond in the long term. Post closure, Nitrate N, Ammoniacal N and other assessed trace element concentrations (relative to the mining phases) are expected to continue at similar levels or reduce as a result of rehabilitation of mining elements within the catchments.

As modelled, there is a low risk of compliance limit exceedance of the current consented water quality criteria within Deepdell Creek and the Shag River. Modelled exceedances of iron are a result of the assumed high background concentrations and are considered to be over stated. Modelled exceedances of Arsenic during mining should be prevented by operational control of the Maori Tommy silt pond during low flow periods.

In the NBWR, the implementation of selected mitigation measures within the catchment (which include progressive rehabilitation of WRSs, implementation of the Passive Treatment Systems (PTS), collection and controlled release of all accumulated seepage from the Frasers West, South and Golden Bar WRSs to the NBWR catchment and if required, selective pumping of waters back to Frasers Pit) will likely result in a low risk of compliance exceedance within the receiving surface water environment. Elevated modelled arsenic at compliance location NB03 is a result of the Golden Bar pit spill and could be managed by controlled discharge (during high flows) and/or treatment (eg. dosing the pit lake with Ferric Chloride) if required. As in the Shag River catchment, modelled exceedances of iron in the NBWR catchment are the result of the assumed high background concentrations and are considered to be over stated.

Overall, the results of the groundwater and surface water modelling suggest that the proposed development can be undertaken within the currently consented surface water compliance criteria limits provided that:

- The consented Camp Creek Dam (or a suitable alternative source of dilution water) is available and can augment Deepdell Stream flow against elevated concentrations at DC07 and DC08 during low flow periods;
- The consented Back Road WRS (BRWRS) is not utilised during the MPIV mine life;
- The Frasers West / South and Golden Bar WRSs are rehabilitated so that infiltration (and seepage) reduces to a rate of 29.2 mm/year;

- Passive Treatment Systems (PTS) are capturing and treating all seepage water from the Frasers West, Frasers South and Golden Bar WRS and reducing sulphate loads by 30% before discharge to the respective silt ponds / collection sumps;
- The Frasers West Silt Pond, Clydesdale Silt Pond and Murphys Silt Ponds are converted to sumps and discharge to the receiving surface water environment only at elevated flows. The sumps are equipped with a system that ensures excess water is returned back to Frasers Pit to avoid uncontrolled overflow;
- A new sump capturing seepage from the Frasers West and South WRSs is constructed at or near the monitoring location NBWRTR. This sump will operate in a similar manner to the Frasers West, Murphys and Clydesdale silt ponds in terms of proposed discharge to the NBWR and return to Frasers; and
- Suitable operational controls and adaptive management processes are developed and implemented as part of the site water management plan during mining and in the early stages of closure.

In addition, it is recommended that options to either limit and /or decrease the leachate volumes and contaminant loadings entering the surface water receiving environment together with potential remedial measures should be considered as part of the site's water management plan. These options could include but are not necessarily limited to the following:

- Installation of flow monitoring on the Waikouaiti River North Branch to support design, construction and operation of discharge controls;
- Alternative WRS construction methodologies and/or reducing overall WRS heights could be considered to reduce the sulphate and trace element loadings entering the surface water environment from seepage waters;
- Targeted passive and/or active treatment of seepage sources could be investigated and implemented in areas where the discharge loadings are elevated; and
- Further optimisation of flow augmentation from Camp Creek reservoir (and/or other potential dilution sources) to Deepdell Creek can be carried out to ensure there is sufficient dilution water available during low-flow periods.

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Abbreviations

Term	Definition
AWBM	Australian Water Balance Model
BRWRS	Back Road waste rock
CCP	Continuity Consents Project
CHD	Constant Head Discharge
CO6	Coronation Stage 6 Development
EOY	End of year
FRBF	Frasers Pit backfill embankment
FRIM	Frasers Innes Mills Open Pit
FROP	Frasers open pit
FRUG	Frasers Underground
FTSF	Frasers Tailings Storage Facility
GB2	Golden Bar Stage 2 Development
GHB	General Head Boundary
GHD	GHD New Zealand Limited
GMS	Groundwater Modelling System
GPUG	Golden Point underground
GPUG ext	Golden Point underground extension
HMSZ	Hyde Macraes Shear Zone
IMOP	Innes Mills Open Pit
K	Hydraulic conductivity
Kh	Horizontal hydraulic conductivity (Kx, Ky)
Kz	Vertical hydraulic conductivity (Kz)
L/s	Litres per second
LOM	Life of mine
m bgl	Meters below ground level
m RL	Meters relative level (above sea level)
MGP	Macraes Gold Project

MPIV	Macraes Phase IV Project
MTI	Mixed Tailings Impoundment
n	Porosity
NBGR	Waikouaiti River North Branch at Golden Bar Road and Griffin Road
NBWR	Waikouaiti River North Branch
ne	Effective porosity
OGNZL	Oceana Gold New Zealand Limited
PED	Potential evaporation deficit
PTS	Passive Treatment System
RCP	Representative concentration pathways
RMS	Root mean square
SP11	SP11 Tailings Facility
SRMS	Scaled root mean square
Ss	Specific storage
Sy	Specific yield
TSF	Tailings Storage Facility
TTTSF	Top Tipperary Tailings Storage Facility
WBM	Water balance model
WRS	Waste rock stack

1. Introduction

OceanaGold New Zealand Limited (OGNZL) operate the Macraes Gold Project (MGP) in east Otago, situated approximately 56 km north of Dunedin. The MGP began operations in 1990 and currently comprises two operational open cast pits (Frasers and Deepdell North Pits), two underground mines – Frasers Underground (FRUG) and Golden Point Underground (GPUG), and a processing plant. Waste rock is placed both in pit and at a number of waste rock stacks (WRSs) located around the open pit margins. Tailings from processed ore are stored at the Top Tipperary Tailings Storage Facility (TTTSF). There are also two decommissioned tailings storage facilities (TSFs) the Mixed Tailings Impoundment (MTI) and the SP11 Tailings Storage Facility (SP11).

A current site layout plan highlighting the main site facilities is shown in Figure 1.

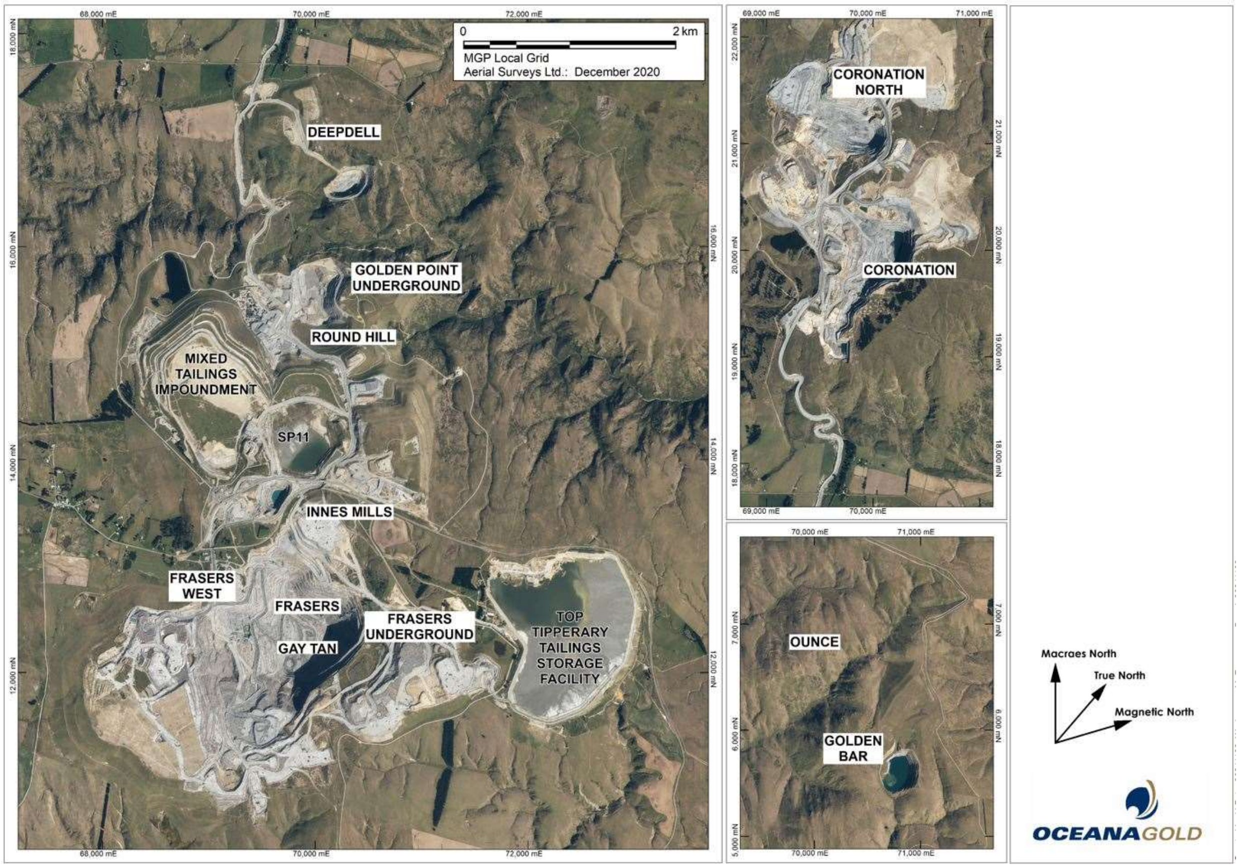


Figure 1 ***Macraes site plan***

Macraes Phase IV (MPIV) project is the next major proposed development at MGP which aims to extend the life of mine (LOM) to around 2030. To support MPIV it is being consented in three stages:

– Stage 1. Consent renewals;
– Stage 2. Existing tailings facilities; and
– Stage 3. Open pit and underground mine extensions and Frasers TSF.

Stage 2 of the MPIV project have involved increasing the capacity of the existing TTTSF to a height of 570 m RL allowing an additional 3.2 Mm^3 of tailings storage, the minor expansion of the existing Innes Mills Open Pit (IMOP) beyond the MPIII consented limits and the construction of a dry mixed tailings / waste rock embankment structure within the existing Fraser's Pit (Frasers Co-disposal[1]). Surface water and groundwater assessments of Stage 2 (of

[1] Frasers Co-Disposal was consented in early 2023. Dry tailings will no longer be co-disposed with waste in the construction of the Frasers Backfill embankment. An initial stage including wet tailings is currently being consented (Continuity Consents Project).

MPIV) have previously been undertaken by GHD (GHD New Zealand Limited) and are reported in the following documents:

– GHD 2022a. TTTSF 570 Crest Raise. Surface Water and Groundwater Assessment. Prepared for Oceana Gold New Zealand Limited.
– GHD 2022b. Frasers Co-disposal Surface Water and Groundwater Assessment. Report prepared for Oceana Gold New Zealand Ltd, 10 November 2022.

OceanaGold have brought forward some aspects of Stage 3 to manage operational continuity risks. In October 2023, it applied for an expansion and extension of GPUG (GPUG ext) and in December 2023, applied for a further minor extension of IMOP and an initial stage of tailings storage in the Frasers Tailings Storage Facility (FTSF) (instead of a dry tailings co-disposal) as part of the Continuity Consent Project (CCP). Surface water and groundwater assessments of these two components have previously been undertaken and are reported in the following documents:

– GHD 2023a. Golden Point Underground Extension – Analytical Assessment of Effect on Deepdell Creek. Report prepared for Oceana Gold New Zealand Ltd, 12 October 2023.
– GHD 2023b. Continuity Consent Project (CCP). Surface and Groundwater Assessment. Report prepared for Oceana Gold New Zealand Ltd, 04 December 2023.

For the purposes of the assessment presented here, these stages (and their previously modelled assumptions and effects) are considered consented and built.

Notwithstanding the previous assessed TTTSF crest raise and the Frasers backfill construction, the key components of the Stage 3 development in relation to surface water and groundwater effects are as follows:

– Frasers Pit Tailings Storage. FTSF will be filled with a further 30 Mt of tailings (a total of 36 Mt).
– Open Pit Mining extensions in Innes Mills (Stages 9-10), Golder Bar (Stage 2) and Coronation (stage 6).

1.1 Proposed mining activities

Specific details regarding the proposed pit expansions and mining activities which are incorporated in this assessment are included in Section 2. This assessment outlines the groundwater and surface water assessment associated with Stage III of the Macraes Phase IV expansion. It excludes specific assessment of the Coronation Pit expansion and Golden Bar pit expansion components (which are detailed in GHD 2024a and 2024b respectively), however does address cumulative impacts on the receiving surface waters associated with these developments, specifically in the Deepdell Creek and Waikouaiti River North Branch (NBWR). The proposed IMOP developments, associated WRSs and FTSF are depicted in Figure 2 and Figure 3 and form the central part of the MPIV Stage 3 project. The Coronation and Golden Bar mine extensions and waste disposal areas several kilometres to the north and south respectively, complete the Stage 3 development.

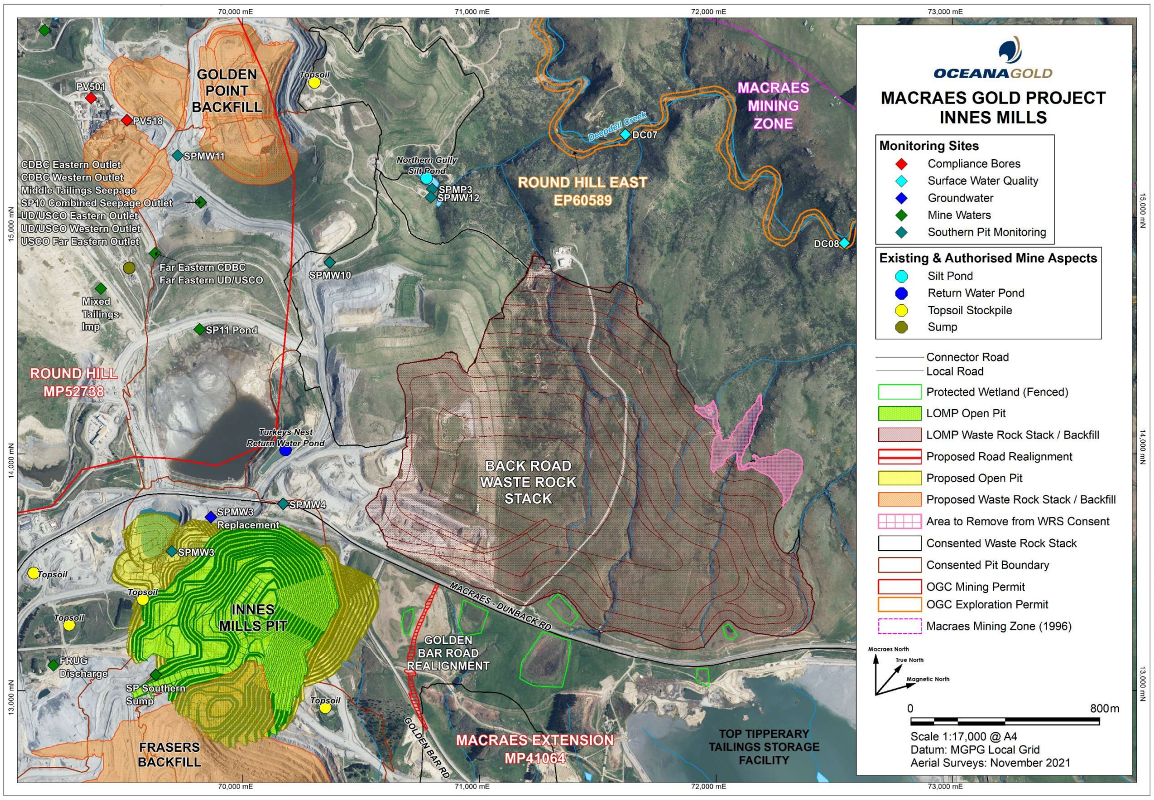


Figure 2 *Phase IV Innes Mills Pit Development*

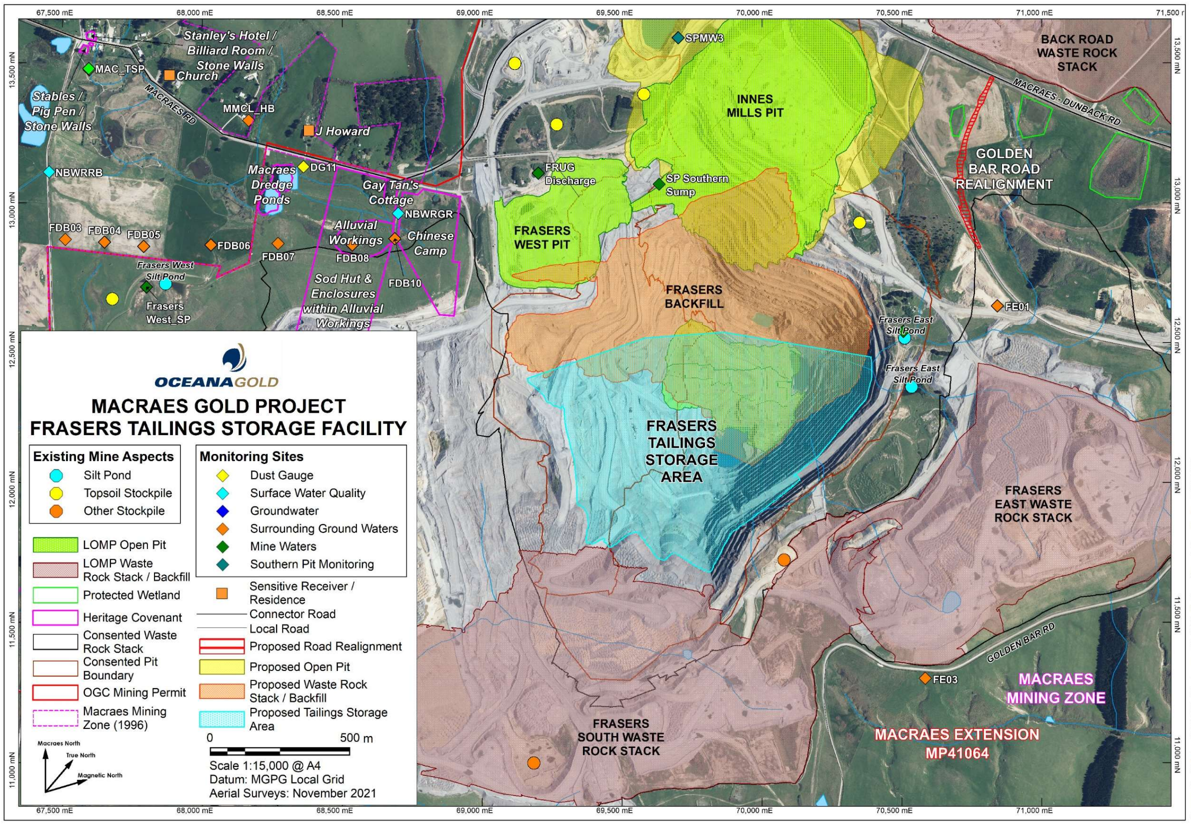


Figure 3 FTSF / IMOP Waste Rock Stacks and Development.

1.2 Purpose of this report

The purpose of this report is to present the results of the groundwater and surface water modelling associated with OGNZL proposed Stage 3 of the Macraes Phase IV project to support the Assessment of Effects. Assessing the potential effect on the receiving surface water bodies is the key objective of this report.

1.3 Scope and limitations

1.3.1 Scope of works

GHD New Zealand Limited (GHD) has been engaged by OGNZL to assess the surface and groundwater effects associated with the Macraes Phase IV project. This report has been prepared in line with the GHD proposal dated 22 March 2022 and subsequent variations to that scope and presents the findings of the surface water and groundwater studies associated with the project.

The modelling scope and extents include:

- Groundwater dewatering as well as recharge/recovery and its effects associated with the proposed pit extensions.
- Surface water modelling encompassing pit lake filling curves and receiving surface water bodies surrounding the site.
- This report assesses the water balance for the site and contaminant mass transport effects from the proposed pit, WRS and FTSF extensions.

The focus of this assessment is surface water and groundwater cumulative effects of the proposed IMOP extension, Golden Point Pit filling and Frasers Tailings Storage Facility (FTSF) developments within the Deepdell and the Waikouaiti River North Branch (NBWR) catchments. The cumulative effects include the separately reported effects from the MPIV GPUG Expansion and Extension, Coronation and Golden Bar pit developments and associated waste rock disposal (GHD 2022a, GHD 2022b, GHD 2023a, GHD 2023b, GHD 2024a and GHD 2024b). As a cumulative assessment, it includes consideration of all the aforementioned mine elements that have been reported on separately for MPIV and includes consideration of activities both consented and under application where it is likely that those consents will be given effect as part of the MPIV development.

1.3.2 Limitations

This report: has been prepared by GHD for Oceana Gold New Zealand Ltd. and may only be used and relied on by Oceana Gold New Zealand Ltd. for the purpose agreed between GHD and Oceana Gold New Zealand Ltd. as set out in section 1.3.

GHD otherwise disclaims responsibility to any person other than Oceana Gold New Zealand Ltd. arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared the surface water and groundwater models for, and for the benefit and sole use of, Oceana Gold New Zealand Ltd. to support consenting and must not be used for any other purpose or by any other person.

The Models are a representation only and does not reflect reality in every aspect. The Models contains simplified assumptions to derive a modelled outcome. The actual variables will inevitably be different to those used to prepare the Models. Accordingly, the outputs of the Models cannot be relied upon to represent actual conditions without due consideration of the inherent and expected inaccuracies. Such considerations are beyond GHD's scope.

The information, data and assumptions ("Inputs") used as inputs into the Models are from publicly available sources or provided by or on behalf of the Oceana Gold New Zealand Ltd., (including possibly through stakeholder engagements). GHD has not independently verified or checked Inputs beyond its agreed scope of work. GHD's scope of work does not include review or update of the Models as further Inputs becomes available.

The Models are limited by the mathematical rules and assumptions that are set out in the Report or included in the Models and by the software environment in which the Models are developed.

The Models are customised and not intended to be amended in any form or extracted to other software for amending. Any change made to the Models, other than by GHD, is undertaken on the express understanding that GHD is not responsible, and has no liability, for the changed Models including any outputs.

GHD has prepared this report on the basis of information provided by Oceana Gold New Zealand Ltd. and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

1.4 Key Assumptions

GHD has relied upon data (project timeline and schedule, shapefiles, volumes and material properties) provided by OGNZL to inform this assessment, we have assumed that the data is correct and representative of the groundwater and surface water environment. GHD has also relied upon the information presented in previous assessments. These sources are referenced through the report.

Key assumptions relating to surface and groundwater movement and connectivity between the FTSF and FRIM pits, and associated backfills (namely the Frasers Pit Backfill (FRBF)) and WRSs are:

1.4.1 FTSF and FRBF Embankment

– A pit lake will form on top the tailings placed in Frasers Pit
– No tailings seepage will enter IMOP during operational phase.

- Seepage to groundwater (for g/water model) for the FTSF footprint is based on process water (via tailings pore water). Seepage to groundwater from the FRBF Embankment footprint is assumed reflective of the Frasers Pit Lake water quality.
- Mass loads from FRBF embankment below the saturated tailings volume will drain to IMOP, with mass loads above the saturated tails divided equally between both FROP and IMOP pit lakes. Mass loads are based on infiltrated rain to FRBF embankment using calculated WRS seepage estimates and existing height / age algorithm (MWM, 2023).
- Water in FRBF embankment is assumed continuous with Frasers Open Pit (FROP) and IMOP pit lakes (ie. seepage times for infiltrating rain are not taken into account).

1.4.2 FROP / IMOP Pit Lake

- Collected seepage water from TTTSF, SP11 and MTI will be directed to FROP for a 20+ year period. Post that period the remaining seepage flows will need to be managed by alternative methods – ie. passively / actively treated. Alternatively, continued pumping and discharge to FROP (and ultimately FRIM) could be utilised as a way to manage these seepage waters in the long term.
- Collected seepage at the Frasers West Silt Pond, Clydesdale Silt Pond, NBWRTR Sump (to be constructed) and Murphys Silt Pond will be pumped to FROP where capacity reaches 90% post closure. This is outlined as a mitigation scenario but is considered necessary to achieve compliance within NBWR.
- Increased seepage through Frasers South WRS (above the FROP / WRS interface - located at the low point on the natural FROP pit rim in the south at 487 mRL) as a result of the FRIM pit lake level above this level is assumed returned to FROP via pumping.
- The spill point for the combined FROP / IMOP pit lake (FRIM) is located at 497 mRL and drains to a branch of the Waikouaiti River North Branch (NBWR).
- All oxidised products in backfills and submerged WRSs are mobilised into the corresponding pit lakes.

1.4.3 Groundwater Modelling Limitations and Assumptions

The results of numerical models are dependent on the level of detail incorporated and the accuracy of the parameters used in the development and calibration of the model. As a result, modelled effects cannot be exact. Actual effects will vary somewhat (and maybe larger or smaller) than those predicted. It is not possible to collect all the data needed to characterise the aquifer system in detail and therefore a number of assumptions have been made and are discussed below. The following assumptions were made:

- The production schedules and plans are an estimate of the LOM plan and assumptions have been made regarding the end of year (EOY) surfaces and proposed timeline.
- Waste rock deposited has the same hydrogeological properties as other waste rock material across the MGP site.
- Drain boundary and increased hydraulic conductivity around FRUG and around GPUG was incorporated into the current conditions model by applying boundary conditions and hydrogeological properties to elements roughly reflecting the FRUG and GPUG extent. This assumes that the portal is sealed prior to backfill.
- Historical underground mining around the Golden Point Pit has not been incorporated into this modelling. OGL is committed to effectively sealing these underground workings, so the groundwater model simulates the expected seepage flows from Golden Point Pit to Deepdell Creek.
- Groundwater recharge is applied at the same rate to all units in the model.
- A very small (0.0001 mg/L) background sulphate concentration (aquifer and rivers) was applied to all layers.

Future additional data, refinement of these assumptions and of the adopted parameter values by further calibration would help reduce predicted uncertainties and will improve accuracy of the model outputs.

Additional assumptions and limitations of the modelling undertaken are detailed throughout the report.

2. Mining Operations

A summary of the main development areas associated with the Phase IV development are shown in Figure 2 and Figure 3 and are based on the OGNZL, Project Description, dated 16 August 2023. The Coronation and Golden Bar developments are not portrayed within this figure.

2.1 Open Pit Excavation and Underground Mines

Most mining operations at MGP have been in the form of open cast pits with underground mines operated at GPUG and FRUG. A summary of active, closed and proposed mining operations is included in Table 1.

Table 1 Mining Operations Summary

Feature	Status	Deepest point (historic) (m RL)
Coronation Pit	Active – north of main MGP site	Ongoing
Deepdell North Pit	Closed – WRS backfill	441
Deepdell South Pit	Closed – pit lake	362
Frasers Pit (Gay Tan)*	Not active, pumped and awaiting FTSF development	240
Southern Pit	Closed – now SP11 TSF	420
Innes Mills Pit	Active – WRS backfill, proposed to be re-mined	405
Golden Point Pit	Not active – partially backfilled, pumped. Backfilled as part of MPIV	325
GPUG	Active	276
Round Hill Pit	Closed, merged into Golden Point Pit – WRS backfill	285
FRUG	Active – east of Frasers Pit	-290 – entrance portal at 340 m
Historic Underground Workings	Closed – adits along Deep Dell Creek (actively discharging groundwater)	340
GPUG Extension	Proposed (Stage IV)	145
Coronation Stage 6 (CO6) Pit	Proposed (Stage IV)	552
Golden Bar Stage 2 (GB2) Pit	Proposed (Stage IV)	415
IMOP (Stage 9-10)	Proposed (Stage IV)	315

**Gay Tan is an active mining stage within Frasers Pit*

2.2 Waste Rock Disposal

Waste and tailings have been placed in final landforms around the site since mine inception. The key structures present on site around the FTSF / IMOP development include the following WRSs: Lone Pine WRS, Western WRS, Northern Gully WRS, Frasers West WRS, Frasers South WRS, and Frasers East WRS as well as backfill of waste rock associated with the TSF embankments. The FTSF will be separated from IMOP by the FRBF. In addition, the Back Road WRS (BRWRS) is a consented future site facility but it is not required as part of the proposed MPIV development and its effects have not been considered in this assessment. Tailings are stored in the now inactive MTI and SP11 as well as the active TTTSF. The TTTSF is currently consented to a height of 570 m RL. It is proposed to store an additional 30 m Tonnes of tailings in FTSF within the Fraser's Open Pit.

Additional pit extensions and WRSs associated with the proposed mine extensions at Golden Bar and Coronation are discussed in separate reports (GHD, 2024a and 2024b).

2.3 Project Closure

- IMOP is not backfilled and eventually floods to form a pit lake.
- FROP will be backfilled with tailings to a maximum height of 416.5 m RL and a wet cover will result in a pit lake forming above the tailings.
- The pit lakes in IMOP and above FSTF (in FROP) will eventually combine to form a single pit lake (FRIM) once water reaches the top of FRBF (480 m RL). The low point of the FRIM pit margin is at 497 m RL with any spill water directed to the North Branch of the Waikouaiti River. In addition, the natural low point along the FRIM pit margin (above which waste rock is stored) is located at 487 m RL. A FRIM pit lake level above this elevation will likely result in increased seepage to the south through the Frasers South WRS.
- The slopes of the WRS will be shaped and revegetated progressively, using standard site rehabilitation techniques.

2.4 Project Timeline

- Current to 2029: Mining phase
- 2030: Site rehabilitation

The project timeline in terms of the operational pits and underground mining areas in Stage 3 of the Macraes PhIV project is provided in Table 2. The mine is assumed to enter a closure phase from 2030 onwards.

Table 2 Open Pit Project timeline

Timeline / Mine Area		Frasers Pit	FRUG	IMOP	GPUG	GPUG ext	Golden Bar Stage 2	Coronation Stage 6
2020	Q2							
	Q3							
	Q4							
2021	Q1							
	Q2							
	Q3							
	Q4							
2022	Q1							
	Q2							
	Q3							
	Q4							
2023	Q1							
	Q2							
	Q3							
	Q4							
2024	Q1							
	Q2							
	Q3							
	Q4							
2025	Q1							
	Q2							
	Q3							
	Q4							
2026	Q1							
	Q2							
	Q3							
	Q4							
2027	Q1							
	Q2							
	Q3							
	Q4							
2028	Q1							
	Q2							
	Q3							
	Q4							
2029	Q1							
	Q2							
	Q3							
	Q4							
2030	Q1	Site Closure / Rehabilitation Phase						
	Q2							
	Q3							
	Q4							

3. Site Setting

The environmental conditions present at Macraes have been summarised in a number of previous reports written for the MGP MPIII resource consents. This assessment has relied solely on existing data and previous reports made available by OGNZL. The following subsections present a short overview of the environmental setting across the MGP site, as has been summarised in previous reports.

3.1 Topography / Surface Water Bodies

The topography of the wider Macraes site is driven by the geologic evolution of the region. Long term weathering and erosion of the underlying rock resulted in a distinctive low relief peneplain which is bounded by Waikouaiti River North Branch to the west, Deepdell Creek to the north, and Murphys Creek to the south. Deepdell Creek has been deeply incised into this erosional surface resulting in steep valley slopes and minimal alluvial deposition. In contrast, the NBWR is characterised by shallow relief, broad valleys and alluvial deposition.

The original topography has been altered by thirty years of mining and waste deposition. Mining has been generally aligned with the orientation of the major Hyde-Macraes Shear Zone (HMSZ) which is the primary structural feature that controlled the ore body development (refer to Section 3.3). Mining has altered portions of original catchments in the main MGP site, but the primary streams and rivers surrounding the mining site remain and are intermittent / permanent in nature.

The MGP site is located within the Shag River/Waihemo, Taieri and NBWR catchments as shown in Figure 4. The Shag River flows in a south-easterly direction and enters the ocean close to Matakaea. The NBWR flows in a southerly direction from the mine site and enters the ocean near Karitane. The Taieri River flows in a southerly direction to the ocean south of Dunedin. Land use within these catchments consists primarily of agriculture and forestry.

Discharges from the FRIM pit lake have the potential to reach the Shag River and NBWR via several tributaries. Seepage from the FRIM pit lake has the potential to reach Deepdell Creek (a tributary of the Shag River), Murphys Creek and headwaters of the NBWR. Any spill water from the FRIM pit lake (above the pit crest level of 497 m RL) will drain directly to the headwaters of the NBWR. Increased seepage through Frasers South WRS (above the FROP pit rim / WRS interface - located at 487 m RL) will likely occur as a result of the FRIM pit lake level above this level.

Additional groundwater seepage through the surrounding schist from FRIM and the surrounding WRSs could reach the surrounding surface water bodies. Assessing this potential and the effect on these surface water bodies is the key objective of this report.

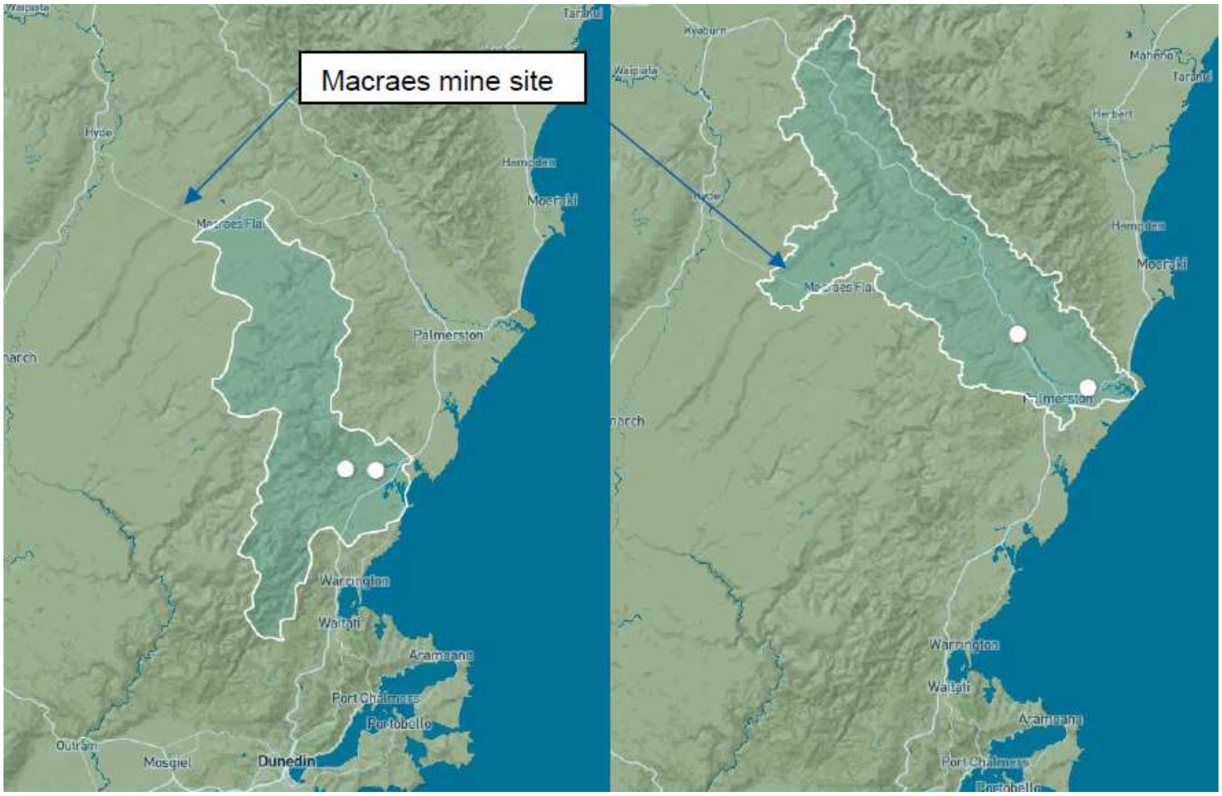


Figure 4 *Waikouaiti River North Branch (left) and Shag River / Waihemo (right) catchments*

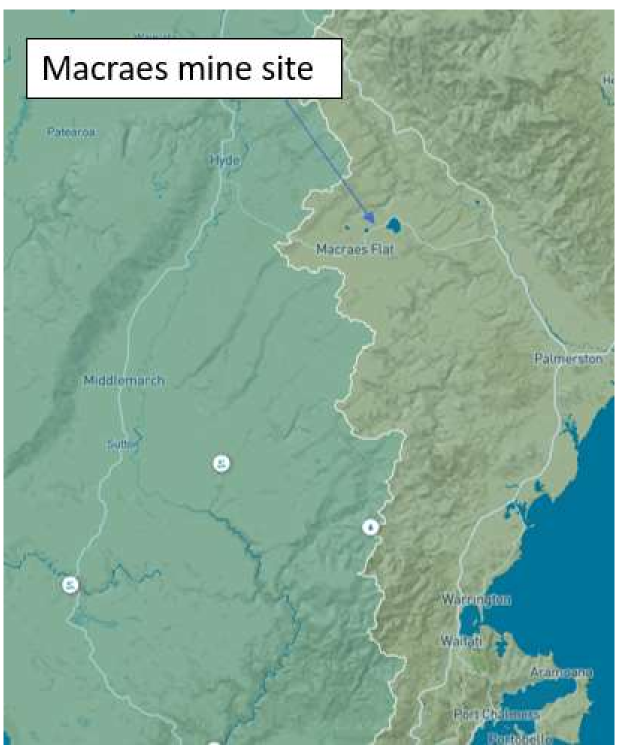


Figure 5 *Taieri River catchment*

3.2 Climate

The climate at Macraes is controlled predominantly by the mountains to the west of the site (Rock and Pillar Range) which act as a barrier to incoming weather systems from the west, leading to a fairly dry climate with limited precipitation. Rainfall data from the MGP are available from three locations, Glendale, Deepdell and Golden Point stations. Deepdell and Golden point stations were installed to monitor rainfall at the MGP site while Glendale is part of the national climate monitoring programme. Glendale station data spans from 1959 to 2013. Climate and climate change representation is further discussed in Section 5.3.

3.3 Background Geology

Regionally, the geology is dominated by the Mesozoic-aged crystalline metamorphic rock of the Rakaia Terrane Otago Schist (CDM Smith, 2016). Significant weathering and tectonic deposition resulted in the erosion of more recent alluvial sediments. The landscape is now dominated by widespread outcrops of Otago Schist and a very thin superficial layer or alluvium and colluvium. This alluvium and colluvium layer has generally been found at a maximum thickness of 1.8 m (Golder, 2011b) and is generally not considered to have a major impact on the groundwater flow system. Deformations and major discontinuities have been driven by the structural features described below.

3.3.1 Hyde Macraes Shear Zone (HMSZ)

The MGP began due to ore potential within the schist deformed by the HMSZ. This shear zone runs north-south through the Macraes site (aligned with Macraes Map Grid North). The shear zone comprises the Hanging Wall Shear and Footwall Shear zones which are considered to have enhanced hydraulic conductivity along the orientation of the features. The vertical separation between the top of the Hanging Wall Shear and the Footwall Fault is approximately 100 to 120 m.

3.3.2 Additional Structural Features

There are three major northeast-southwest trending faults that are present across the MGP site:

– The Deepdell Fault - aligned with Deepdell Creek.

– The Macraes Fault - intersects the northern end of Frasers Pit and extends out to Top Tipperary Creek forming the northern boundary of Frasers Underground Mine (FRUG).

– Unnamed Fault – aligned with Murphys Creek, south of Frasers Pit.

3.4 Hydrostratigraphy

Due to the structural complexities present within the schist body and the manmade waste deposition that has occurred, there are a number of hydrostratigraphic units which have been incorporated into previous groundwater models. It appears that the number of hydrostratigraphic units has reduced throughout the evolution of numerical groundwater modelling, opting for more simplified models. Throughout these simplifications, the values have not changed significantly. Units considered in previous groundwater models are listed below:

– Highly weathered schist
– Moderately weathered schist
– Slightly weathered schist
– Unweathered schist
– Footwall Fault
– Hanging Wall Shear
– Intra-shear schist
– Embankment materials
– Waste rock
– Flotation tailings
– Mixed tailings / Concentrate tailings
– Fine / coarse tailings

In 2016, CDM Smith compiled a review of all hydrogeological properties that have been applied to different groundwater models created and updated over the years. This summary has been reviewed and updated by GHD (2021) to include the values applied by CDM Smith in the groundwater model (2016) and GHD (2021). Data are presented in **Appendix B**. In addition, hydrogeological investigations were undertaken recently associated with the GPUG Ext. development and are detailed in WSP (2023). The primary hydrogeological units and parameters used in this assessment are discussed in further detail in the subsections below.

3.5 Schist

The Otago Schist is a crystalline metamorphic rock with effectively no porosity or permeability except where weathered. The permeability and porosity in this unit are primarily driven by the defects within the rock mass (fractures and faults) which create groundwater seepage routes and flow paths. The foliation dips around 15° to 30° south-southeast but rotate approaching major faults in the area. The deformities and foliation within the schist make it anisotropic with slightly higher hydraulic conductivity in the north/south direction (Ky).

The intensity of the weathering of the schist rock mass decreases with depth. However, geotechnical investigations have indicated that the moderate weathering of the schist only extends to about 5 m, while slight weathering only extends to about 35 m (Golder, 2011a). Therefore, on the scale of mining extents, the weathering is not considered to have a significant impact on the groundwater flow regime.

CDM Smith (2016) compiled a summary of historic hydraulic testing of schist undertaken at around the MGP site originally sourced from Golder, 2011a (**Appendix B**). The raw data were reviewed in graphical format and the geometric mean (geomean) and averages from the CDM Smith summary are presented in GHD (2021) and in Table 3. Further testing, near GPUG, was undertaken by WSP (2023) and estimated hydraulic conductivity values are generally in the same order of magnitude (or lower at depth) as those presented and used in previous assessments and in this report (lower hydraulic conductivity values compared to those presented in Table 3 were estimated at depth by WSP).

Table 3 Hydraulic testing summary (Adapted from CDM Smith, 2016)

Depth (m bgl)	Average minimum (m/s)	Average maximum (m/s)	Geomean (m/s)
<10	2.2E-07	2.4E-04	6.9E-07
10 – 20	5.1E-08	1.7E-04	3.9E-07
20 – 30	1.3E-07	1.9E-05	2.7E-07
30 – 40	3.5E-07	2.3E-04	4.4E-07
40 – 50	1.2E-07	6.7E-07	9.8E-08
> 50	9.7E-08	3.7E-06	4.5E-07
250-500	1.0E-08	7.0E-07	-

3.6 Waste Rock

Waste rock is the rock that contains insufficient ore to process economically. It is typically coarse in nature (gravel to boulders <1.5 m in diameter) and angular, due to the blasting process used to break down the schist. It is typically stacked and compacted in 15 to 20 m lifts. The rock often contains sulphide minerals which have potential to oxidise and create acidic and metalliferous leachate.

3.7 Tailings

Tailings are the material left after ore processing has been undertaken. The material typically comprises a slurry of water, sediment (silt with sand and clay sized particles), and possibly leftover additives used during processing. The tailings at Macraes often contain high concentrations of arsenosulphides due to the presence of arsenopyrite in the sheared schist. After processing, tailings are deposited into the TSFs, grading out with coarse sediments settling out close to the deposition point.

4. Groundwater Assessment

4.1 Draindown Model – TTTSF

Following closure, the phreatic surface within a tailings facility will likely drain down (due to the cessation of tailings and tailings porewater deposition and/or capping) resulting in seepage flow diminishing with time. A series of 2D draindown models have been constructed to investigate long term flow rates once the TTTSF facility is complete and has been capped. This is to inform long term management requirements for seepage from the TTTSF. Modelling results have also been utilised to inform captured seepage volumes during the initial post closure period which will be directed to the FROP / FRIM Pit lake. Modelling parameters and boundary conditions applied in the draindown models are based on the 2D models developed as a component of the 570 m crest raise assessment. This work is detailed in GHD, 2022a.

4.1.1 Draindown Model Construction

The three SEEP/W cross sections (location shown in Figure 6) depicting the fully built TTTSF (proposed to 570 m RL) that were constructed to assess the effects of the 570 m RL crest raise (GHD, 2022a) have been utilised to assess draindown volumes.

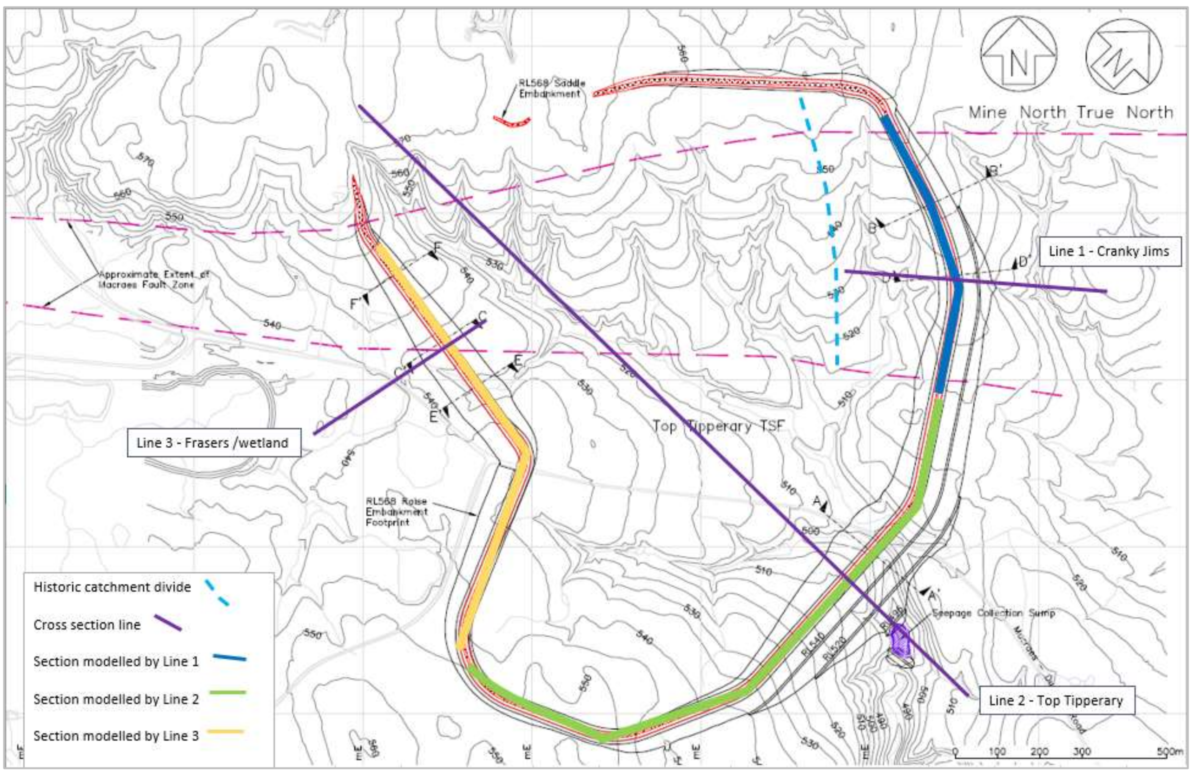


Figure 6 Location of model cross sections (modified from EGL, 2021 – 568 m design)

Boundary conditions applied to the three cross sections, shown in Figure 6 in accordance with GHD (2022a), have been adjusted to reflect long term draindown conditions. For each cross section (Line 1, Line 2 and Line 3) four model runs were undertaken to simulate likely changes to the long-term hydraulic behaviour of the TTSF. These model runs depict a removal of the Total Head boundary condition applied to the tailings to reflect standing water and the constant source of wet tailings to the TTTSF. In addition, modelling scenarios with a recharge boundary reflective of groundwater recharge rates (~32 mm/year) versus no recharge boundary (due to effective cap and shedding cover) have been assessed as well as the effect of existing drainage failure over time. These various scenarios (and the key changes to the modelled boundary conditions (compared to the modelling scenarios detailed in GHD, 2022a) are outlined in Table 4.

Table 4 *Seep/W boundary conditions updates to reflect Long Term Draindown Scenarios*

Modelling Scenario	Total Head Boundary Applied to Top of Tailings	Water Recharge Boundary Applied to Top of Tailings	Drainage Boundary Conditions applied through the embankment (drainage pipes)
A	Removed	Not Present	Present
B	Removed	Not Present	Removed
C	Removed	Applied	Present
D	Removed	Applied	Removed

The models were all run over a simulated duration of 400 years utilising as initial conditions the steady state simulation results from the initial fully built scenarios as outlined in GHD, 2022a. In model runs where drainage boundary conditions were removed (Scenario B and D, Table 4), the drainage boundary conditions were removed after an assumed post closure period of 20 years. The results from these scenarios are presented below.

4.1.2 Draindown Model Prediction

Seepage rates estimated draining through the base of the TSF (ie. uncaptured seepage) for the four model scenarios are summarised and plotted in Figure 7. The removal of the drain boundary 20-years post mine closure in modelling scenarios B and D (Table 4) represent a slow deterioration (blockage) of the drainage system after 20 years (as opposed to a sudden complete failure which is considered unrealistic). Modelling scenarios (C and D) that include a recharge boundary on top of the tailings show increased long term seepage predictions from the tailings to schist (compared to Scenarios A and B where no water recharge is assumed – and represent a 100% effective water shedding cover). It is likely that the future actual seepage volumes may be closer to the lower modelled predictions shown in Figure 7 and potentially with a rapidly reduced timeframe (due to consolidation, the presence of water shedding cover and drainage deterioration). The upper range of the modelled results is considered a relatively conservative maximum based on the modelled assumptions.

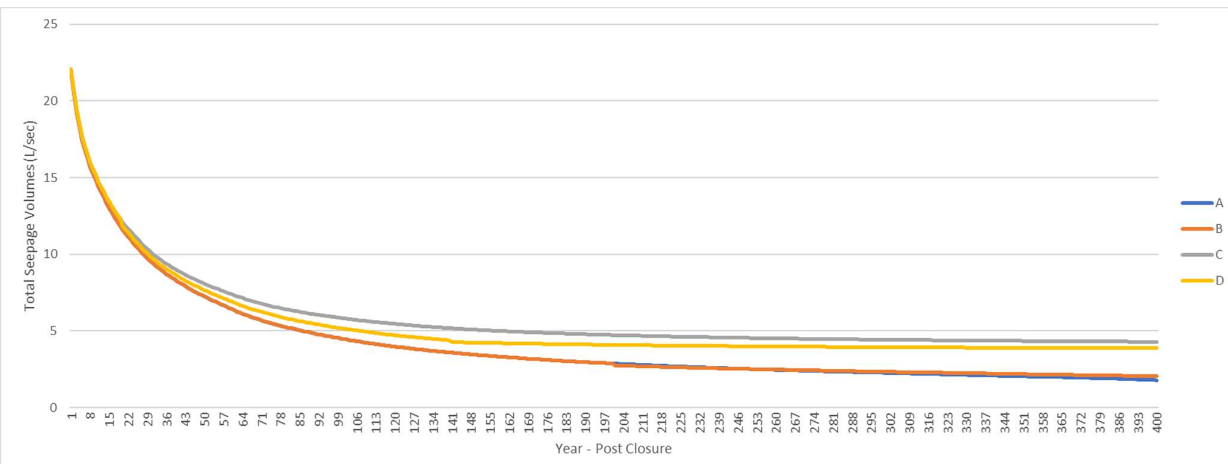


Figure 7 *Summarised Draindown Model Predictions – Scenarios A-D*

Modelling results indicate that total seepage rate from the TTTSF for all scenarios (collected through the drains / captured and “uncaptured”) will initially be approximately 22 L/sec. The modelled volume reduces to approximately 11-12 L/sec after a period of approximately 20 years before reaching a total value of between 1 and 4 L/sec in the long term.

In terms of captured seepage (captured by underdrains and embankment drainage system) during the immediate post closure period (ca. 20 years following TTTSF completion), Figure 8 illustrates the initial drawdown curves with captured seepage decreasing from an estimated 20 L/sec to 11 L/sec during the first 20 years post closure for scenarios A and C.

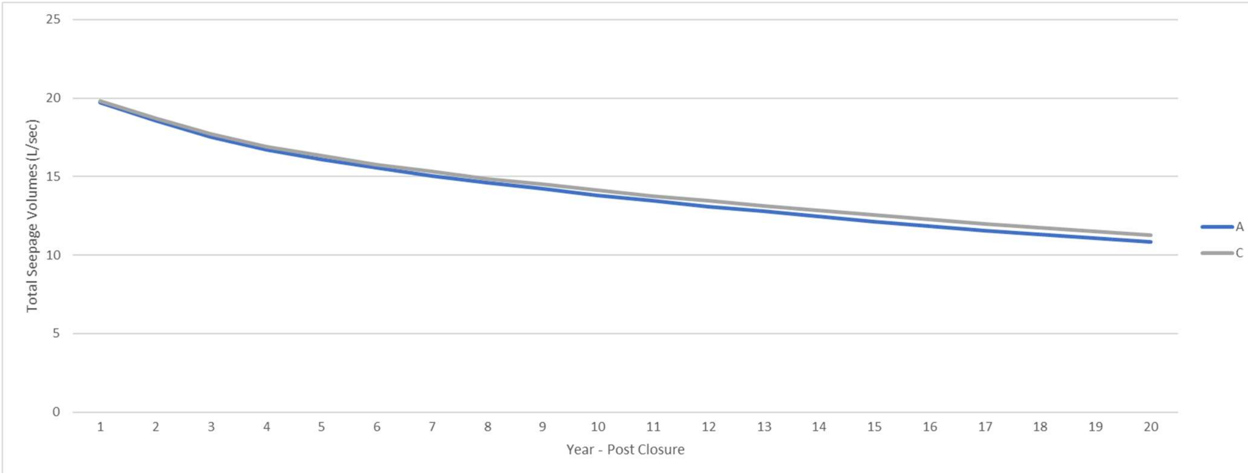


Figure 8 *Summarised Draindown Model Predictions – Captured Seepage - Scenarios A and C*

The modelled seepage volumes (captured and uncaptured) are summarised in Table 5.

Table 5 *Summarised captured and uncaptured modelled seepage rates for TTTSF post mine closure*

Period	Captured in Drainage System	Seepage through Embankment (“uncaptured”)	Total
Initial	20 L/sec	2 L/sec	22 L/sec
20 Years	11 L/sec	1 L/sec	12 L/sec
Long Term (~400 years)	0 – 4 L/sec*	2 – 4 L/sec	2 – 4 L/sec

4.1.3 Comparison with MTI / SP11

In order to provide short term (initial closure period ~20 years) and long term (~400 years) estimates of seepage volumes from all three TSF facilities on site (MTI, SP11 and TTTSF) and to sense check the predictions from the TTTSF draindown model presented in Section 4.1.2, post closure data (defined loosely as period since last tailings deposition) from MTI and SP11 has been collated for comparison.

In terms of comparability, MTI and TTTSF have similar volumes of stored tails (design volume of 50.4 Mm^3 for MTI compared to the TTTSF RL570 design volume of 50.0 Mm^3) (Table 6). Additionally, the relatively large area to depth ratio and long embankment constrained boundaries of both MTI and TTTSF are similar (Golder, 2011c). The TTTSF does offer a much larger catchment area though (154.6 Ha versus 79.5 Ha for the TTTSF and MTI respectively). It is also important to point out that the SP11 and MTI facilities have been partially capped and irrigation of seepage water has been undertaken on the surface of these closed facilities sporadically. So bearing in mind these various differences, the facilities are not directly comparable with one another.

Table 6 *Tailings Storage Facility Summaries*

Facility	Footprint Area (m^2)	Design Storage (Mm^3)	Design Density (t/m^3)	Final Tails Deposition
SP11	55.5	14.0	1.35	January 2012
MTI	79.5	50.4	1.25	October 2013
TTTSF	154.6	50	1.25	Proposed ~ end 2023

The total measured seepage post closure for MTI and SP11 (end of tails deposition) has been plotted on Figure 9 together with the modelled volumes for the TTTSF post closure period. The plotted data includes collected seepage from drains and collected embankment seepage from MTI and SP11. In the case of SP11, the capture and measurement of seepage into the Innes Mills pit ceased in 2015 and has been reporting to the Frasers Pit since that time. It is assumed (for the sake of estimating total seepage from the SP11) that this discharge has been ongoing at a consistent rate of 5 L/s since 2015 to present.

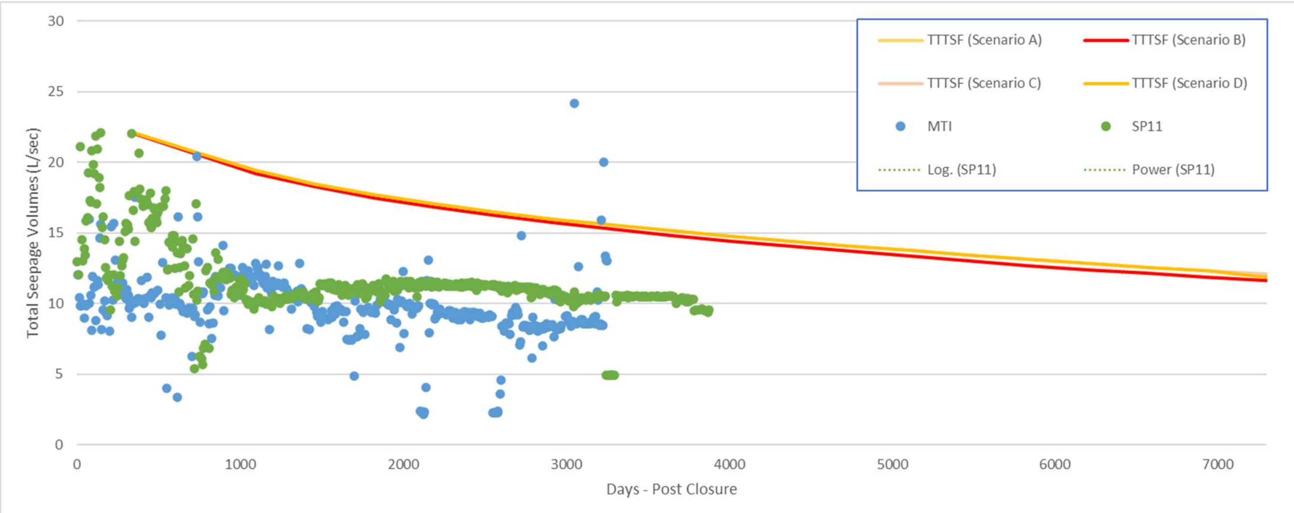


Figure 9 *Tailings Facility Post Closure Seepage (actual versus modelled)*

The modelled seepage estimations for the TTTSF are greater than the measured values from the MTI and SP11 facilities and this is probably a reflection of both the conservative nature of the modelling undertaken and the greater surface area of the TTTSF facility compared to both the MTI and SP11 facilities. It is also worth noting that both the MTI and SP11 recorded seepage data show a reasonably steep initial decrease in seepage volumes. This may suggest that drawdown is a lot faster than modelled within the TTTSF. The apparent stabilisation of seepage volumes after a period of approximately 3 years (ca. 1000 days) is potentially associated with irrigation on top of the surface of these facilities and/or reflective of a reduction of seepage generation following a rapid initial drawdown period.

In terms of captured seepage reporting to the FROP in the initial post closure period (ca. 20 years), and volume of seepage requiring management (via passive or other measures) long term, these have been estimated based on the modelling undertaken and the site data collected to date and are presented in Table 7. These values have been utilised in the Water Balance Model (WBM) (refer Section 5) to estimate the volume of seepage water diverted to FROP post closure (during the initial 20 years of closure). Post this period, it is assumed pumping to FROP has ceased, and these remaining seepage flows will need to be managed by alternative methods – ie. passively / actively treated. Alternatively, continued pumping and discharge to FROP (and ultimately FRIM) could be utilised as a way to manage these seepage waters in the long term.

Table 7 *Summarised captured seepage rates from monitoring data and TTTSF draindown modelling*

	Current Measured Captured Seepage Rate (L/sec)	Mine closure (2030) (L/sec)*	20 years post closure (L/sec)*	400-year post closure (L/sec)*
MTI	8.5	5.8	3.9	1.5
SP11#	10	4.7	3.1	1.2
TTTSF	28	22	12	4
Total	46	33	19	7

*The reduced rates are based on the TTTSF modelled drawdown curve (proportional reduction) and time since facility closure
#Seepage volumes are reduced by 32% to account for reduction in tails volume stored within this facility

4.2 Macraes Main Site Groundwater Model

4.2.1 Previous Models

Kingett Mitchell (2002, 2005a, 2005b), Golder Associates (2011a), CDM Smith (2016) and GHD (2021) have all used 3D groundwater models for previous Macraes hydrogeological assessments. CDM Smith reviewed the Kingett Mitchell and Golder Associates models as part of their data review (CDM Smith, 2016, p. 3-21). In 2021 GHD updated the CDM Smith Model (2016), as part of the proposed mining expansion of the existing Golden Point and Round Hill Open Pits (RHOP project). The model utilised in this assessment is largely based on the GHD (2021) model, with updated modelling code, mine plan, and Frasers Pit co-disposal options.

Both GHD (2021) and CDM Smith (2016) models were developed using MIKE-DHI - FEFLOW finite element modelling software. However, due to software limitations with grid refinement and updates, the current modelling code has been changed to MODFLOW-USG. This modelling code (MODFLOW-USG) has been developed and maintained by the United States Geology Survey (USGS) and is widely used in the groundwater modelling industry. Groundwater Modelling System (GMS) has been used as a graphical user interface to MODFLOW-USG to pre-and-post process of the modelling data.

4.2.2 Current Model Updates

The current model has largely been based on the 12-layer FEFLOW model GHD (2021), using the same model layers (top and bottom elevations) and recharge rates. A simplified stratification was employed in the FEFLOW model which designated all elements below the original (pre-mined) topography as schist (Layers 6 - 12) with overlying layers representing waste rock stacks, tailings dams, or excavated pit shells. The model layers were derived from topographic surfaces while 3D shapes within the original model were used to assign material properties to specific entities (i.e. TSF, WRS).

The model domain comprises an area of 204 km^2. It has been aligned with Macraes Grid North projection which follows the orientation of the Hyde Macraes Shear Zone (HMSZ).

The boundaries have been set far enough away from the MGP area to minimise boundary-induced effects on groundwater flow predictions. The boundaries were originally defined by topographic ridges and major catchment divides which act as natural groundwater flow divisions/boundaries:

- The northern boundary and northern part of eastern boundary follows a topographic ridge.
- The remaining eastern boundary follows the Shag River.
- The southern boundary follows McCormicks Creek and additional drainage pathways.
- The western boundary generally follows the Waikouaiti River North Branch.

Modifications undertaken in the current model update are listed below:

– Change of numerical modelling code from FEFLOW to MODFLOW-USG.
– River boundary conditions have been applied to model the Deepdell Creek, Tipperary Creek, NBWR, Murphys Creek, Clysdale Creek, Golden Bar Creek, McCormicks Creek and Shag River.
– Layer 9 in the FEFLOW model (represented FRUG) and in places was approximately 500 m thick) was split into two layers to better represent vertical flow in the FRUG mining area.
– Previous layer 12 was removed and replaced by the base of the previous layer 11. As noted above layer 9 has been split into two layers, therefore current model also has 12 layers.
– Grid dimensions for the MODDFLOW-USG model has been refined to 25 m spacing near the proposed mining, tailings, waste rock and along the Deepdell Creek and Tipperary Creek, and 100 m spacing outside. Grid design is presented in Figure 10 and Figure 11. This grid design resulted in a total of 730,356 model cells for the 12 layers (or 60,863 model cells per layer).
– Model layer structure and a vertical cross-section together with the material properties are presented in Figure 12.

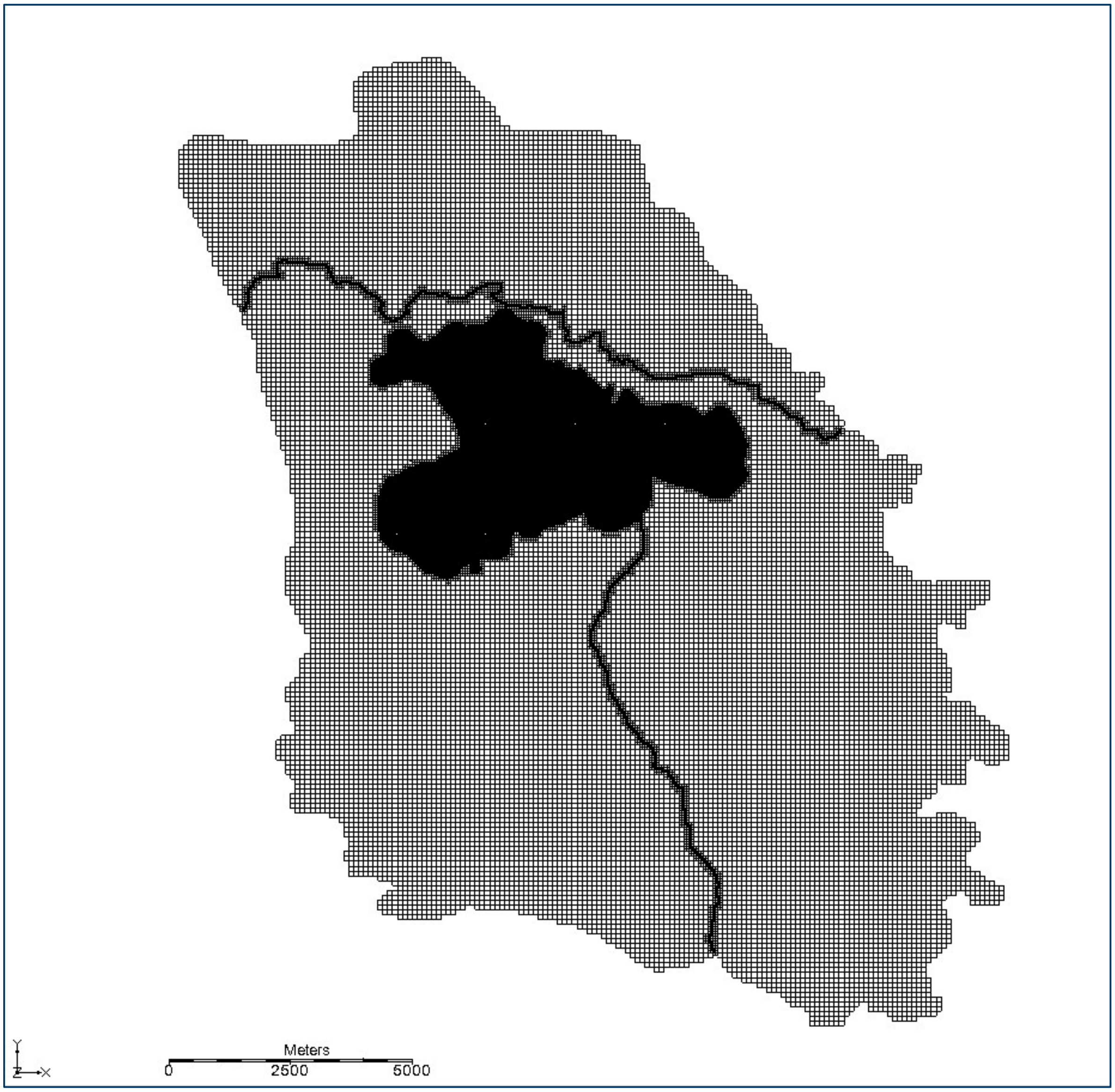


Figure 10 *Grid design- entire model domain*

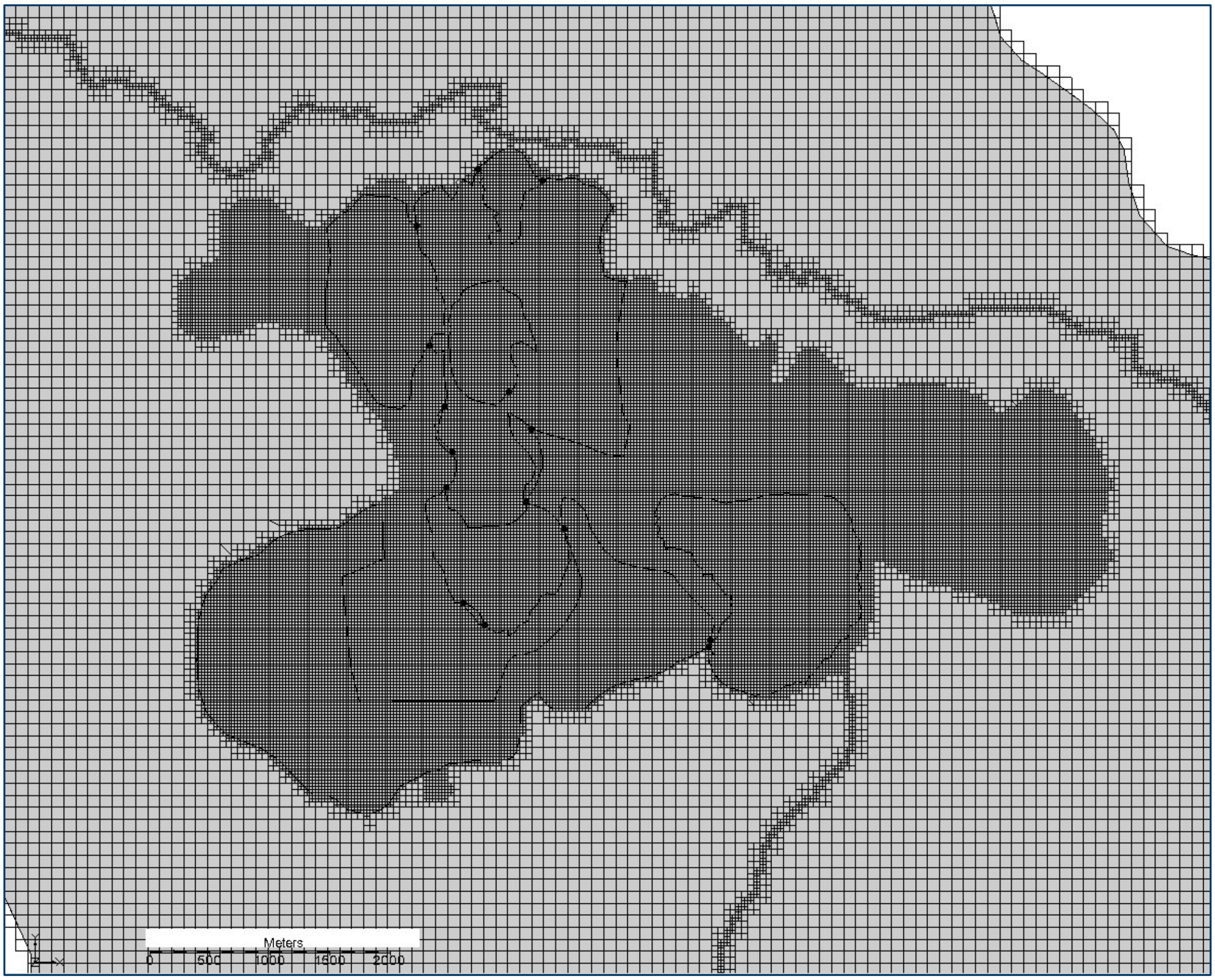


Figure 11 ***Grid design- near proposed mine, tailings and waste rock areas (with 25 m spacing), and 100 m outside.***

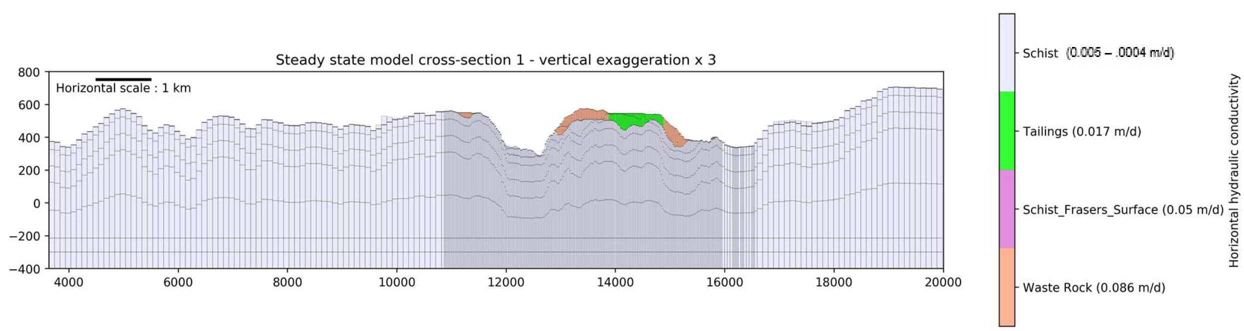


Figure 12 ***North-South cross-section through the Frasers pit, displaying the model layers and material properties.***

4.2.3 Boundary Conditions

The boundary conditions are driven by the catchments and surface water bodies within the model domain. The following boundaries have been applied:

Recharge boundary: Several reports (Kingett Mitchell, 2005a, Golder, 2011a, CDM Smith, 2016) have stated that the accepted recharge rate of the area is 32 mm/yr (equating to 5.3% of annual rainfall of 607 mm). The 32 mm/yr value was also applied to the TTTSF 2D draindown modelling undertaken and presented in section 4.1 of this report. Golder, 2011a noted that the precipitation was slightly less than the original Kingett Mitchell report and therefore recharge might be slightly less. The GHD (2021) groundwater model calibration and sensitivity analysis resulted in an applied recharge of 29.2 mm/yr. This value generally reflects 4.5% of GHD's synthetic annual rainfall average used in the Water Balance Model (GHD, 2021; details are summarised in section 5.3 of this report). In this assessment a recharge rate of 29.2 mm/yr was applied to the 3D groundwater model as it resulted in the best overall calibration under steady state conditions for the groundwater model.

River Boundary: The Deepdell Creek, Tipperary Creek, Waikouaiti River North Branch, Murphys Creek, Clydesdale Creek, Golden Bar Creek, McCormicks Creek and Shag River have been modelled as river boundaries. Further details on this boundary conditions are presented in Figure C1, **Appendix C**. River stage was set at ground surface level and river bottom was set at 1 m below the surface, riverbed conductance was assigned with 5 m^2/d/m for all river boundaries.

Drainage Boundaries (Local Creeks): The remaining streams and wetlands across the site have been modelled as drain boundary conditions to reflect the ephemeral nature of the streams in the area. Drain bottom elevation was set at the ground surface level and conductance of 10 m^2/d/m was used. The location of surface drain boundaries is presented in Figure C1 (**Appendix C**).

Drain Boundaries (Pit and underground Dewatering): The FROP, FRUG, IMOP and GPUG has been simulated using the drain boundary conditions during mining, with drain bottom elevation corresponding the base of the mining. Their location is presented in Figure C2 and Figure C3 (**Appendix C**). These drain boundary conditions were removed during the recovery runs (post mine closure).

General Head Boundaries: The pit lakes/sump locations across the site, known to hold water all year were modelled with general head boundaries during recovery run. The applied head values were derived from the surface water modelling results. These boundaries were applied during the recovery of water level post-mining in FRIM Pit Lake. Their location is presented in Figure C4 (**Appendix C**).

Constant Head Boundaries (CHD): To simulate water pooling on the surface of tailings facilities (TTTSF and MTI/SP11) constant head boundaries with head values of 570 mRL (TTTSF) and 550 mRL(MTI/SP11), have been applied in a small area of these TSFs. The location of CHD boundary applied in the model is presented in Figure C5 (**Appendix C**).

4.2.4 Steady-State Model Calibration

For the model calibration initial model parameters used were based on previous studies (Golder Associates, 2011a, Golder Associates, 2016, GHD, 2021 and WSP, 2023b) and values were adjusted during the calibration process. The model developed for this assessment was calibrated and compared against existing conditions at the Site (i.e. recent available physical observations of the system collected from stream observations and water levels measured in bores across the site). The final hydraulic parameters from the model calibration (Model run ID "Macraes_Site_Wide_SS_017") are presented in Table 8. As discussed above, a uniform recharge rate of 29.2 mm/year was applied in the model.

Groundwater level data available have been used as calibration targets and are presented in **Appendix D**.

Table 8 Model input parameters

Unit Name	Model Layer (Thickness of layer)	Kx m/s (m/d)	Kz m/s (m/d)	Ky m/s (m/d)	Specific Yield *	Specific Storage 1/m*
Tailings	1 to 4 (Various thickness)	2.0×10^{-7} (0.017)	2.0×10^{-7} (0.017)	2.0×10^{-7} (0.017)	0.35	1E-5
Waste Rock	1 to 4 (Various thickness)	1.0×10^{-6} (0.086)	1.0×10^{-6} (0.086)	1.0×10^{-6} (0.086)	0.15	1E-5
Weathered Schist	1 to 4 (Various thickness at the surface of the open pit areas)	5.8×10^{-7} (0.05)	5.8×10^{-8} (0.005)	5.8×10^{-7} (0.05)	0.02	1E-5
Moderately Weathered Schist	5 (Various thickness)	1.0×10^{-7} (0.0086)	6.0×10^{-8} (0.0052)	2.5×10^{-7} (0.022)	0.02	1E-5
Moderately Weathered Schist	6 (Mostly 50 m thick)	1.0×10^{-7} (0.0086)	6.0×10^{-8} (0.0052)	2.5×10^{-7} (0.022)	0.02	1E-5
Slightly Weathered shist	7 (50 m thick)	5×10^{-8} (0.0043)	5×10^{-9} (0.00043)	5×10^{-8} (0.0043)	0.01	1E-5
Slightly weathered / Unweathered Schist Bedrock	8 (100 m thick)	1.5×10^{-8} (0.0013)	1.5×10^{-9} (0.00013)	1.5×10^{-8} (0.0013)	0.01	1E-5
Slightly weathered - Unweathered Schist Bedrock	9-10 (Various thickness)	1.5×10^{-8} (0.0013)	1.5×10^{-9} (0.00013)	1.5×10^{-8} (0.0013)	0.01	1E-5
Unweathered Schist	11 – 12 (L11 85 m and L12 100 m thick)	5×10^{-9} (0.000432)	5×10^{-10} (0.000043)	5×10^{-9} (0.00043)	0.01	1E-5
Notes:	Kx-denotes horizontal hydraulic conductivity in x direction Ky-denotes horizontal hydraulic conductivity in y direction Kz-denotes vertical hydraulic conductivity Vertical anisotropy represents ratio of hydraulic conductivity in horizontal x (Kx) to z (Kz) directions (Kx/Kz) *Parameter used in transient model only.					

The performance of model calibration is commonly associated with the difference between measured and modelled water levels. This measure is quantified through the scaled root mean square (SRMS) error. The SRMS is expressed as a percentage and is a more representative measure of the fit than the standard root mean square (RMS), as it accounts for the scale of the potential range of data values. Therefore, if the ratio of the RMS error to the total head change is small, the error is only a small part of the overall model response. The steady-state calibration for the Site Wide model resulted in SRMS of 7.9% and is considered acceptable (Barnett et al, 2012).

The modelled (computed) vs observed (measured) head from the steady-state model calibration is plotted in Figure 13 and tabulated in **Appendix D** along with the residuals (modelled minus measured head)

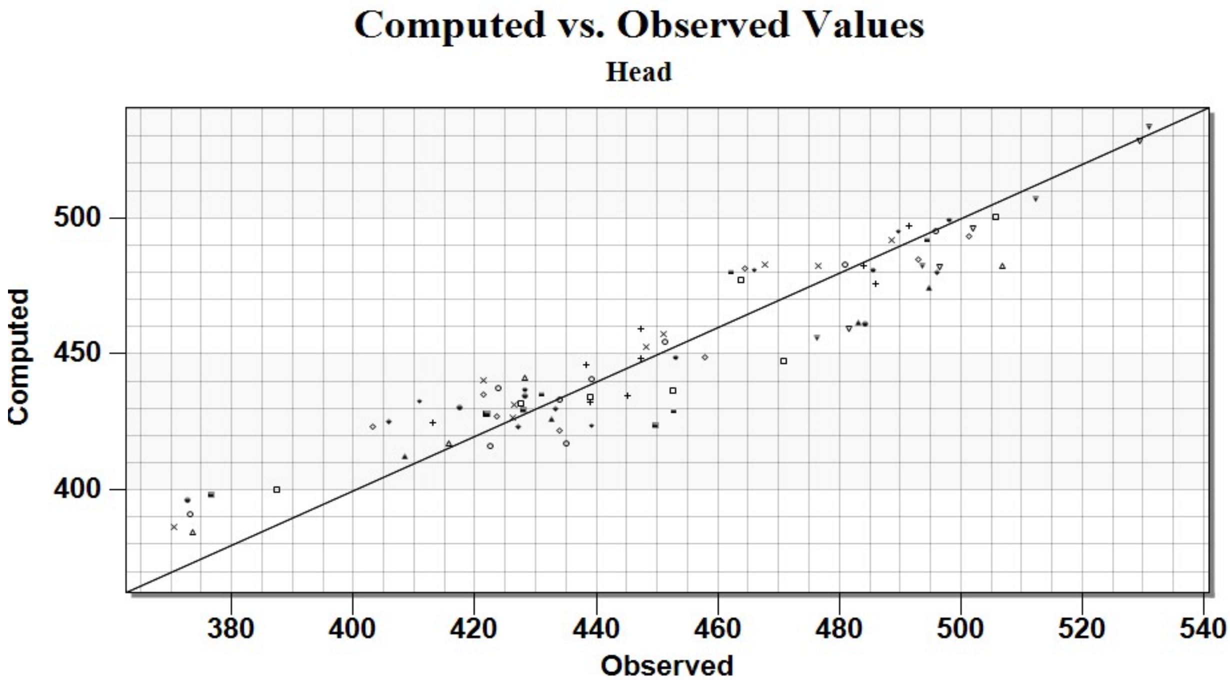


Figure 13 *Steady state scatter plot (model computed vs observed head)*

The overall mass balance error (outflows - inflows) for the steady state model (Figure 14) is <0.01%, suggesting that the model is numerically stable. As shown in this figure, the main input to the groundwater system is via rainfall recharge with inflow rate of 16,658 m^3/d (or 193 L/s) which accounts for 73% of the total model inflow (22,702 m^3/d or 263 L/s). Direct seepage flows between adjacent river cells with slightly different defined heads leads to localised recharge to river cells but they have no influence on the groundwater balance for the wider model.

```
 VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP       1 IN STRESS PERIOD       1
 -------------------------------------------------------------------------------------

    CUMULATIVE VOLUMES      L**3       RATES FOR THIS TIME STEP      L**3/T
    ------------------                 ------------------------

          IN:                                   IN:
          ---                                   ---
            STORAGE =           0.0000            STORAGE =           0.0000
      CONSTANT HEAD =         257.3830      CONSTANT HEAD =         257.3830
             DRAINS =           0.0000             DRAINS =           0.0000
      RIVER LEAKAGE =        5786.3379      RIVER LEAKAGE =        5786.3379
           RECHARGE =       16658.2891           RECHARGE =       16658.2891

           TOTAL IN =       22702.0100           TOTAL IN =       22702.0100

         OUT:                                  OUT:
         ----                                  ----
            STORAGE =           0.0000            STORAGE =           0.0000
      CONSTANT HEAD =           0.0000      CONSTANT HEAD =           0.0000
             DRAINS =       13205.3914             DRAINS =       13205.3914
      RIVER LEAKAGE =        9496.5820      RIVER LEAKAGE =        9496.5820
           RECHARGE =           0.0000           RECHARGE =           0.0000

          TOTAL OUT =       22701.9735          TOTAL OUT =       22701.9735

           IN - OUT =       3.6522E-02           IN - OUT =       3.6522E-02

PERCENT DISCREPANCY =           0.00     PERCENT DISCREPANCY =           0.00
```

Figure 14 ***Steady state model water balance***

Steady-state modelled head contours using the parameters presented in Table 8 and are plotted in Figure 15 and Figure 16. Model layer 6 has been chosen because layers 1-5 represent mainly the mining features and layer 6 represents the first layer of undisturbed natural rock within the model.

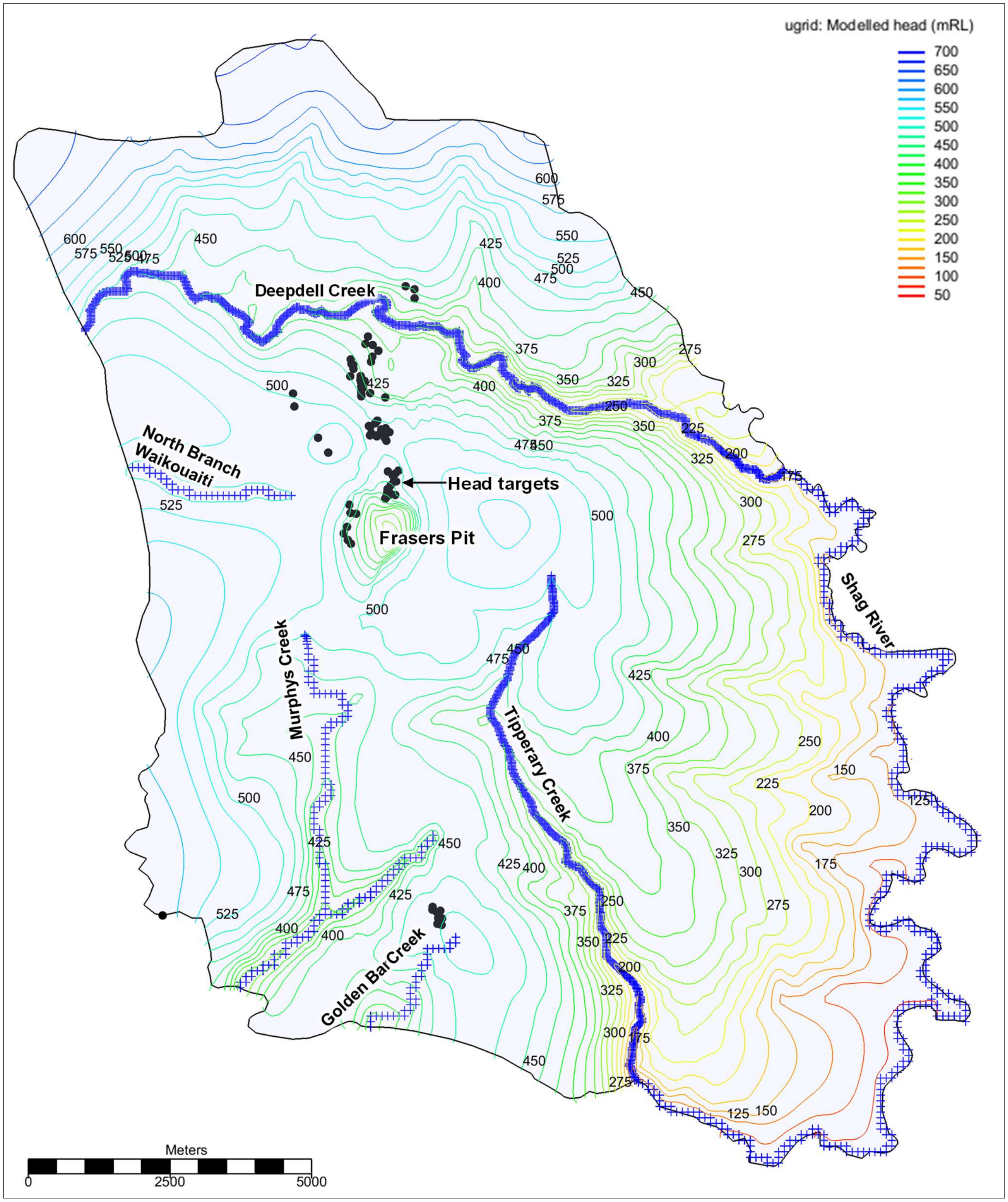


Figure 15 ***Steady state groundwater head contours (model layer 6).***

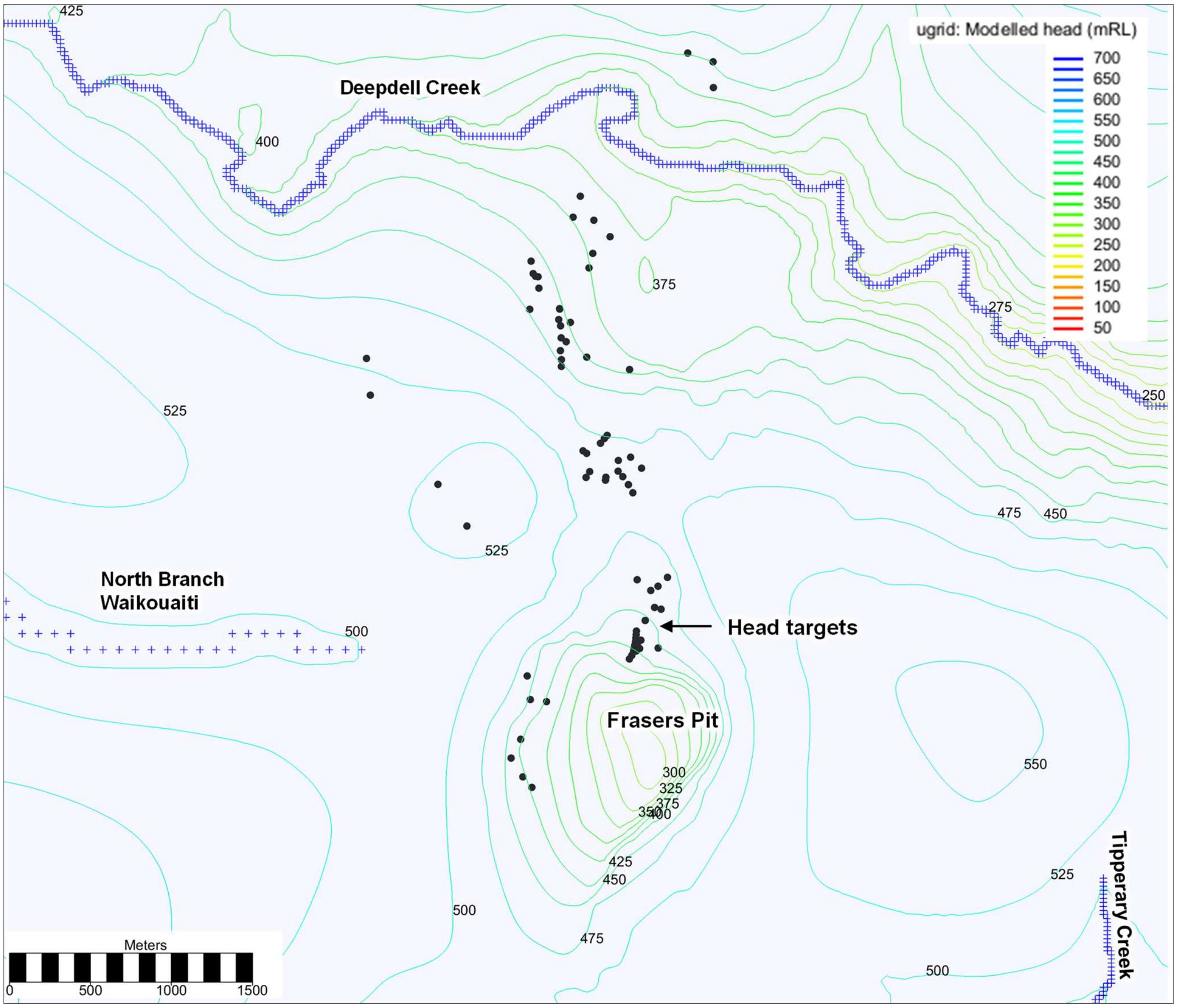


Figure 16   ***Steady state groundwater head contours zoomed near mine features (model layer 6)***

4.2.5 Transient Model Recorded Discharge Check

The FRUG has been operational since 2008, and it is proposed to cease to operate during 2024 (approximately 17 years of operation). Recorded mine water discharge from FRUG are typically between 1,000 to 2,000 m^3/d (12-24 L/s) with peaks of around 5,000 m^3/d (58 L/s) (WGA, 2020).

The initial hydraulic head around FRUG was set by applying drain boundary conditions in model layers 7 to 11 to reflect the constant pumping to manage groundwater within the underground tunnels. These were estimated using the current understanding of the FRUG geometry, known to lower in elevation at ~30° from portal located at the Fraser pit (at 340 mRL) to -290 m RL (below TTTSF). These boundary conditions were removed during the recovery runs.

Since the FRUG mining area comprises of various underground workings, tunnels, overall permeability of the rock mass in the FRUG mining area is considered significantly higher than that of the host rock, hence the following hydraulic properties were assigned for the FRUG mining area during the transient calibration.

Table 9 Hydraulic parameters used in the transient model.

Unit Name	Kx (m/d)	Kz (m/d)	Horizontal Anisotropy (Ky/Kx)	Vertical Anisotropy (Kx/Kz)	Specific Storage (1/m)	Specific Yield
FRUG	0.086	0.086	1	1	1E-5	0.1

A conductance of 10 m/d/m length was assumed for the drain boundary, such that it is not restricting inflow to the drain boundary. The modelled inflow rates to the FRUG is presented in Figure 17 (Model run ID "Macraes_Site_Wide_Tran_Calib_007")). The initial flow rate presented in Figure 17, assuming FRUG mining being active at once, while in reality, it was developed with time (in increments). The estimated rate of around 23 L/s (Figure 17) is in general agreement with recorded dewatering rates of 12 L/s to 24 L/s (WGA,2020).

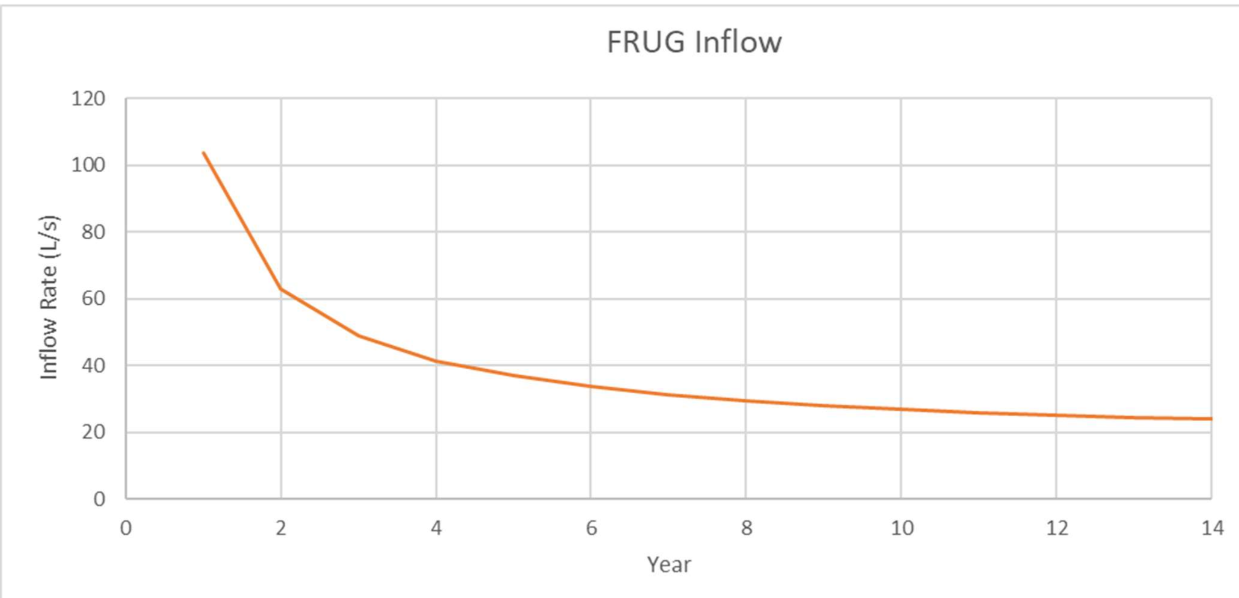


Figure 17 Model predicted FRUG inflow rate since its operation.

4.2.6 Predictive Analysis

4.2.6.1 Open Pit Dewatering

It is understood that FROP has been operational for a long time (since early 1990s) and it will continue to be dewatered until the end of 2023. Other pits (IMOP and Golden Point) are planned to be dewatered and these pits increase in size as per the Macraes mining schedule presented in Table 2. Pit dewatering was simulated by applying drain boundary conditions for the duration of the operation of each pit. The drain boundary condition was removed to simulate recovery of groundwater (post closure of mine). Groundwater inflows to the pits continue when dewatering pumping ceases but at decreasing rates as the pit lakes fill. The results of simulated pit inflow rates during dewatering are presented in Figure 18.

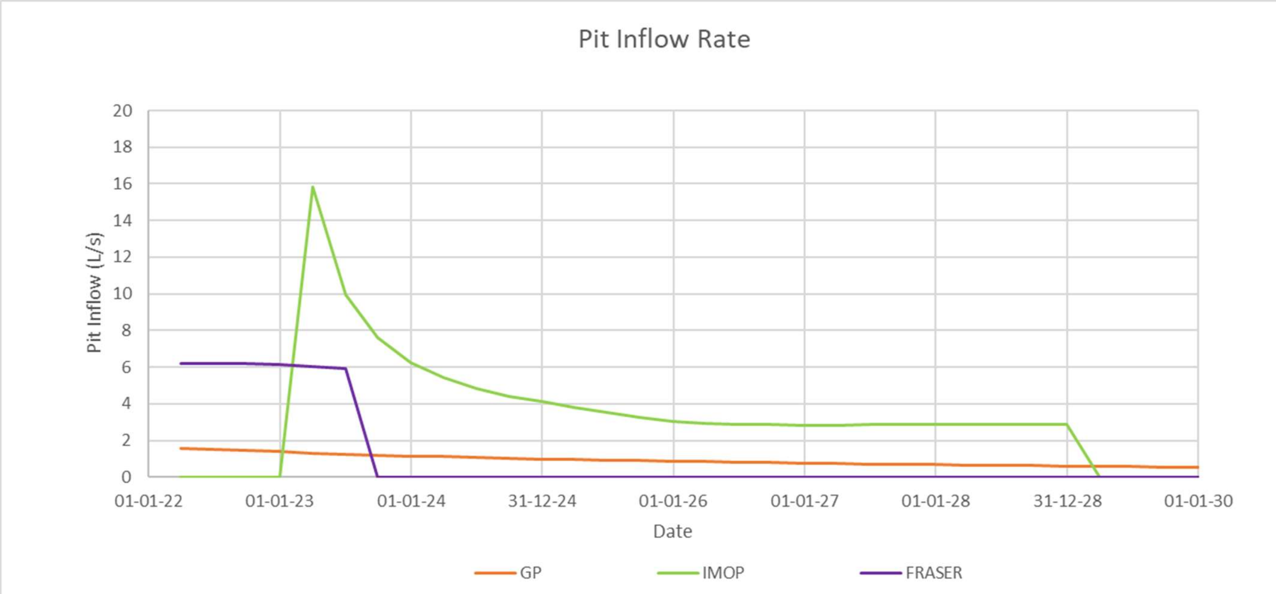


Figure 18 ***Model predicted pit-inflow rate***

Towards the end of pit dewatering, the expected pit inflow rate for each pit is presented below:

- FRASER- 5.9 L/s
- GP -0.5 L/s
- IMOP-2.9 L/s

Modelled head contours at the end of Q4 2028 (end of IMOP dewatering, Table 2) are plotted in Figure 19 and the water balance from the end of proposed dewatering of all pits and underground workings is presented in Figure 20. A relatively small reduction in the river leakage inflow rate value is estimated from simulating the pit dewatering compared to the values estimated from the steady-state model run (Figure 14 and Figure 20). The estimated reduction in the groundwater contribution to the river boundary (outflow) is approximately 284 m^3/d (3.3 L/s) which is less than 3% of the total modelled river gains (9,496 m^3/d) in the steady-state simulation. These results indicate that the proposed additional dewatering across the site will have a relatively small change to the estimated base flow of the rivers in the model domain.

A slight decrease in total drain outflow (groundwater contribution to the drain boundary) has been estimated at the end of proposed dewatering (Q4 2030) compared to that estimated by the steady-state simulation. Total drain outflow from the creeks (modelled with a drain boundary) at the end of dewatering is 12,201 m^3/d which is 1,004 m^3/d less than the 13,205 m^3/d of total drain discharge estimated in the steady-state simulation (Figure 14). Therefore, modelling results indicate that the proposed dewatering may reduce the total base flow of local creeks/streams by less than 8%.

The groundwater contributions to the Deepdell Creek are estimated to be reduced by ~260 m^3/d (~3 L/s) or ~ 7.8% (at the river boundary) and ~215 m^3/d (2.5 L/s) or ~7.6 % at the drain boundary due to dewatering. For the remaining of the creeks/rivers, modelling results show a reduction of 23 m^3/d (from 6134 m^3/d to 6111 m^3/d) or by 0.4%) on the river boundary and a reduction by 789 m^3/d (from 10,360 m^3/d to 9,571 m^3/d) or by 7.6% on the drain boundary at the end of dewatering. Most creeks in the mine area are transient in nature and there are no surface flows during summer as evaporative losses from the creeks exceed the groundwater discharges to these creeks. Therefore, modelled reductions in seepage discharges to creeks are expected to have negligible impacts on creek and river flows through summer low flow periods.

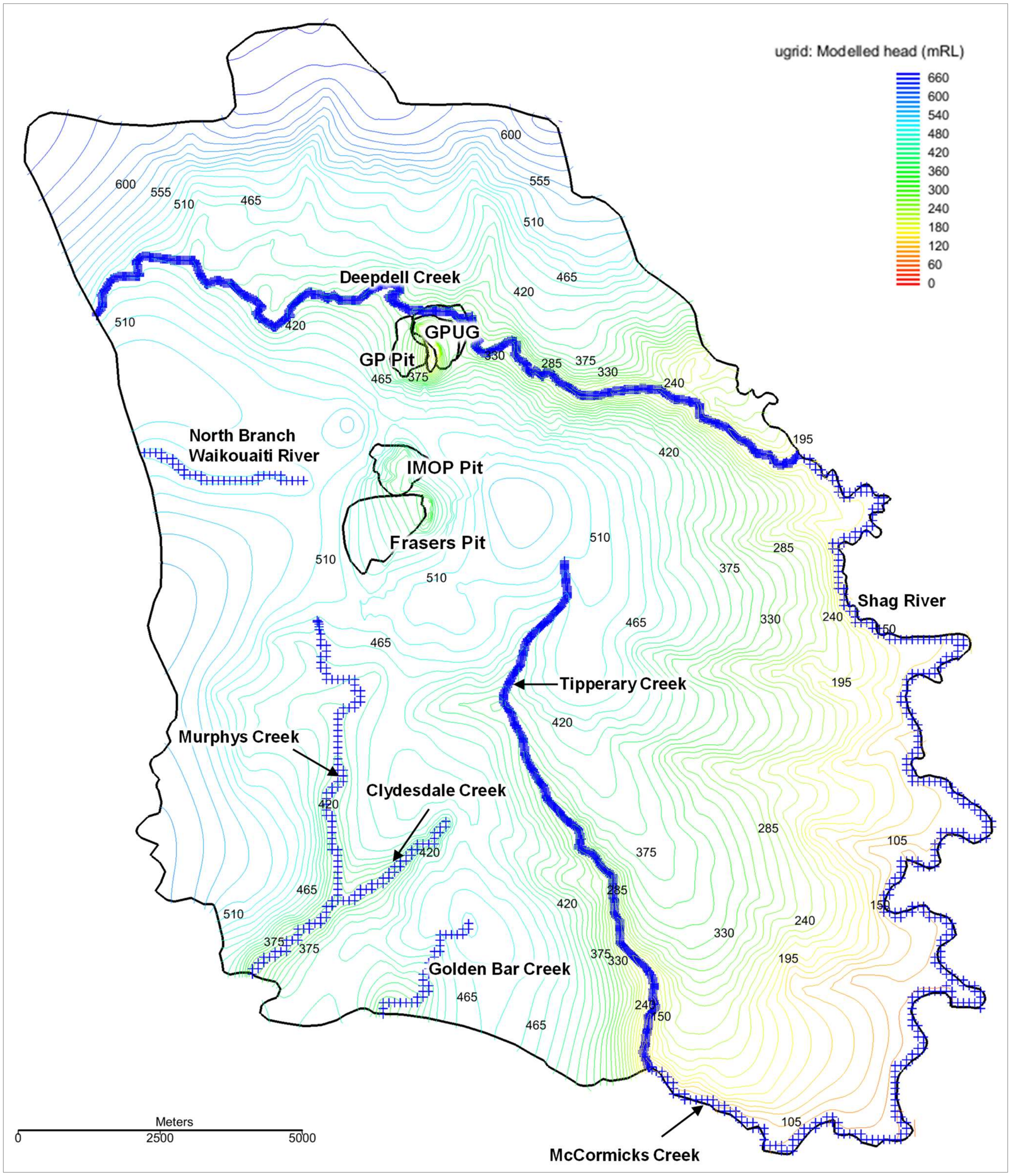


Figure 19 *Model predicted head in model layer 6 at the end of dewatering (Q4 2028)*

```
 VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP      3 IN STRESS PERIOD     28
 ------------------------------------------------------------------------------------

   CUMULATIVE VOLUMES      L**3       RATES FOR THIS TIME STEP      L**3/T
   ------------------                 ------------------------

         IN:                                   IN:
         ---                                   ---
           STORAGE =    12930474.0984            STORAGE =       2153.2901
     CONSTANT HEAD =      817185.7518      CONSTANT HEAD =        328.9639
            DRAINS =           0.0000             DRAINS =          0.0000
     RIVER LEAKAGE =    14786398.8016      RIVER LEAKAGE =       5787.9131
          RECHARGE =    42561927.6650           RECHARGE =      16658.2891

          TOTAL IN =    71095986.3169           TOTAL IN =      24928.4562

        OUT:                                  OUT:
        ----                                  ----
           STORAGE =     4251496.8941            STORAGE =       2096.2365
     CONSTANT HEAD =           0.0000      CONSTANT HEAD =          0.0000
            DRAINS =    42961285.2768             DRAINS =      13583.8421
     RIVER LEAKAGE =    23883203.5348      RIVER LEAKAGE =       9248.3779
          RECHARGE =           0.0000           RECHARGE =          0.0000

         TOTAL OUT =    71095985.7057          TOTAL OUT =      24928.4565

          IN - OUT =           0.6112           IN - OUT =     -3.4289E-04

PERCENT DISCREPANCY =          0.00     PERCENT DISCREPANCY =         -0.00
```

Figure 20 Water balance at the end of IMOP dewatering (Q4 2028).

4.2.6.2 Groundwater Recovery

Groundwater recovery was computed for 400 years with the proposed Fraser and Innes Mills pit-lake levels modelled as general head boundary (GHB) condition. The head values for the boundary condition were derived from the WBM that was used to estimate filling rates and the long-term equilibrium level (refer Section 5.10). During the recovery run, contaminant (Sulphate) transport modelling was also undertaken, and results are discussed in Section 4.2.6.3

The water balance summary as well as modelled pressure head contours at the end of the recovery run (for model layer 6) are presented in Figure 21 and in Figure 22 respectively.

```
 VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP      60 IN STRESS PERIOD      74
 --------------------------------------------------------------------------------------

    CUMULATIVE VOLUMES      L**3       RATES FOR THIS TIME STEP      L**3/T
    ------------------                 ------------------------

          IN:                                   IN:
          ---                                   ---
            STORAGE =    13370046.8099            STORAGE =       3.2180E-11
      CONSTANT HEAD =    37053712.5255      CONSTANT HEAD =         223.7742
             DRAINS =           0.0000             DRAINS =           0.0000
      RIVER LEAKAGE =   844758478.6910      RIVER LEAKAGE =        5784.4336
    HEAD DEP BOUNDS =     9902440.9929    HEAD DEP BOUNDS =           0.0000
           RECHARGE =  2432110203.1250           RECHARGE =       16658.2891

           TOTAL IN =  3337194882.1443           TOTAL IN =       22666.4968

         OUT:                                  OUT:
         ----                                  ----
            STORAGE =    69021345.7957            STORAGE =          13.0552
      CONSTANT HEAD =           0.0000      CONSTANT HEAD =           0.0000
             DRAINS =  1788196856.8220             DRAINS =       12340.3136
      RIVER LEAKAGE =  1404642607.3852      RIVER LEAKAGE =        9764.1943
    HEAD DEP BOUNDS =    75330477.6271    HEAD DEP BOUNDS =         548.9316
           RECHARGE =           0.0000           RECHARGE =           0.0000

          TOTAL OUT =  3337191287.6301          TOTAL OUT =       22666.4948

           IN - OUT =        3594.5142           IN - OUT =       2.0638E-03

PERCENT DISCREPANCY =           0.00     PERCENT DISCREPANCY =           0.00
```

Figure 21 ***Water balance at the end of recovery run after 400 years***

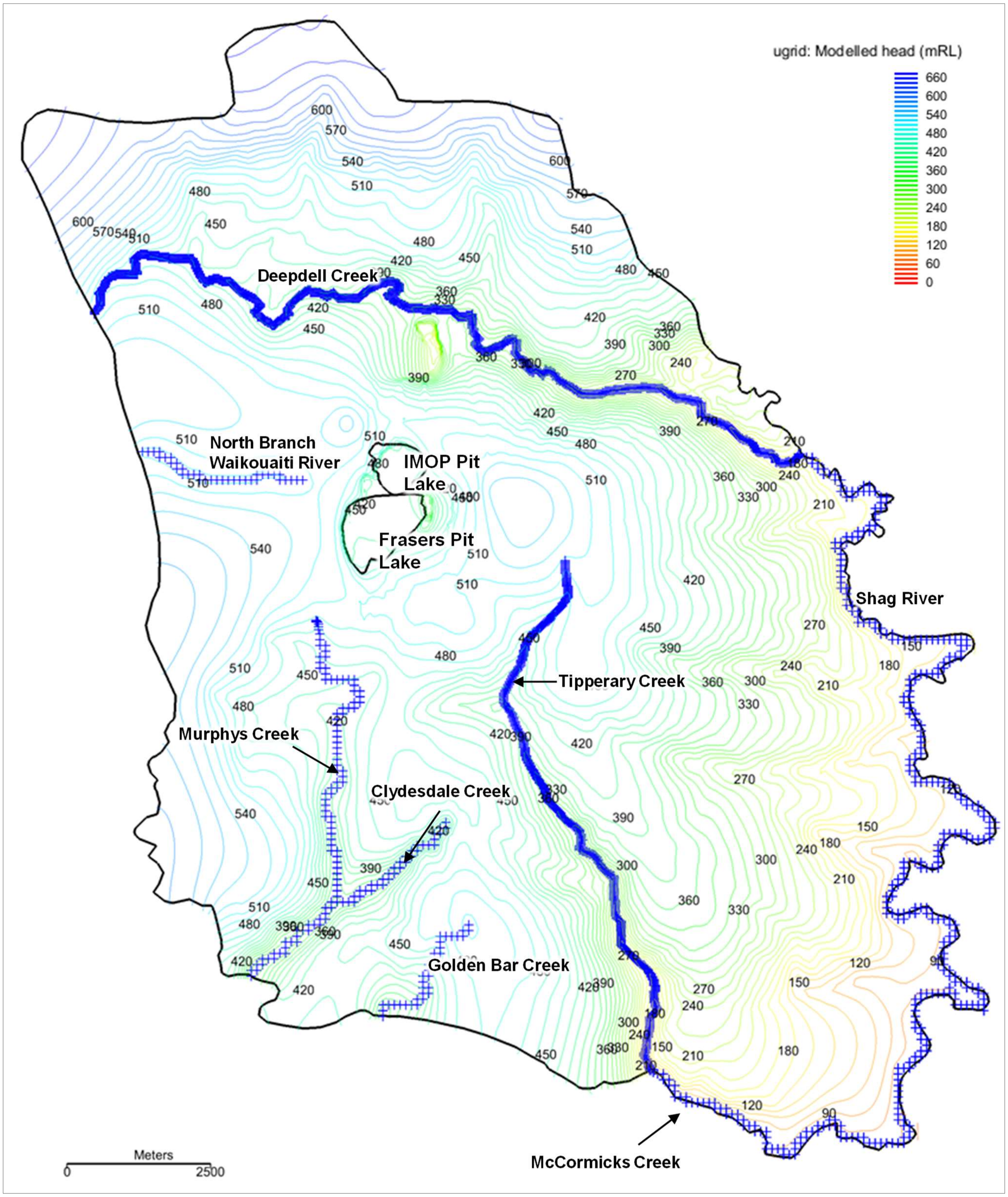


Figure 22 ***Groundwater head in model layer 6 at the end of the recovery run after 400 years***

Estimated inflow and outflow rates for the FROP and IMOP pit lakes are presented in Figure 23. As these two pit lakes become one pit lake during the recovery phase, single inflow and outflow has been presented. As presented in this figure, the FROP and IMOP pit lakes combine as one lake (FRIM) and becomes a “sink” (where inflow rate to the pit is estimated to be greater than outflow).

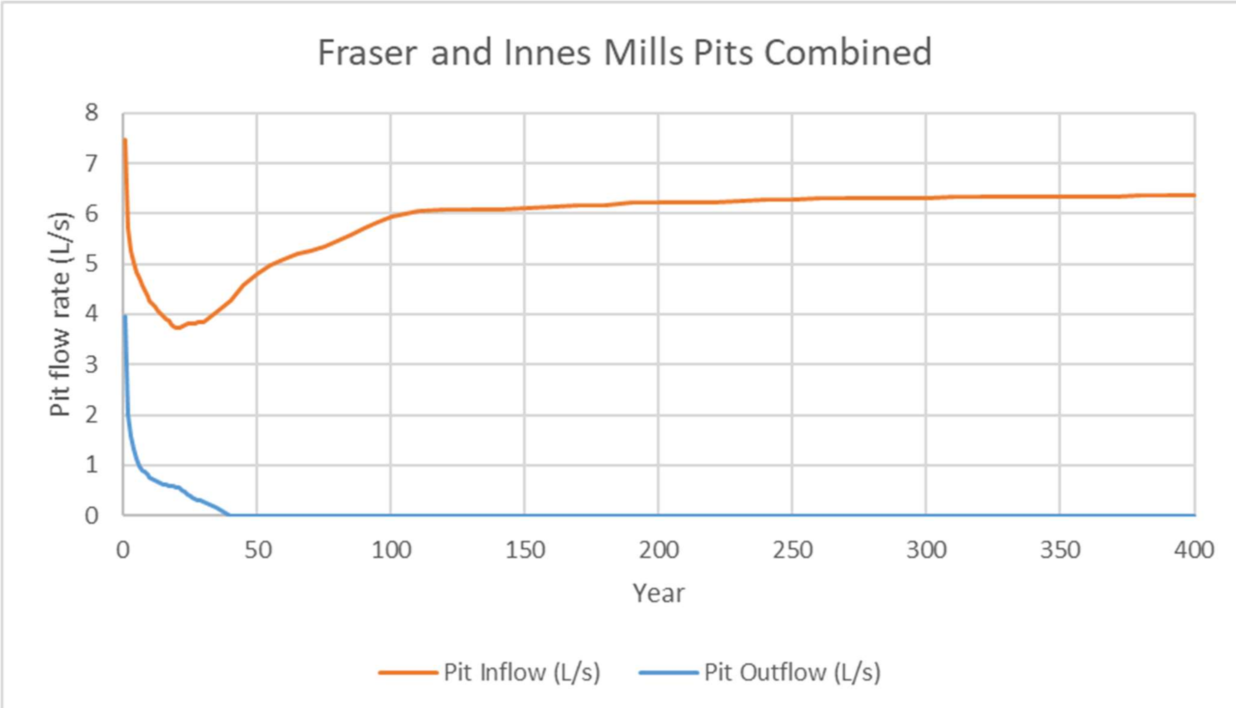


Figure 23 *Fraser and Innes Mills (FRIM) pit lake combined inflow and outflow during recovery*

4.2.6.3 Contaminant Transport

Contaminant transport modelling was undertaken using MODFLOW USG-TRANSPORT VERSION 1.8.0 at the end of the IMOP pit dewatering in Q4 2028 and for a total of 400 years with the following inputs:

– Sulphate has been modelled due to its expected elevated concentration (relative to other key contaminants), its existing elevated nature in some receiving surface water bodies as a result of mining activity, and its limited ability to attenuate within the groundwater system. It is therefore considered a conservative element with which to assess contaminant mobilisation and transport from the backfilled waste and subsequent pit lakes to receiving surface water bodies via the groundwater system. The sulphate concentrations applied in the contaminant transport modelling are outlined in Table 10 with the location plan presented in Figure 24.
– The sulphate concentration value applied to the FROP, IMOP and FRIM pit lakes has been based on the concentration values estimated in MWM, 2024.
– The sulphate concentration value applied to the WRSs utilised the height / age relationship as defined in MWM, 2023 (refer Table 10).
– The sulphate concentrations applied to the tailings facilities are based on site monitoring data and previous assessments (refer Table 10).
– Effective porosity values equal to specific yield values (Table 8)
– Longitudinal dispersivity value = 20 m (assumed 10% of plume length based on initial test run where plume was expected to migrate approximately 200 m)
– Transverse dispersivity value = 2 m (10% of the longitudinal)

Table 10 Sulphate concentrations applied to contaminant transport model

Location	Sulphate Concentration (mg/L)	Source
Backroad WRS#	2,842	MWM (2023)
Frasers East WRS	1,228	MWM (2023)
Frasers South WRS	5,594	MWM (2023)
Frasers West WRS	4,052	MWM (2023)
Deepdell WRS	1,206	MWM (2023)
MTI / SP11	3,500	OCGNZL Data*
Northern Gully WRS	1,889	MWM (2023)
TTTSF	3,000	GHD (2022a)
FRIM Pit Lake	1,047 – 1,390	MWM (2024)
Golden Point Pit	3,852	MWM (2023)
*Conservative estimate based on long term monitoring data from MTI collection drains #BRWRS is not utilised for MPIV, however it is included for completeness		

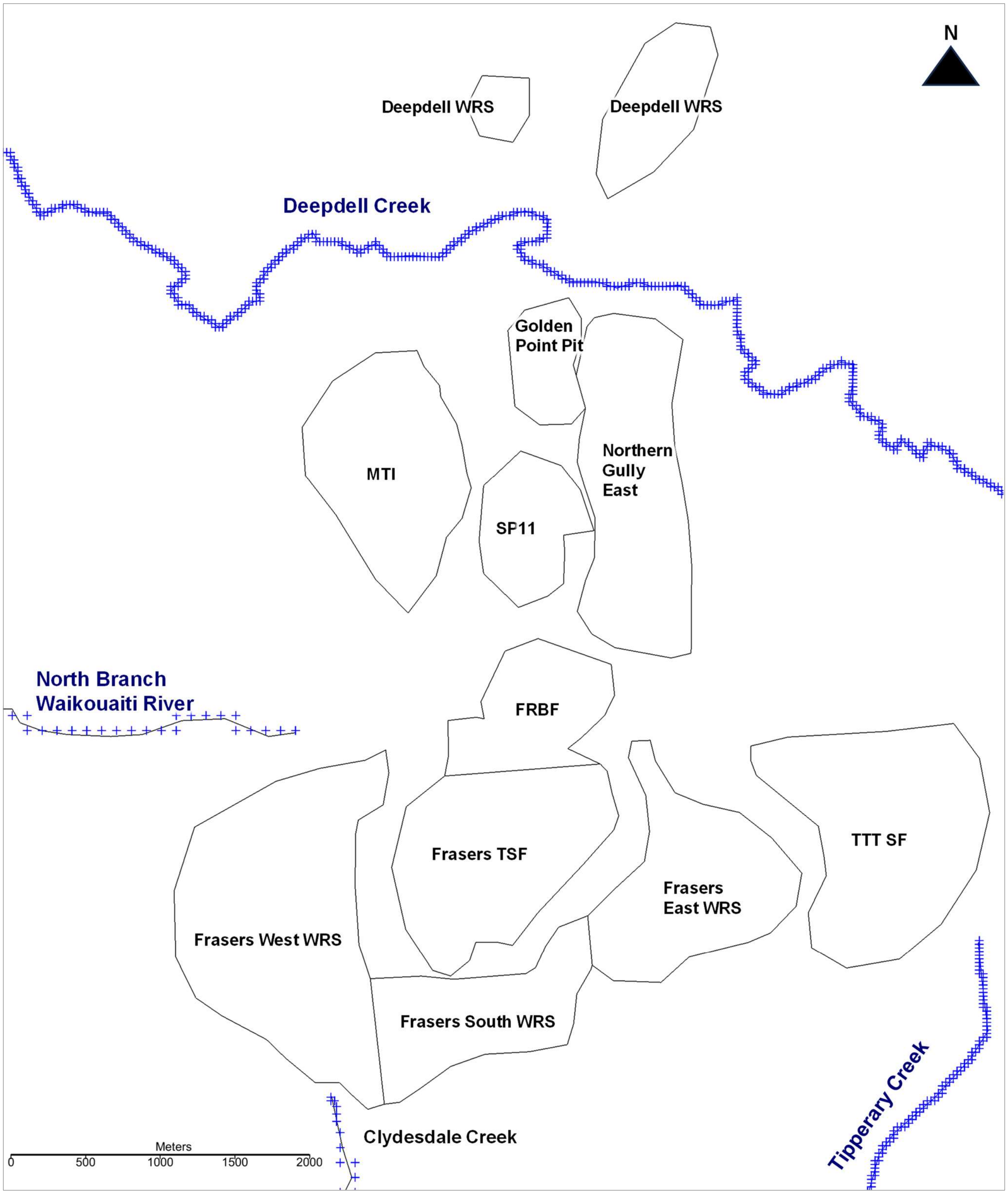


Figure 24 Input concentration location plan

Water balance error (Figure 21) and solute transport mass balance error for the same period (Figure 25) for this run as well as all previous model runs was <0.00% suggesting all model runs completed were numerically stable.

```
 VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP      60 IN STRESS PERIOD      74
 ---------------------------------------------------------------------------------------

    CUMULATIVE VOLUMES      L**3       RATES FOR THIS TIME STEP      L**3/T
    ------------------                 ------------------------

          IN:                                    IN:
          ---                                    ---
       MASS STORAGE = 31758793547.6129         MASS STORAGE =       9968.5479
   PRESCRIBED CONCS =563806742107.1365     PRESCRIBED CONCS =    3168976.0000
   CNST H MASS FLUX =           0.0000     CNST H MASS FLUX =          0.0000
      GHB MASS FLUX =       2.9096E-02        GHB MASS FLUX =          0.0000
      DRN MASS FLUX =           0.0000        DRN MASS FLUX =          0.0000
      RIV MASS FLUX =           0.0000        RIV MASS FLUX =          0.0000
      RCH MASS FLUX =           0.0000        RCH MASS FLUX =          0.0000

           TOTAL IN =595565535654.7784             TOTAL IN =    3178944.5479

         OUT:                                   OUT:
         ----                                   ----
       MASS STORAGE =331188266661.3970         MASS STORAGE =     749890.0625
   PRESCRIBED CONCS = 57445850916.5444     PRESCRIBED CONCS =     328936.9062
   CNST H MASS FLUX =           0.0000     CNST H MASS FLUX =          0.0000
      GHB MASS FLUX = 21849245518.8897        GHB MASS FLUX =     194879.2969
      DRN MASS FLUX = 30524517464.8103        DRN MASS FLUX =     312295.5938
      RIV MASS FLUX =154557655112.1587        RIV MASS FLUX =    1592942.7500
      RCH MASS FLUX =           0.0000        RCH MASS FLUX =          0.0000

          TOTAL OUT =595565535673.8000            TOTAL OUT =    3178944.6094

           IN - OUT =         -19.0216             IN - OUT =     -6.1523E-02

PERCENT DISCREPANCY =          -0.00     PERCENT DISCREPANCY =          -0.00
```

Figure 25 Solute mass balance 400-years

The extent of the sulphate plume at the end of 400-year simulation is presented in Figure 26 and in Figure 27 for model layer 6. In these figures, plume is defined with the outer concentration of 10 mg/L. As presented in these figures, the maximum horizontal extent of the plume is approximately 4000 m (along the Deepdell Creek) to the east direction of the source area (Northern Gully WRS); approximately 800 m (along the Deepdell Creek) to the north from the source area (MTI), approximately 1700 m (along the Murphys Creek) to the south from (Frasers South WRS), approximately 1700 m (along the Tipperary Creek) to the south from the source area (TTTSF) and approximately 800 m to the west (along the NBWR) from the source area (Frasers West WRS).

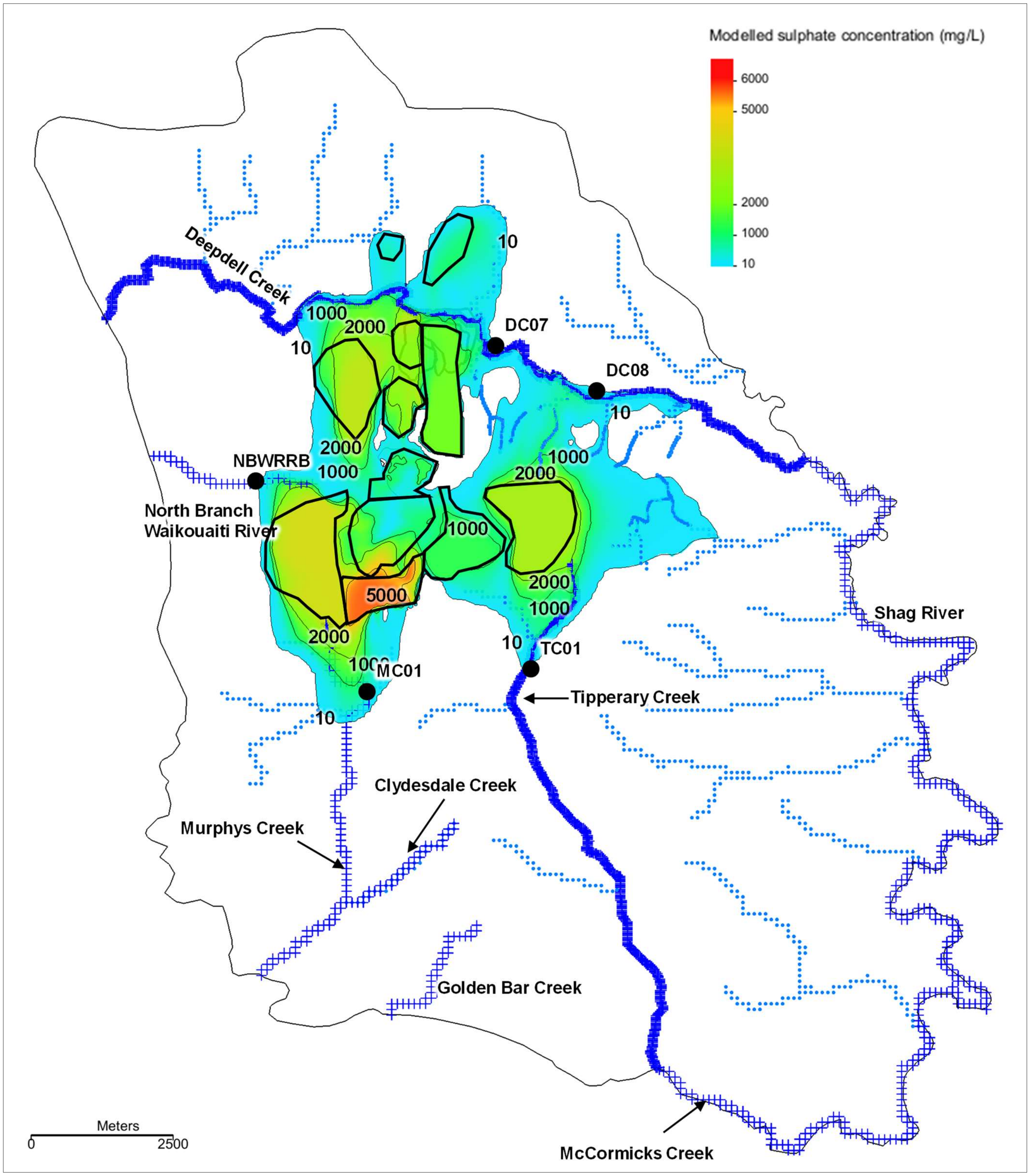


Figure 26 ***Sulphate plume extent in model layer 6 after 400-years post mine closure (entire model domain)***

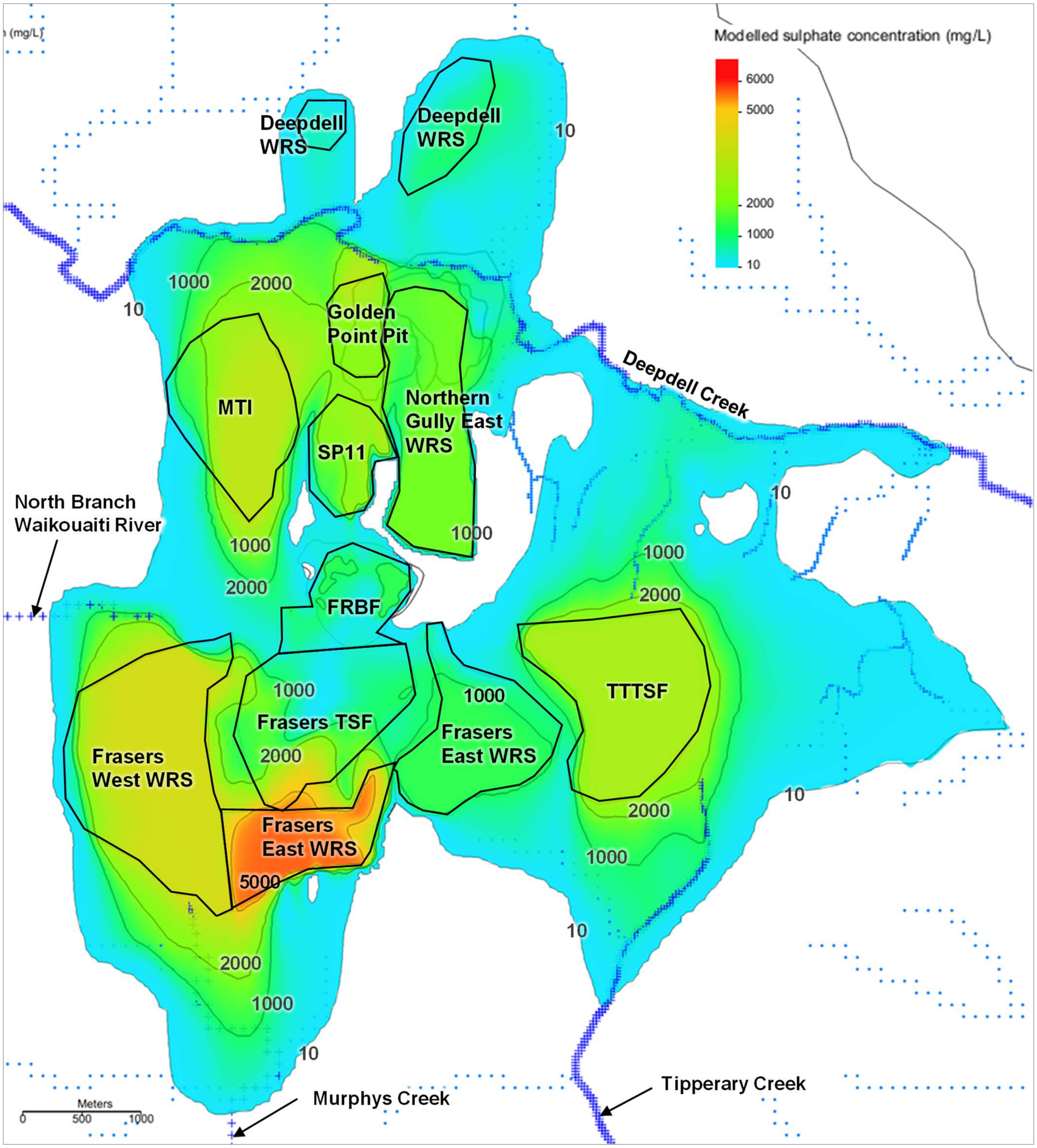


Figure 27 *Sulphate plume extent in model layer 6 after 400-years post mine closure (zoomed)*

The calculated mass flux of sulphate into the receiving surface water environment at key compliance locations is provided in Table 11.

Table 11 Sulphate Mass Flux from Groundwater Modelling

Surface Water Location	Kg/day		
	20 years post closure	200 years post closure	400 years post closure
DC07	24	773	990
DC08	24	853	1,100
Deepdell creek (downstream of DC08)	24	861	1,122
NBWRRB	5	117	141
TC01	<1	128	171
MC01	79	287	375
Murphys creek (downstream of MC01)	79	290	384

4.3 Groundwater Summary

A numerical groundwater 3D model has been developed using MODFLOW-USG (flow modelling code) and MODFLOW-USG-TRANSPORT (for solute transport modelling code). The 3D model has been used to assess groundwater inflow rates into the existing and proposed expanded pits as well as the groundwater recovery and contaminated transport 400 years post mine closure. The model was calibrated to reflect the current mine status before undertaking model predictions.

Modelling results indicate a reduction of ~260 m^3/d (3 L/s) or ~ 8% (at the river boundary) and ~215 m^3/d (2.5 L/s) or ~8 % at the drain boundary, of the groundwater contributions to the Deepdell Creek due to pit dewatering. For the remaining of the creeks, modelling results show a reduction of 23 m^3/d (from 6134 m^3/d to 6,111 m^3/d or by 0.4%) on the river boundary and a reduction by 789 m^3/d (from 10,360 m^3/d to 9,571 m^3/d or by 7.6%) on the drain boundary at the end of pit dewatering. Most creeks in the mine area are transient in nature and there are no surface flows during summer as evaporative losses from the creeks exceed the groundwater discharges to these creeks. Therefore, modelled reductions in seepage discharges to creeks are expected to have negligible impacts on creek and river flows through summer low flow periods.

Contamination plume (defined by 10 mg/L concentration of sulphate), is expected to reach:

- approximately 4000 m to the east direction (along the Deepdell Creek) of the source area (Northen Gully East WRS),
- approximately 800 m to the north (along the Deepdell Creek) from the source area (MTI),
- approximately 1700 m to the south (along the Murphys Creek) from (Frasers South WRS),
- approximately 1700 m to the south (along the Tipperary Creek) from the source area (TTTSF) and
- approximately 800 m to the west (along the NBWR) from the source area (Frasers West WRS).

The sulphate flux (of groundwater discharging to Deepdell Creek up stream of the compliance monitoring location DC08) is estimated to be 24 kg/day (20 years post closure), 853 kg/day (200 years post closure) and 1,100 kg/day (400 years post closure). Similarly, for the NBWR the sulphate flux up stream of the compliance monitoring location NBWRRB is estimated to be 5 kg/day (20 years post closure), 117 kg/day (200 years post closure) and 141 kg/day (400 years post closure). For Murphys Creek the sulphate flux up stream of the compliance monitoring location MC01 is estimated to be 79 kg/day (20 years post closure), 287 kg/day (200 years post closure) and 375 kg/day (400 years post closure). The sulphate flux (of groundwater discharging to Tipperary Creek up stream of the monitoring location TC01) is estimated to be <1 kg/day (20 years post closure), 128 kg/day (200 years post closure) and 171 kg/day (400 years post closure).

5. Surface Water Assessment

5.1 Introduction

GHD have previously developed a site wide WBM for OGNZL operations at the Macraes Gold Mine in 2018. This WBM later incorporated the Deepdell North Stage III Project and assessed the potential impact on downstream water quality associated with the project. The combined analysis showed a low potential for future non-compliance in Deepdell Creek and Shag River receiving water bodies and is reported in GHD, 2019. This WBM has since been optimised and updated to incorporate subsequent site changes, additional monitoring data and to assess surface water quality impacts of specific projects at Macraes with the results of the later documented in the following reports, each of which have been utilised to support the consenting of the specific projects:

– GHD 2020. GPUG Cumulative Effects Assessments. Report prepared for Oceana Gold (New Zealand) Ltd
– GHD 2021. TTTSF Crest Raise. [RL 560-568 m RL] Surface and Groundwater Assessment. Report prepared for Oceana Gold (New Zealand) Ltd
– GHD 2022a. TTTSF Crest raise. [RL 568-570 m RL] Surface Water and Groundwater Assessment. Report prepared for Oceana Gold (New Zealand) Ltd.
– GHD 2022b. Frasers Co-disposal Surface Water and Groundwater Assessment. Report prepared for Oceana Gold (New Zealand Ltd, 10 November 2022.
– GHD 2023a. Golden Point Underground Extension – Analytical Assessment of Effect on Deepdell Creek. P. Prepared for Oceana Gold New Zealand Limited. 12 October 2023
– GHD 2023b. Continuity Consent Project (CCP). Surface and Groundwater Assessment. Report prepared for Oceana Gold New Zealand Ltd, 04 December 2023.

The construction, calibration, and input data of the current Goldsim WBM are well documented throughout the above assessments and can be used to estimate future impacts of receiving water quality as a result of site rehabilitation activities.

Updates to the WBM which have been implemented include:

– Revised WRS seepage quantity and quality estimates. The WBM now estimates sulphate concentrations in seepage water based on correlations with WRS dimensions as presented in Mine Waste Management (2022). This also applies a sulphate ceiling in which geochemical equilibrium would limit forever increasing concentrations and correlations of other contaminants to sulphate concentrations to capture the key consenting parameters.
– Recalibration of key compliance points utilising revised catchment boundaries and up to date water quality monitoring data.
– Inclusion of ground water interactions within the pits based on inflow/outflow relationships presented in Section 4.2.6 of this report.

5.2 Model Schematisation

An overview schematic of the WBM is shown in Figure 28 indicating key nodes represented in the model and direction of surface water flows. Not shown in the figure is the surface water catchments areas and ground water / WRS and TSF seepage flows. The direction of flow (of some illustrated components) can be reversed for some elements and is dependent on the stage of mining (ie. active, closure). Additional elements are shown for completeness even though they are not utilised in the current assessment. Catchment maps defining surface types and contributing areas to these nodes are provided in **Appendix A-3**.

Key stage volume inputs and catchment areas are outlined in **Appendix A-1**.

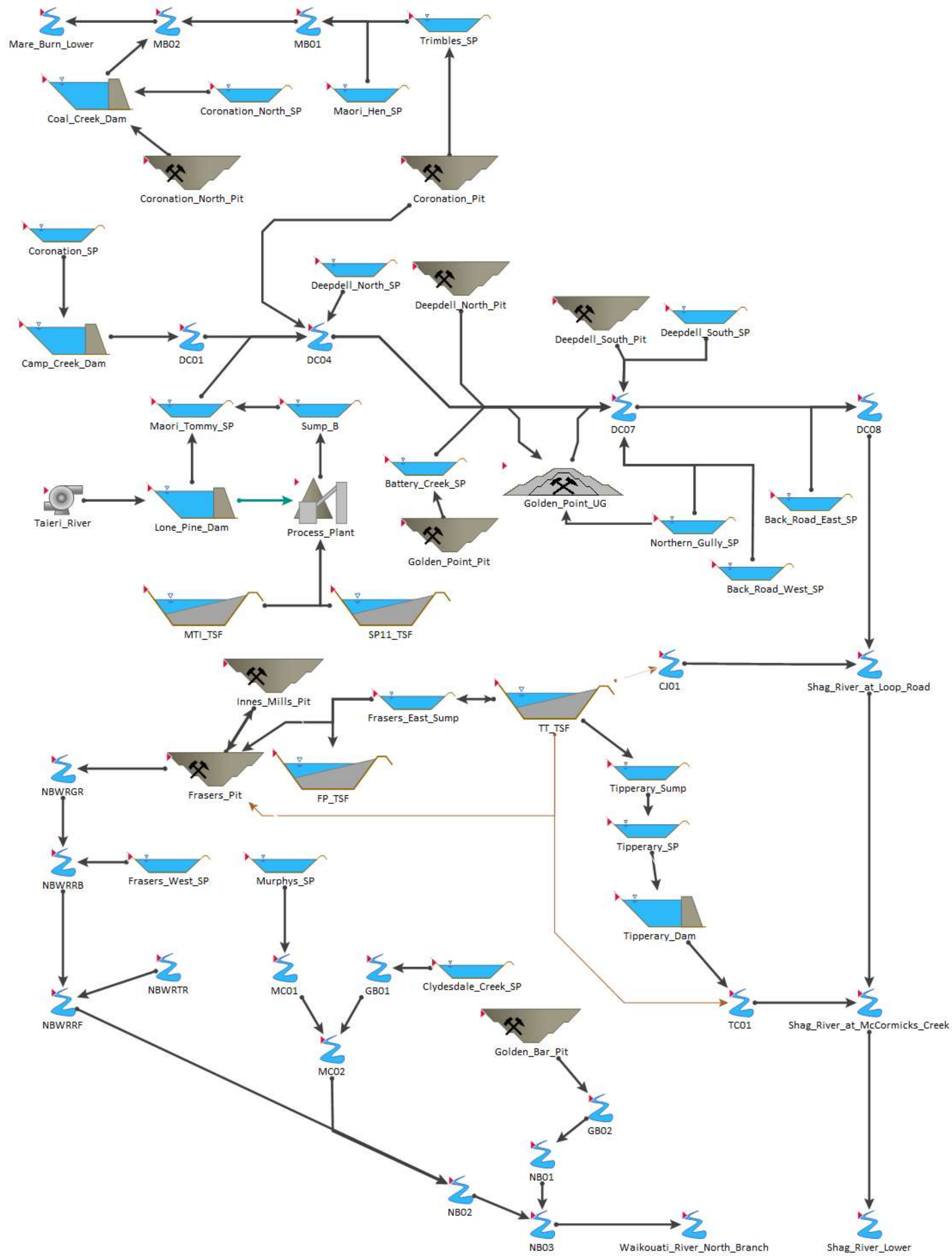


Figure 28 *Schematic of the Macraes Water Balance Model as setup for the MP4 project.*

5.3 Climate and Climate Change Representation

Climate data are applied to the model based on historical measurements, from which a synthetic rainfall time series is generated, and monthly evaporation statistics are derived. Where the model is applied for long term predictive modelling of flows and contaminant concentrations climate change adjustments are applied to the rainfall and evaporation inputs.

Van Vuuren et al (2011) set representative concentration pathways (RCPs) defining approximate total radiative forcing through to the year 2100. The paper presents an RCP8.5 scenario that represents a ‘business as usual’ response to climate change resulting in high greenhouse gas concentrations by 2100. Given the uncertainty of the global response to climate change and the subsequent effects to long-term water management at the Macraes Mine site, the RCP8.5 scenario is seen as the conservative approach to accounting for climate change and it is expected to lead to the following key outcomes:

– increased mean and maximum temperatures,
– increased dry days (no precipitation) and evaporation with more severe and frequent droughts,
– decrease in summer precipitation (December – February),
– increase in winter precipitation (June – August),
– increased mean precipitation concentrated on the extreme events.

5.3.1 Rainfall

Rainfall is represented in the WBM based on a stochastic synthetic data series produced for statistical similarity with recorded rainfall data. The algorithm producing the stochastic rainfall seeks to represent seasonal variation, daily rainfall depth distributions and antecedent rainfall conditions. This makes the extended synthetic rainfall series suitable for representing an increased range of scenarios than what could be achieved with a historic data series alone. The recorded rainfall includes daily rainfall data from Glendale Station (agent number 5370) between 1959 and 2008, and the Golden Point Station on the Macraes site between 1991 and 2018. The synthetic data represents daily rainfall depths for 1,000 years and has a mean annual depth of 664 mm with a range between 355 mm and 1155 mm (Table 12).

Table 12 Rainfall statistics

	Synthetic Record (1,000 years)	Golden Point Station (1991-2022)	Glendale Station No. 5370 (1959-2008)
Mean annual rainfall (mm)	664	665	634
Minimum annual rainfall (mm)	355	414	395
Maximum annual rainfall (mm)	1155	1034	950
Dry days	59%	59%	68%

Seasonal rainfall variations under the RCP8.5 scenario are expected to follow the trends as outlined in Table 13. Typically, this results in dryer summer periods and wetter winters than historical means. The net result is an overall annual increase in precipitation.

Table 13 Mean rainfall changes for RCP8.5 at Macraes Mine (Data extracted from NIWA, 2016)

Season	2055		2090	
	Lower	Upper	Lower	Upper
Summer	-10%	-5%	-10%	-5%
Autumn	5%	10%	10%	15%
Spring	-5%	0%	10%	15%
Winter	10%	15%	20%	25%
Annual	-5%	0%	10%	15%

5.3.2 Evaporation

Evaporation is represented in the model based on monthly statistics derived from pan evaporation data collected from site between 1991 and 2018 as shown in Figure 29. Mean annual evaporation is 952 mm and this is represented in the WBM as a monthly normal distribution with cut-offs applied as per the minimum and maximum valves.

An evaporation reduction factor of 0.7 is applied to evaporation from the pit lakes to account for differences between pan evaporation rates and evaporation rates expected from large water bodies.

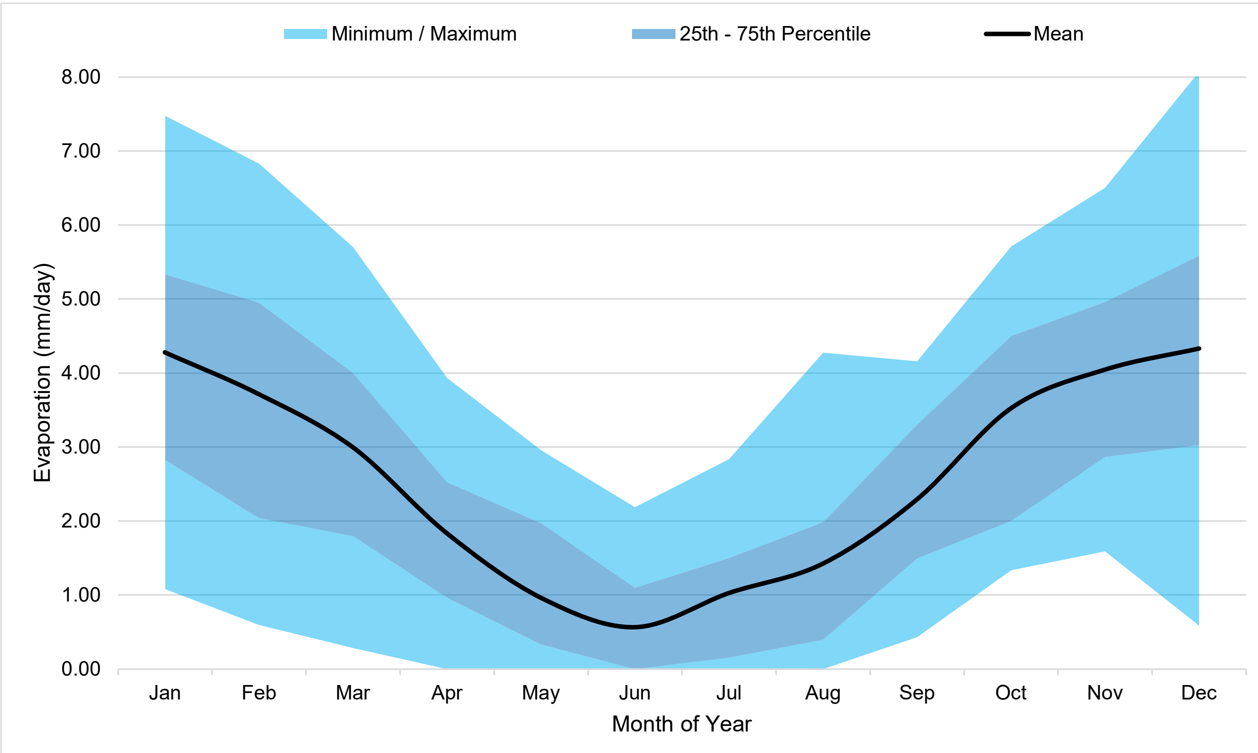


Figure 29 Evaporation statistics applied in WBM

Under the RCP8.5 scenario an increase in potential evaporation deficit (PED) of approximately 120 mm could be expected by 2110 (Figure 30). At the Macraes Mine site this translates to an increase in mean evaporation potential of approximately 12.5 %. This evaporation potential is applied to the model as a multiplier of the existing evaporation rates, linearly increasing to 12.5 % by the year 2110. From the year 2110 evaporation is fixed to 1.125 times the historical statistics.

The net result from the applied evaporation and rainfall adjustments in the long term is a typical increase in annual runoff, with seasonal decreases in summer periods and increases in winter.

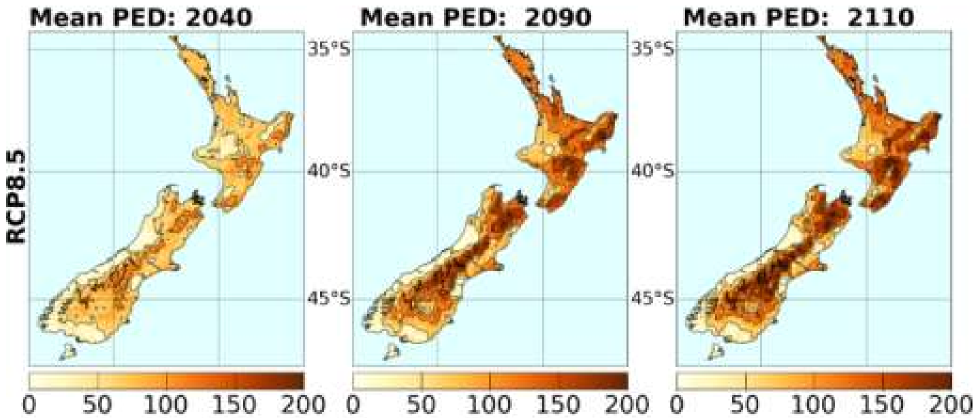


Figure 30 PED projections (exert from MfE 2018, Figure 55)

5.3.3 Runoff

Runoff is represented in the WBM by two methods, the rational method is applied to areas impacted by mining and WRS runoff, and a calibrated Australian Water Balance Model (AWBM) (Boughton 2004) is applied to all other areas.

Table 14 outlines the runoff coefficients applied to impacted and WRS surfaces. Runoff coefficients are interpolated from these given values based on the daily rainfall depth. These coefficients increase with rainfall depth to represent the higher runoff rates from more wetted soils.

Table 14 Runoff coefficients for application of the rational method.

Daily rainfall (mm)	Impacted Areas	Waste Rock Stacks
0	0.05	0
10	0.2	0.05
50	0.4	0.15
90 +	0.7	0.4

Runoff to water bodies surfaces is modelled with a runoff coefficient of 1.0 and the surface area of these water bodies are adjusted based on the defined volume-area relationships, with a corresponding reduction in adjacent catchment area.

For flows from natural catchments a catchment runoff model based on the Australian Water Balance Model (AWBM) (Boughton 2004) is calibrated to gauging undertaken on the Deepdell Creek (at DC04) and on the Waikouaiti River North Branch at Golden Bar Road and Griffin Road gauges (NBGR) between 1991 and 1998. This calibration is presented in **Appendix A**.

5.4 Surface Water Quality

The surface water quality parameters applied to the water balance model are listed in Table 5.4. These values have been derived based on the water quality data provided by OGNZL and based on analysis of typical distributions of the data, a ±30% distribution is applied to the values within the Monte-Carlo simulations.

These source terms are applied in the model based on the following definitions:

– **Natural** is used to define areas that have not been affected by modern mining operations. This may include native/non-native forestry, farmed land and wetlands among other land uses. Natural source terms are applied to all undisturbed (my mining) catchments.

– **Impacted** areas are influenced by mine operations and disturbance is typically near the natural surface only, for example, haul roads, workshop areas and exploration activities.

– **Impacted-Rehabilitated** includes areas that have been impacted, then rehabilitated through establishing vegetation. This surface type is nominally considered to be equivalent to ‘natural’ surfaces once rehabilitated.

- **WRS** (Waste Rock Stack) is surface areas of mined rock placed for purpose of stockpiling or producing a WRS and does not have established vegetation.
- **WRS-Rehabilitated** includes areas that have been WRS, then rehabilitated through establishing vegetation. Typically, this is grass cover suitable for grazing stock.

Table 15 Surface Water quality source terms – mean value inputs

Parameter (g/m^3)	Natural	Impacted	Impacted Rehabilitated	WRS	WRS Rehabilitated
Ammoniacal N	0.01	0.120	0.01	0.500	0.010
Arsenic	0.0025	0.037	0.0025	0.011	0.011
Copper	0.001	0.0012	0.001	0.0018	0.0011
Hardness	100	1000	100	200	220
Iron	0.1 - 0.2	0.2	0.2	0.079	0.079
Lead	0.00015	0.0002	0.00015	0.00015	0.00015
Nitrate N	0.15	0.015	0.15	1.0	0.4
Sulphate	10	930	10	470	150
Zinc	0.0015	0.0015	0.0015	0.0012	0.0012

Pit lake surface water quality utilised in the model is as presented in MWM 2023a. The pit lake water quality has been derived by developing source terms for each component of the GHD pit water balance and modelling of the annualised pit lake concentrations in a hydrogeochemical pit lake model. The time series plots of sulphate and Nitrate N presented in MWM 2024 have been utilised within the WBM.

5.5 Groundwater Quality

The groundwater quality parameters applied to WRS and TSF seepage waters within the WBM are defined in Table 10. The relative mass discharging to the receiving surface water environment is calculated within the WBM utilising the defined sulphate concentration, the area of the WRS / TSF and the relative infiltration / seepage volumes.

5.6 Model Domain

The model domain is centred on and around the IMOP and FROP area and extends north west to include Deepdell WRS and Pits, Coronation WRSs and Pits to the Mare Burn, south east and west to include the Frasers WRS South and east to encompass the TTTSF. The key areas associated with the FRIM area and final landforms are highlighted on Figure 31. The model domain covers the area required to assess the incremental effects of mining IM9-10, the FTSF and infilling of the Golden Point Open Pit. The model also encompasses the Coronation and Golden Bar areas and allows assessment of the cumulative effects of the MPIV project and associated compliance associated with the site. The effects of the proposed CO6 development within the Mare Burn catchment are isolated from the effects within the Deepdell Creek and are reported separately in GHD, 2024a. The full model domain including the Coronation and Golden Bar areas is shown in **Appendix A-3** (Figure   and Figure).

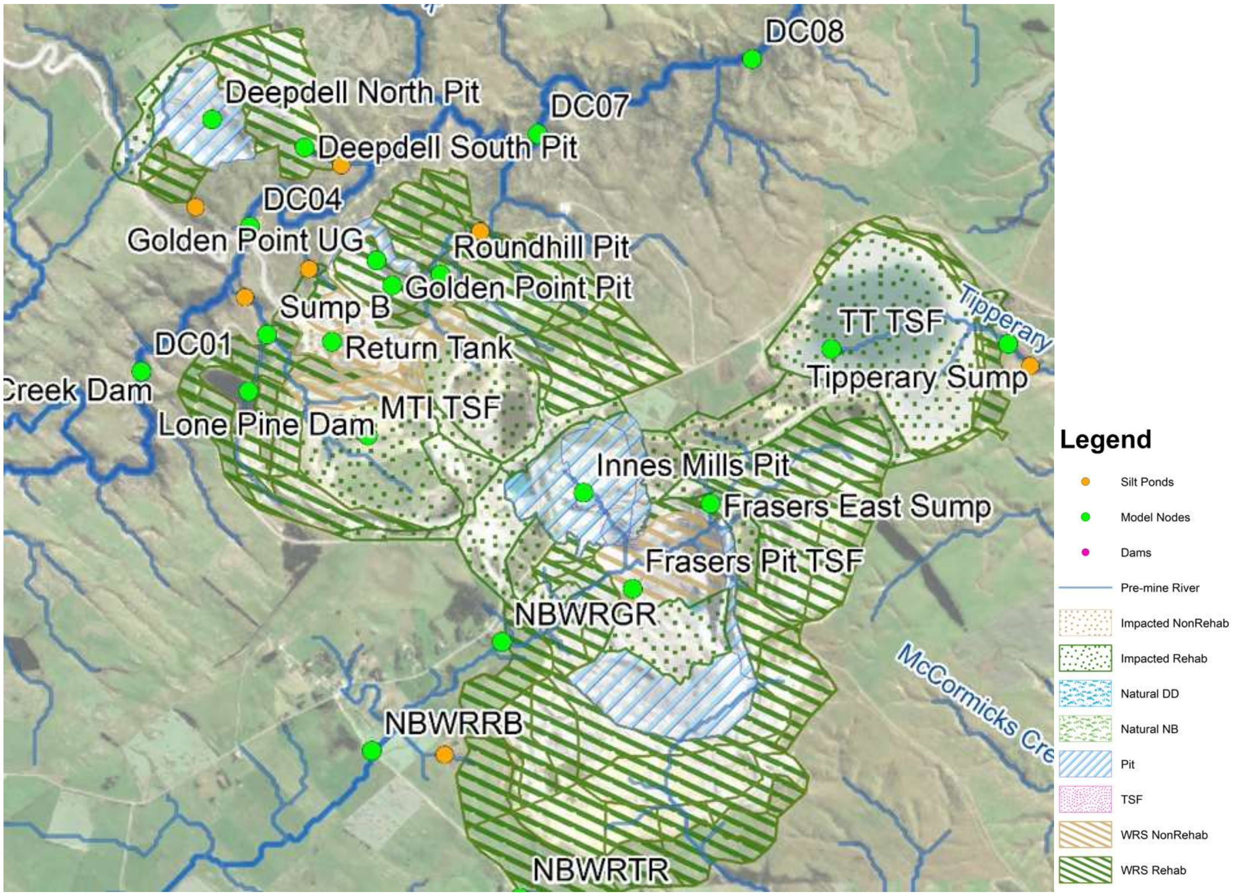
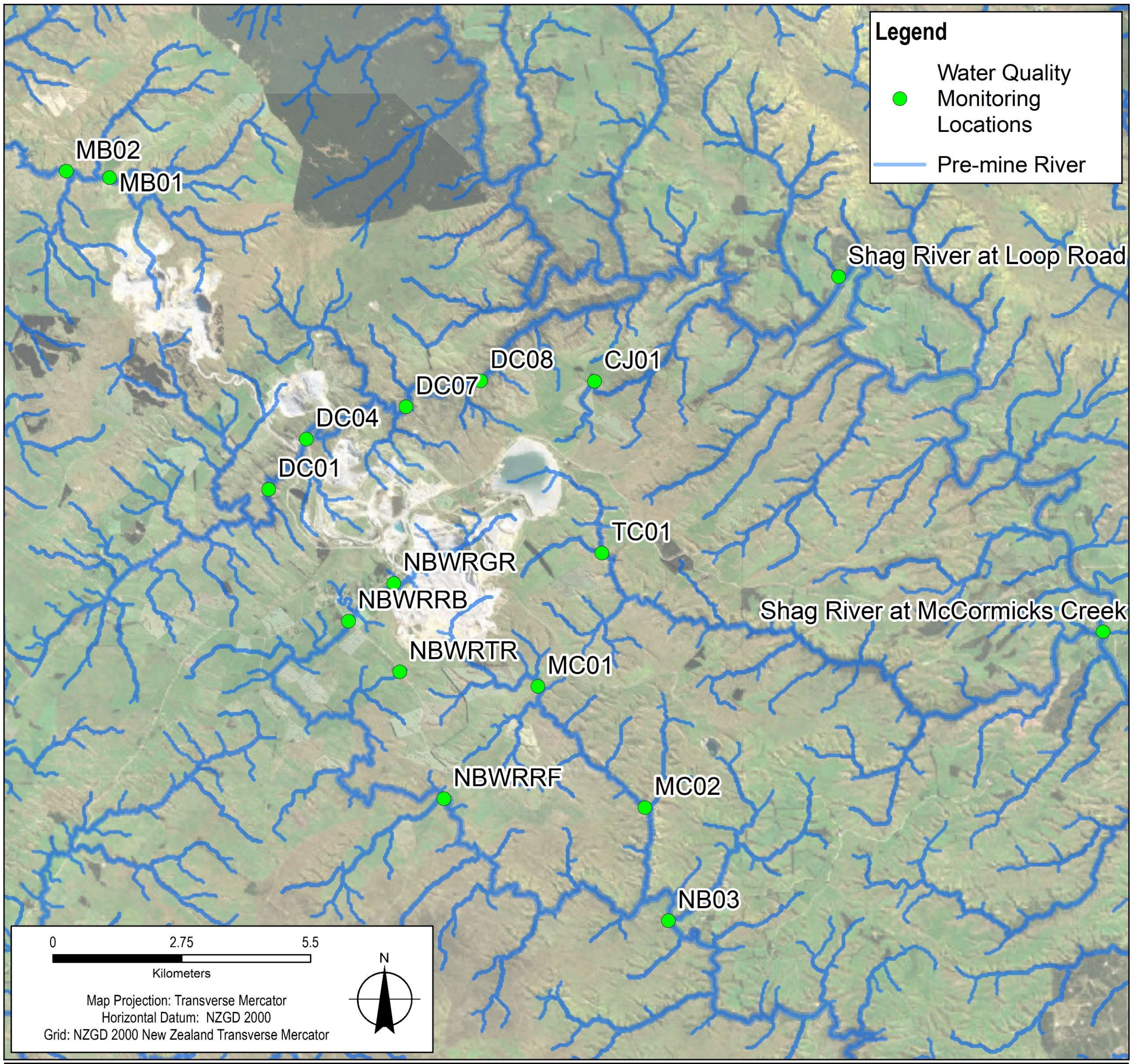


Figure 31 Model domain depicting closure land forms within the vicinity of FROP and IMOP

5.7 Existing Water Quality Compliance Criteria

The proposed MPIV development will influence waters discharging to NBWR, the Deepdell Creek and the Mare Burn, the latter two tributaries ultimately draining to the Shag and Taieri Rivers respectively. Effects to the Mare Burn are covered in GHD, 2024a and effects to Cranky Jim's Creek and Tipperary Creek (as a result of the TTTSF crest raise) are covered in GHD, 2022a. Established water quality monitoring and compliance points relevant to this assessment on the NBWR, Deepdell Creek, Mare Burn and the Shag River are shown in Figure 32. The cumulative surface water assessment presented here is compared to the existing surface water quality compliance criteria. A summary of compliance criteria associated with these locations (with the exception of the Mare Burn, Cranky Jim's and Tipperary Creek) are provided in Table 16.



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Data source: Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors Created by:eosborn

Figure 32 Water quality monitoring and compliance locations in the Waikouaiti River North Branch, Deepdell Creek

Table 16 ***Summary of current existing consented water quality criteria***

Parameter	DC07	DC08	Shag River at McCormicks	Shag River at Loop	MC02	NBWRRF	NB03
Resource Permit		RM120.024.14	RM10.351.13, RM10.351.20 RM10.351.23	RM20.024.14	RM2002.491, RM2002.759, RM2002.763	RM20.167.04	RM10.351.08, RM10.351.11 RM10.351.12
Arsenic (g/m^3)	0.02	0.15	0.01	0.01	0.15	0.15	0.01
Copper (g/m^3)*	0.009	0.009	0.009	0.009	0.009	0.009	0.009
Iron (g/m^3)	1	1	0.2	0.2	1	1	0.2
Lead (g/m^3)*	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
Zinc (g/m^3)*	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Sulphate (g/m^3)	1000	1000	250	250		1000	250
pH (range)		6.0-9.5	7.0-8.5	7.0-8.5	6.0-9.5	6.0-9.5	6.0-9.5
Nitrate-N, NO_3-N (g/m^3)		≤2.4 median; <3.5 95th%					2.4 median#
Ammoniacal Nitrogen NH_4-N (g/m^3)		0.24#					0.24#

* Copper, lead and zinc standards shall be hardness related limits. Values given in the tables above assume a hardness of 100g/m3 $CaCO_3$.
# DC08 has no compliance for Ammoniacal N, however the MB02 limit is implied to be applicable at DC08 as a term of reference
# NB03 has no compliance for Ammoniacal N or Nitrate-N, however the MB02 limits are implied to be applicable at NB03 as a term of reference

5.8 Modelling Scenarios

Modelling covers the full time-domain from present day to long-term operation following overtopping of the pit lake. Within this time domain three key phases of the project are considered, these are:

1. **Mining** – During active mining where WRSs are under construction and pits are being dewatered and excavated. Active management of mine water is in place.
2. **Closure** – All surfaces are rehabilitated (other than pit walls), most pits not yet overflowing, seepage from WRSs may not have reached peak predicted water quality and flow rates, active return pumping of TSF underdrains maintained.
3. **Long-term** – Pits that are projected to overflow have reached the overflow, all surfaces are rehabilitated (other than pit walls), seepage from WRSs have reached peak predicted values, all mine waters discharging to the environment other than where in-perpetuity pumping and treatment provisions are made.
4. **Long-term + Climate Change** – Equivalent to Phase 3 with the addition of climate change effects on rainfall and evaporation.

The summary of the modelled scenarios and their corresponding reported dates / date ranges are outlined in Table 17. Corresponding outputs from the groundwater model are also provided for comparison. The groundwater modelling component of the Coronation assessment predicted a low sulphate mass flux into the Deepdell catchment (<1 kg/day) – this mass is considered insignificant and is not included within the WBM.

Table 17 Summary of modelling scenarios

Scenario / Reference	Phase	Surface Water Model (Reporting years)	Groundwater Model Output (Years post closure / Year)	Description
1	Mining	2027-2029	N/A	During active mining
2	Closure	2045-2050	20 (2050)	Following full rehabilitation
3	Long Term	~2230+	200 (2230)	Following overflow of the Pit Lakes (Coronation, Golden Bar and Deepdell North) and tending towards a hydraulic and mass flux steady state.
4	Long Term + CC	~2230+	200 (2230)	Following overflow of the Pit Lakes (Coronation, Golden Bar and Deepdell North) and tending towards a hydraulic and mass flux steady state. Climate Change Scenario

5.8.1 Key water management assumptions

- Dewatering from pits during mining operations is not represented in the water quality outcomes. These operations are undertaken with a degree of manual control and could be inaccurately reflected in a predictive model. Dewatering is also undertaken within a short time frame early in the modelled time frame and it is assumed that these discharges are undertaken based on existing consent requirements and done in a manner not to negatively impact water quality or aquatic ecology within the receiving environment. Alternatively, these waters are recycled within the mine water management system and reused on site within the 'closed' processing plant water circuit. The dewatering of Golden Bar pit is covered in GHD, 2023c.
- Intermittent seepage from historic mine adits has been observed in the vicinity of Golden Point. It is assumed that the backfilling of Golden Point Pit will also include measures to control seepage through these workings in the long term and as such, this seepage has not been included in the modelling undertaken.
- Rehabilitation of waste rock surfaces is undertaken progressively and completed promptly on completion of mining.
- TSS levels discharging to the receiving environment are managed using appropriately sized siltation ponds and other sediment and erosion protection measures.
- During the mining phase all operational waters are managed on site and remain within a closed system. For example, water from the tailing's impoundments (including captured seepage) is recirculated and re-used for mine operations. Losses of these waters to the environment is through either uncaptured seepage to ground or evaporation.
- Sulphate concentrations from the WRSs are calculated as per MWM, 2023 and the assumed WRS heights are as defined in Table 10.
- Seepage is generally assumed not treated. Where treatment is assumed (ie. via Passive Treatment Systems (PTS)) it is explicitly stated.
- Seepage from WRSs is modelled based on an increase with time to a maximum predicted value. The potential for seepage concentrations to reduce from this maximum due to depletion of contaminant sources is not accounted for.
- All contaminants are assumed to be conservatively transported within both the groundwater and surface water environments on a mass balance basis.
- Following the mine closure period (ending 2050), it is assumed that provision is made for infrastructure to capture and treat all remaining seepage flows from TSF underdrains and discharge is done in a manner that does not adversely affect the receiving surface water environment.

– Seepage reporting to Murphys Creek includes resultant seepage from infiltration (to the WRS only). Additional seepage as a result of the rising FRIM Pit Lake level (above the pit rim of 487 m RL on which waste is stored) is assumed pumped back to the FRIM Pit Lake.
– The freshwater dilution dam at Camp Creek (or an alternative source of augmentation water) is available upon mine closure and can augment the flow within Deepdell Creek at a maximum rate of 20 L/sec during low flow periods (unless overflow should occur), reducing to a minimum discharge of 2 L/s at DC04 flows above 50 L/s as per Figure 33.

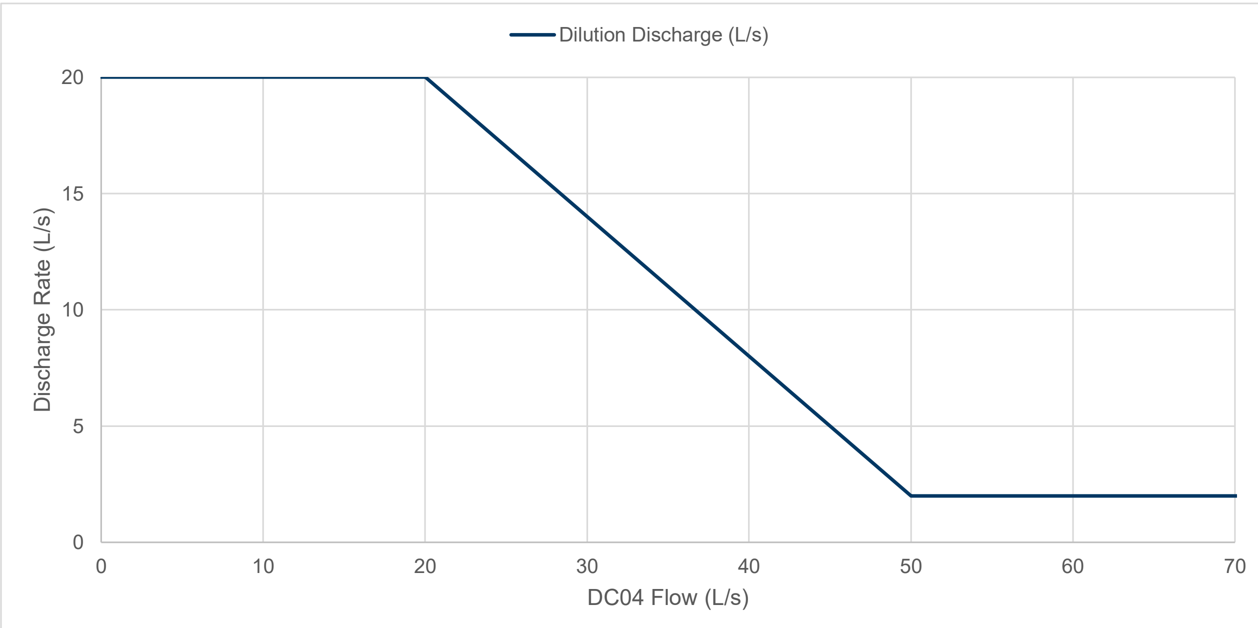


Figure 33 Dilution rating curve for discharges from the proposed Camp Creek Fresh Water Dam to Deepdell Creek.

– The assumed collection and controlled discharge of seepage associated with the Frasers and Golden Bar WRSs is described in Section 5.12.

5.9 Inputs from Groundwater Modelling

Groundwater interaction with the Pit Lakes is applied based on the groundwater inflows and outflows as outlined in Section 4.2.6.

Groundwater fluxes are explicitly represented in the WBM for discharges to the receiving environment for:

– TTTSF to Cranky Jims Creek and Tipperary Creek as described in GHD 2022a, and
– To Deepdell Creek as determined by groundwater modelling presented in this report, specifically the contaminant flux associated with pit seepage component from Coronation, Golden Point, MTI and SP11 and other WRSs reporting to Deepdell (Table 11).

Seepage fluxes from the WRSs are represented in the WBM based on a recharge rate of 29.2 mm/yr or a calibrated value to seepage flow monitoring where site data is available. Mass fluxes associated with these flows are represented for key constituents based on the relationships defined in MWM, 2023.

The contour plots from the groundwater modelling presented in Section 4.2.6.3 show the extent of the predicted sulphate plume and the groundwater modelling illustrates that the flux is largely confined to the upper weathered schist layers. This flux (where it's sourced from WRS and/or TSFs) is considered to be conservatively represented within the WBM utilising the relationships (WRS sulphate seepage concentrations) as defined in MWM, 2023. The estimated sulphate flux from the groundwater modelling is provided in

Table 11. These estimated sulphates fluxes are compared to estimated fluxes within the WBM to identify where additional mass fluxes are reaching the receiving environment. Additional loading in the groundwater model not reflected in the WBM (ie. due to solute transport from pit lakes through waste rock and/or the underlying schist material), has been added to the WBM to reflect this additional load. These additional loads (from the groundwater modelling) and what they represent are outlined in Table 18.

The WBM is shown to represent higher mass fluxes to the upper reaches of the NBWR and Murphys Creek. The key reason for this is that the WBM applies higher basecase recharge rates to WRSs draining to these catchments (60 mm/yr to Frasers West and Frasers South WRSs, 90 mm/yr to Golden Bar WRS and 47 mm/yr to Frasers East WRS) than the groundwater model (29.2 mm/yr) which reflects fully rehabilitated surfaces at closure. The higher basecase infiltration rates (where applied) are based on monitoring data from the site. When reduced infiltration rates are applied to the WBM (reflective of future rehabilitation efforts), the predicted sulphate mass flux within the WBM is subsequently reduced and mass flux estimates align more closely with the groundwater model (Table 18). The long-term mean discharge from the WBM also includes mass from runoff and applies a ±30% distribution to seepage estimates. Given these points: higher infiltration, additional mass from runoff and distribution in seepage estimates, it is considered that the ground water modelling shows good alignment with estimates from the WBM and where there is misalignment, the WBM is generally conservative.

Table 18 WBM adjustments based on ground water modelling for long term ground water and seepage discharges

Receiving Environment	GWM Mean Sulphate Mass Flux (kg/day)	WBM Mean Sulphate Mass Flux (kg/d)	WBM Adjustment (kg/day)	Model Node / Source
Deepdell Creek	861	810		Shag River at Loop Road
Waikouaiti River North Branch (to NBWRRF)	116	736[358][1]	Long term reduction in seepage modelled through reduced WRS recharge	Frasers West WRS
Murphys Creek	290	1,336 [650][1]	Long term reduction in seepage modelled through reduced WRS recharge	Frasers South WRS
Golden Bar (GHD, 2023b)	80	193 [61][1]	Long term reduction in seepage modelled through reduced WRS recharge	
Tipperary Creek	128	138	10 kg/day added, representing additional uncaptured seepage mass from TTTSF	

[1]. Revised long term mean mass flux from GW seepage to receiving environment when rehabilitated WRS is applied (refer Table 20).

5.10 Results – Water Balance

The WBM has been applied to estimate filling rates for Frasers and Innes Mills Pit Lakes and estimate the long term equilibrium level. The pit lakes fill independently while lake levels are below the saddle of the FRBF embankment at 480 m RL with some level of interaction via seepage rates through the FRBF embankment from FROP to IMOP. Modelling projections (Figure 34) indicate that the embankment level could be reached approximately 51 years post closure (year 2081), following which water from FROP will spill to IMOP for a period until lake levels equalise. The combined FRIM pit lake is modelled to reach a long-term equilibrium of between 486 m RL and 494 m RL. Spill above the in-situ schist level on the northwest pit rim (497 m RL) is considered unlikely based on the modelling undertaken.

FRIM pit water levels above 487 m RL will potentially result in increased seepage through to Murphys Silt Pond (as a result of pit water seeping through the Frasers South WRS). All else being equal, as the water head on the WRS increases (with increasing pit water level), the volume of water seeping to Murphys will also increase. Water draining through this pathway is planned to be captured in the Murphys Silt pond and is pumped back to FRIM. Therefore, although an increased volume of water through this pathway is anticipated, no net effect on discharge volumes to the receiving environment is expected.

The filling results include 5th and 95th percentile estimates associated with expected variation in climatic conditions as the water bodies develop. These uncertainties do not account for uncertainties in the modelled groundwater inflow and outflow rates and these effects are considered separately in Section 5.4.1.

Figure 35 shows the sensitivity of filling to climate change through applying the RCP 8.5 scenario. The climate change projections are shown to result in a more rapid rate of lake filling with increased long-term equilibrium lake levels. Table 19 shows the long term lake level statistics.

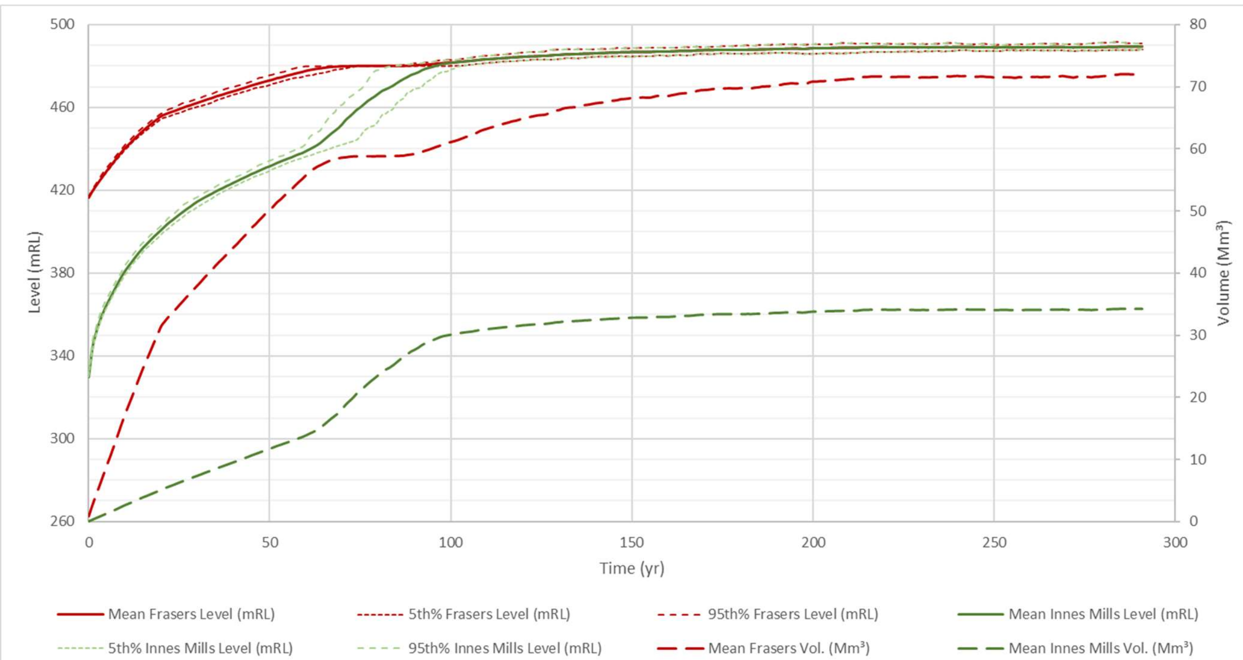


Figure 34 Pit Lake filling assessment

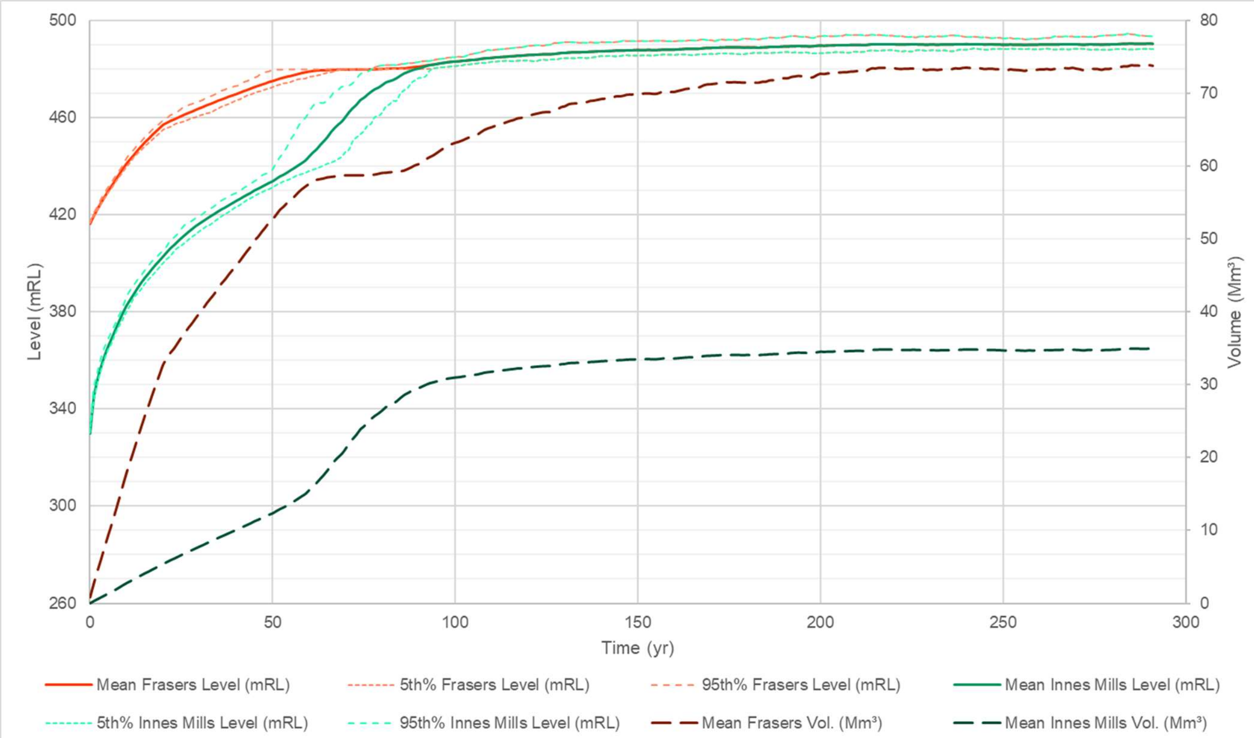


Figure 35 Pit Lake filling assessment – Climate Change Scenario

Table 19 WBM Model Run FRIM Pit Lake Milestones / Comparison

	Basecase line (mean)	**Basecase Run (5th %ile)**	**Basecase Run (95th %ile)**	**Climate Change Run (mean)**	**Climate Change Run (5th %ile)**	**Climate Change Run (95th %ile)**	**Minimum Predicted**	**Maximum Predicted**
Top of Embankment Reached (model year / actual year)	77 (2104)	86 (2146)	71(2115)	69(2098)	93 (2122)	51 (2081)	51 (2081)	117 (2146)
FRIM Pit Lake Formed (model year / actual year)	110 (2139)	119 (2148)	97 (2126)	89 (2118)	94 (2123)	78 (2107)	78 (2107)	119 (2148)
m RL @ 100 years	480	480	481	483	481	485	480	485
m RL @ 200 years	487	484	489	490	486	494	484	494
m RL @ 275 years	487	486	489	490	488	494	486	494

The key inflows to the FROP and IMOP water balance are direct rainfall and surface runoff with evaporation and groundwater loss the key outflows (Figure 36 to Figure 39).

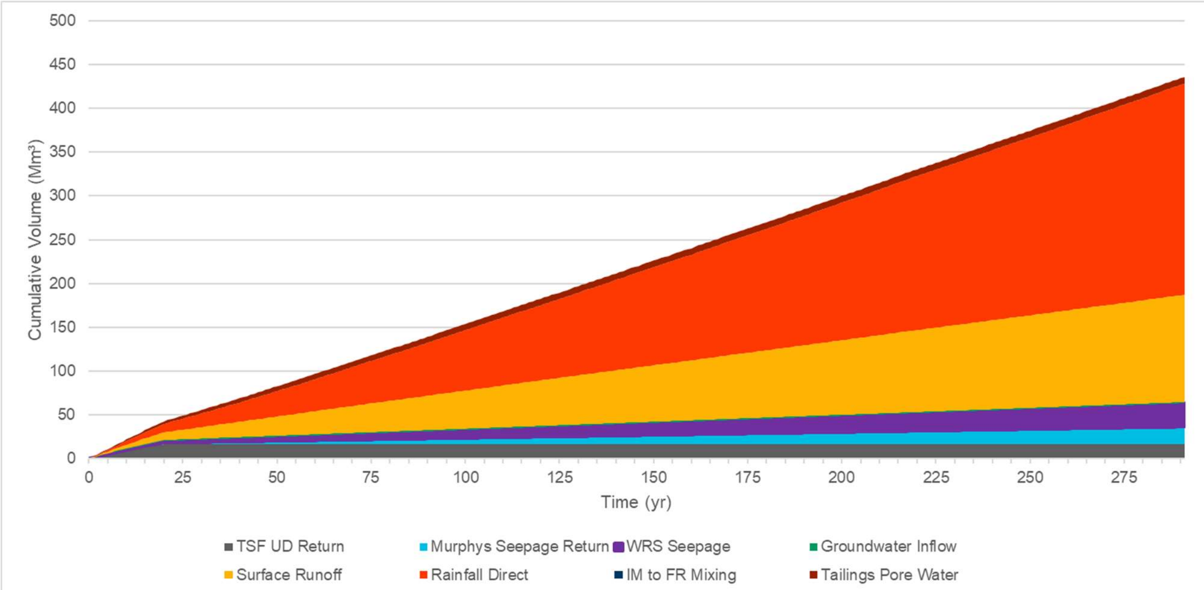


Figure 36 ***Frasers Pit Lake cumulative water inflows once filling commences.***

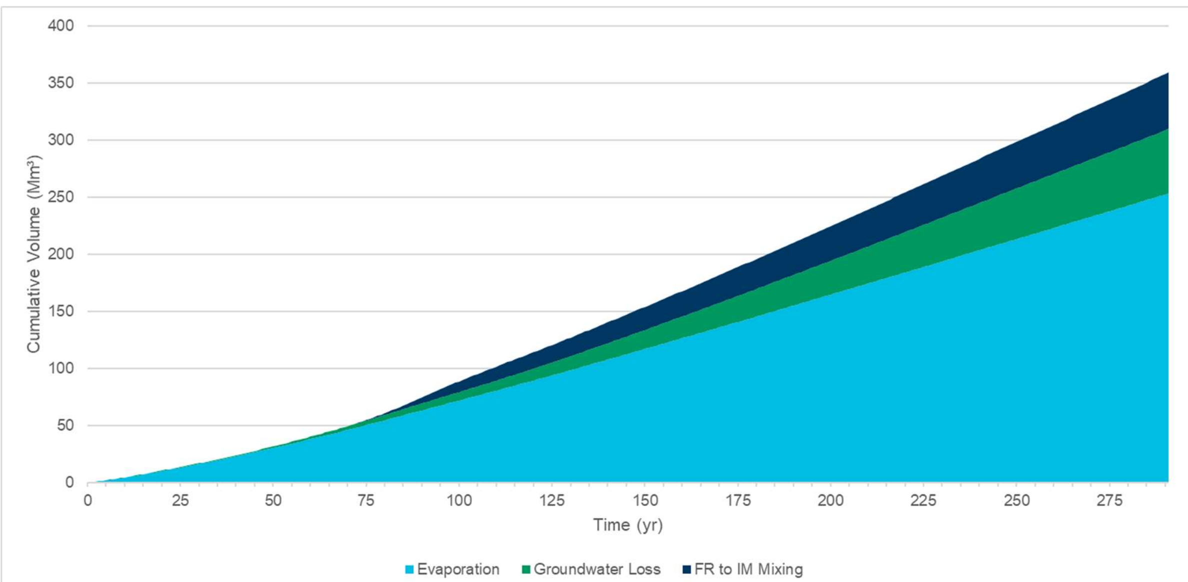


Figure 37 ***Frasers Pit Lake cumulative water outflows once filling commences.***

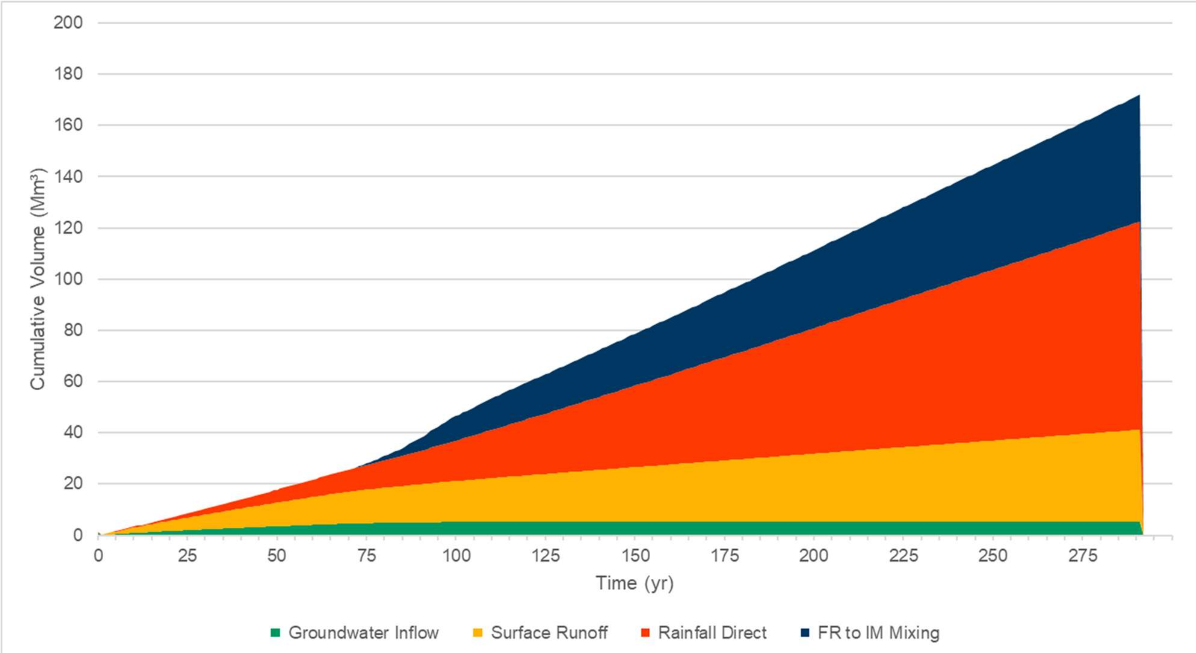


Figure 38 ***Innes Mills Pit Lake cumulative water inflows once filling commences.***

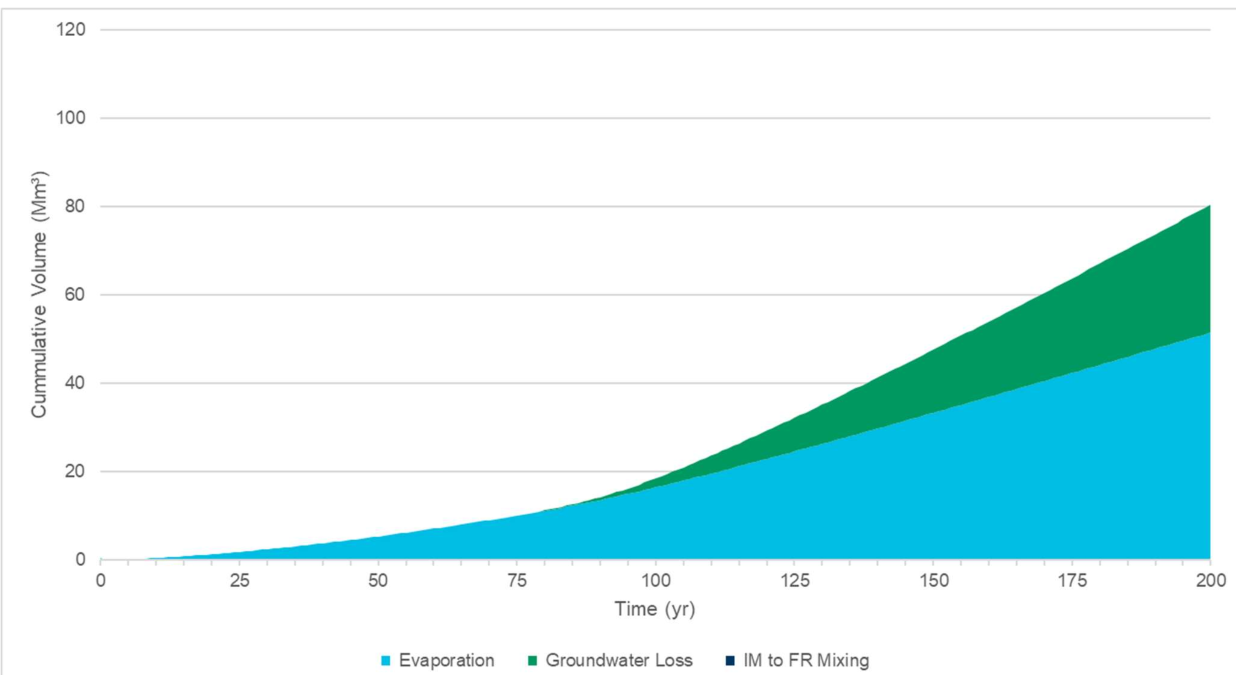


Figure 39 ***Innes Mills Pit Lake cumulative water outflows once filling commences.***

5.11 Results – Water Quality – Deepdell/Shag Catchments

The proposed Phase IV project includes development of the IMOP pit as well as the development of the Frasers backfill, FTSF, formation of the FRIM pit lake, Golden Bar Stage 2 development, Coronation Stage 6 pit expansion and Golden Point backfill. These developments result in additional flow and mass fluxes to Deepdell Creek via:

- Overflow from the Coronation Pit Lake,
- Seepage from the combined FRIM Pit through the in situ shist and waste rock embankment,
- Runoff from the Golden Point waste infill surface, and
- Seepage from the Golden Point waste infill.

The water quality results are presented at monitoring and compliance points DC07, DC08, Shag River @ Loop Road and Shag River @ McCormicks. Selected contaminants (comprising Sulphate, Ammoniacal N, Nitrate N, Arsenic and Iron) predictions are presented for each location where they are considered key elements in terms of the current and predicted future impacts. The modelled results of these constituents are also within the range of consented limits applied to other surface water bodies within the wider MGP area. Other consented constituents (cyanide, copper, lead and zinc) are typically lower in the receiving water bodies and modelled concentrations are generally well below the stated compliance limits. Where there are existing consent limits applied in previous consents, these limits are displayed on the figures for reference. Selected modelled statistical outputs for the key contaminants of concern are presented in **Appendix F**.

Concentrations are presented as concentration exceedance curves based on statistics from multiple realisations of the model. With this approach, where an exceedance is rare, this exceedance may be a result of specific hydrological conditions that occur on a given day/s for a given model run, and does not always guarantee the outcome will occur. Where exceedances are more common, typically they occur across multiple iterations of the modelling and may last for a discrete number of days or extended periods.

5.11.1 Basecase

The basecase scenario assumes the following:

- Collected seepage from the MTI and SP11 tailings facilities, along with seepage from the backfilled Golden Point Pit and Northern Gully WRSs is collected within the Battery Creek and Maori Tommy Silt Ponds from which discharge is controlled by relative inflows and evaporation such that overflow during low flow periods is limited (ie. the model optimises the operation of the silt ponds at closure).
- The construction and operation of the Camp Creek reservoir is not included.

5.11.2 Proposed Mitigation Options (Flow Augmentation)

The proposed mitigation option includes all measures as outlined in the basecase scenario with the additional construction of the Camp Creek reservoir or alternative source of dilution water (flow augmentation) allowing for flow augmentation during low flow periods.

5.11.3 Deepdell Creek – DC07

The modelled Sulphate concentrations at DC07 are given in Figure 40 and Figure 41 for the three key phases considered for the scenarios with (mitigation option) and without dilution from flow augmentation (basecase). Sulphate concentrations are predicted to increase post closure due to an increase in sulphate concentration and mass from seepage waters (associated with pit and WRS development) and Coronation pit lake overflow into Deepdell Creek. In terms of compliance with the existing 1,000 mg/L compliance limit, the probability of exceedance of this limit is considered small (<0.5%) with or without flow augmentation, however in river sulphate concentrations are generally lower when the flow augmentation is operational. This is particularly the case during low flow periods. The basecase does however assume that overflow water from the Maori Tommy and Battery Creek Silt Ponds (which are estimated to ultimately collect large volumes of the seepage waters draining to the Deepdell Creek) operate so that no (or a very limited) volume of water spills to Deepdell Creek during low flow events. Spill events from these silt pond during low flow events could potentially result in sulphate concentrations up to 1,500 mg/L at DC07 when no additional dilution is present (ie. No flow augmentation).

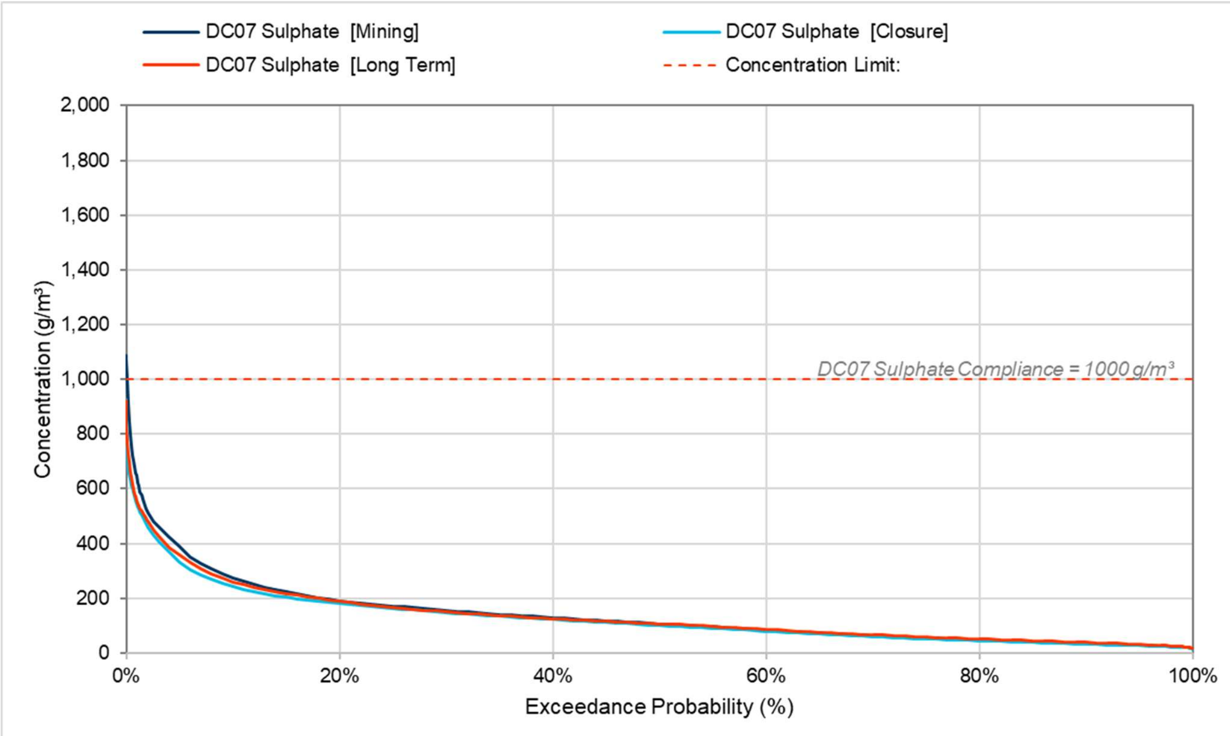


Figure 40 DC07 Sulphate – Modelled probability exceedance – Mitigation + Flow Augmentation

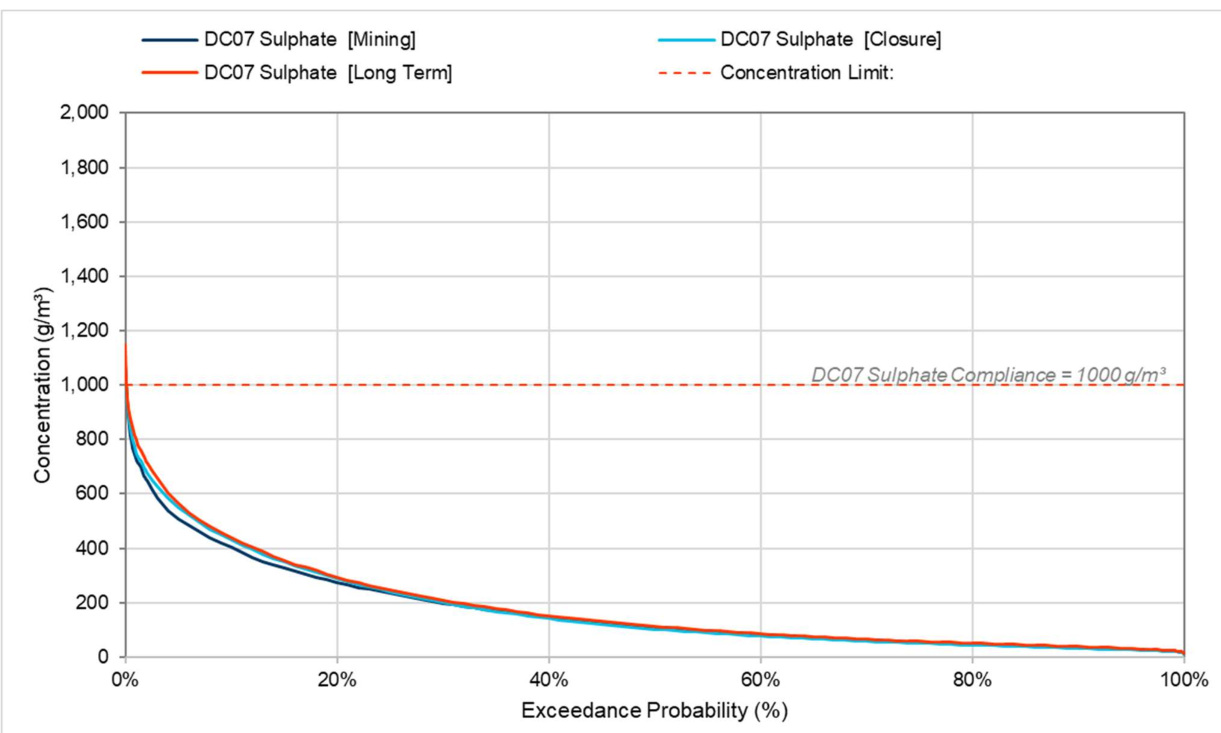


Figure 41 DC07 Sulphate – Modelled probability exceedance – Basecase + No Flow Augmentation

The modelled Nitrate N concentration exceedance curves for DC07 are given in Figure 42 and Figure 43 for the three key phases considered for the scenarios with and without the flow augmentation. Concentrations are reasonably stable over all mining phases presented with a minor elevation noted during the mining phase in the Mitigation scenario. This is the result of the flow augmentation becoming operational part way through the defined mining phase.

In terms of compliance with the annual median 2.4 mg/L and annual 95%ile 3.5 mg/L compliance limits, the water quality at DC07 is expected to be in compliance in the mitigation scenario with flow augmentation. The modelled exceedances of the 95th%ile 3.5 mg/L during the mining phase is likely to be within statistical limits of the 95%ile results over an annual period.

In the basecase scenario without the flow augmentation water, exceedances of the 95%ile limit (3.5 mg/L) are modelled to occur approximately 5% of the time for all mining and post mining phases. This will likely result in exceedance of the 95% limit during prolonged low flow periods.

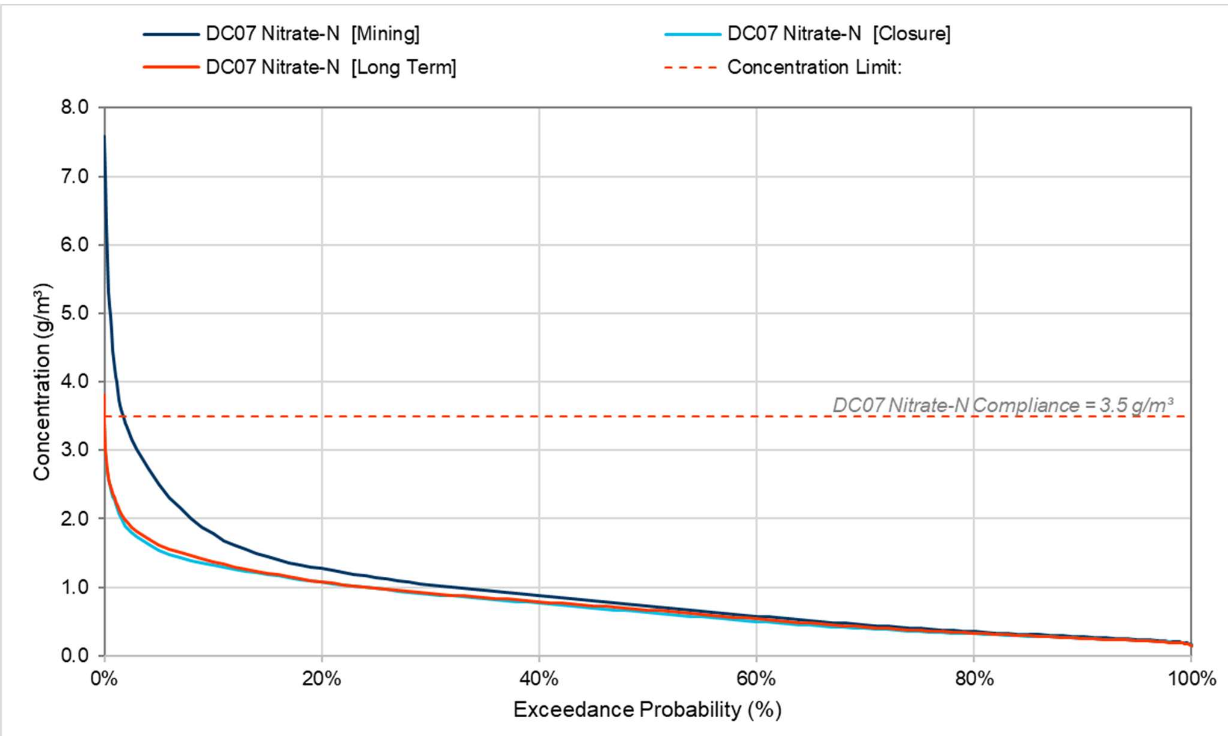


Figure 42 ***DC07 Nitrate N – Modelled probability exceedance – Mitigation + Flow Augmentation***

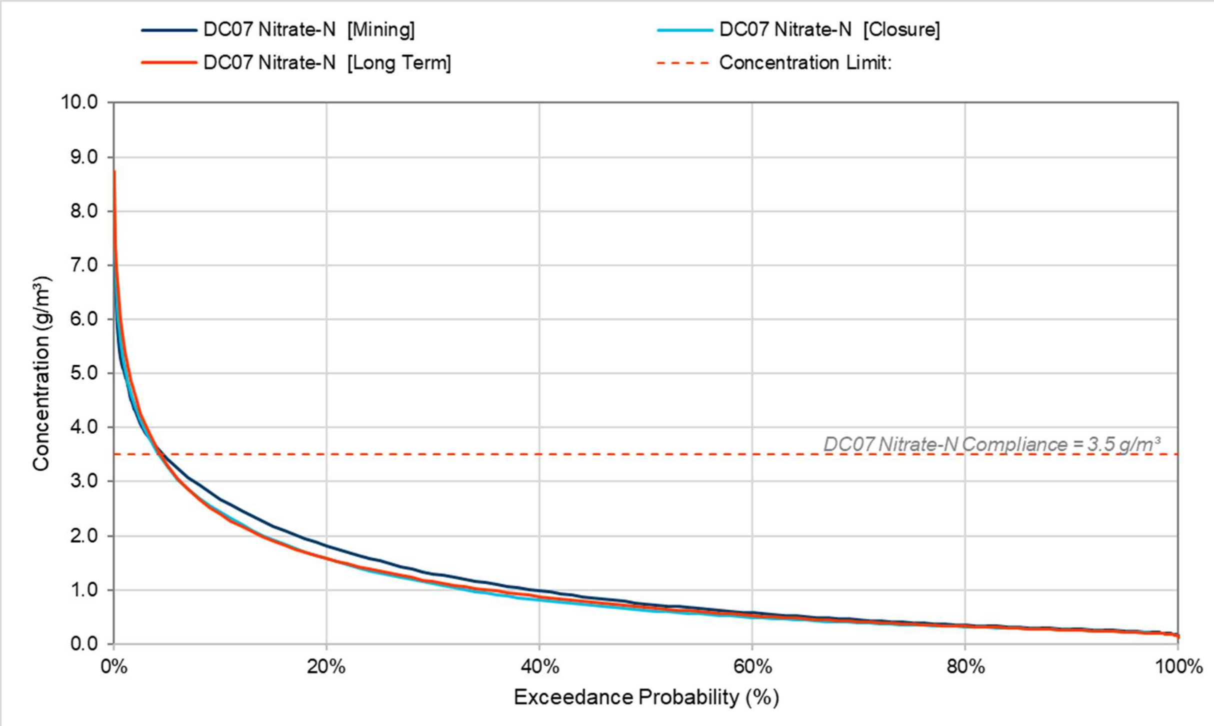


Figure 43 DC07 Nitrate N – Modelled probability exceedance – Basecase + No Flow Augmentation

The modelled Arsenic concentration exceedance curves for DC07 are given in Figure 44 and Figure 45 for the three key phases considered for the scenarios with and without the flow augmentation operational. Concentrations are reasonably similar between both scenarios with elevated concentrations of arsenic noted during the mining phase. In terms of compliance with the limit of 0.02 mg/L, the water quality at DC07 shows exceedances during mining (approximately 4% risk of exceedance). This is associated with spill events from the Maori Tommy Silt Pond which reduce post mining due to the smaller volume of water entering these ponds. It is considered that this modelled risk of exceedance is easily mitigated during mining by operational controls and an increased rate of pumping back into the mine water system when required.

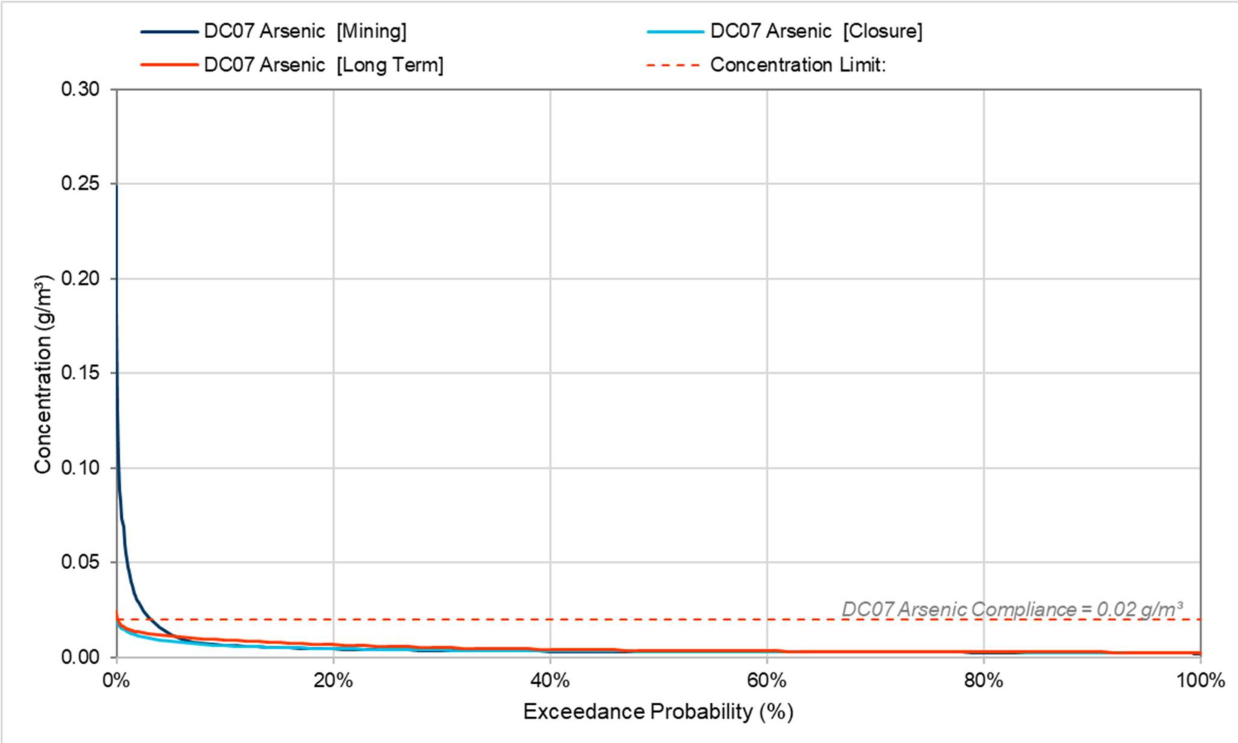


Figure 44 ***DC07 Arsenic – Modelled probability exceedance – Mitigation + Flow Augmentation***

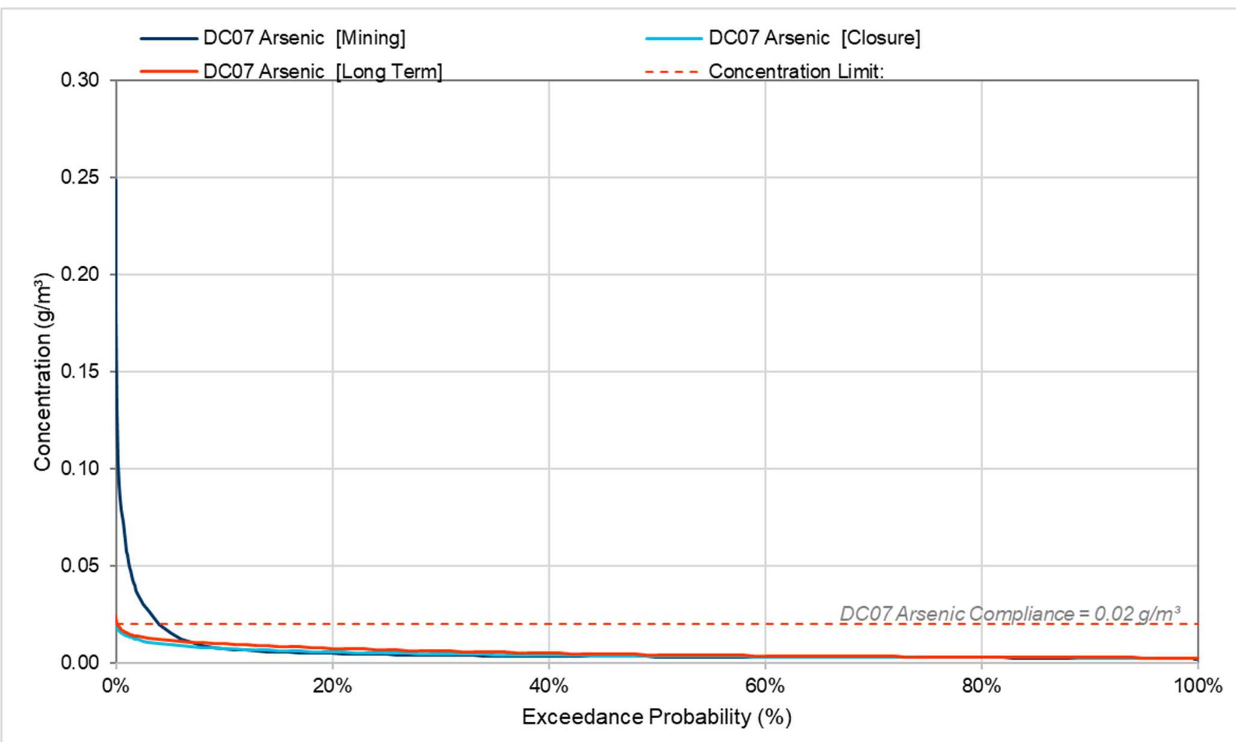


Figure 45 ***DC07 Arsenic – Modelled probability exceedance – Basecase + No Flow Augmentation***

5.11.4 Deepdell Creek – DC08

The modelled Sulphate concentrations at DC08 are given in Figure 46 and Figure 47 for the three key phases considered for the scenarios with (mitigation option) and without the flow augmentation operational (basecase).

Sulphate concentrations are predicted to increase post closure due to an increase in sulphate concentration and mass from seepage waters (associated with pit and WRS development) and Coronation pit lake overflow into Deepdell Creek. In terms of compliance with the existing 1,000 mg/L compliance limit, the probability of exceedance of this limit is considered small (<0.5%) with or without the flow augmentation, however in river sulphate concentrations are generally lower when the flow augmentation is operational. This is particularly the case during low flow periods. The basecase does however assume that overflow water from the Maori Tommy and Battery Creek Silt Ponds (which are estimated to ultimately collect a large volume of the seepage waters draining to the Deepdell Creek) operate so that no (or a very limited) volume of water spills to Deepdell Creek during low flow events. Spill events from these silt pond during low flow events could potentially result in sulphate concentrations up to 1,500 mg/L at DC08 when no additional dilution is present (ie. No flow augmentation

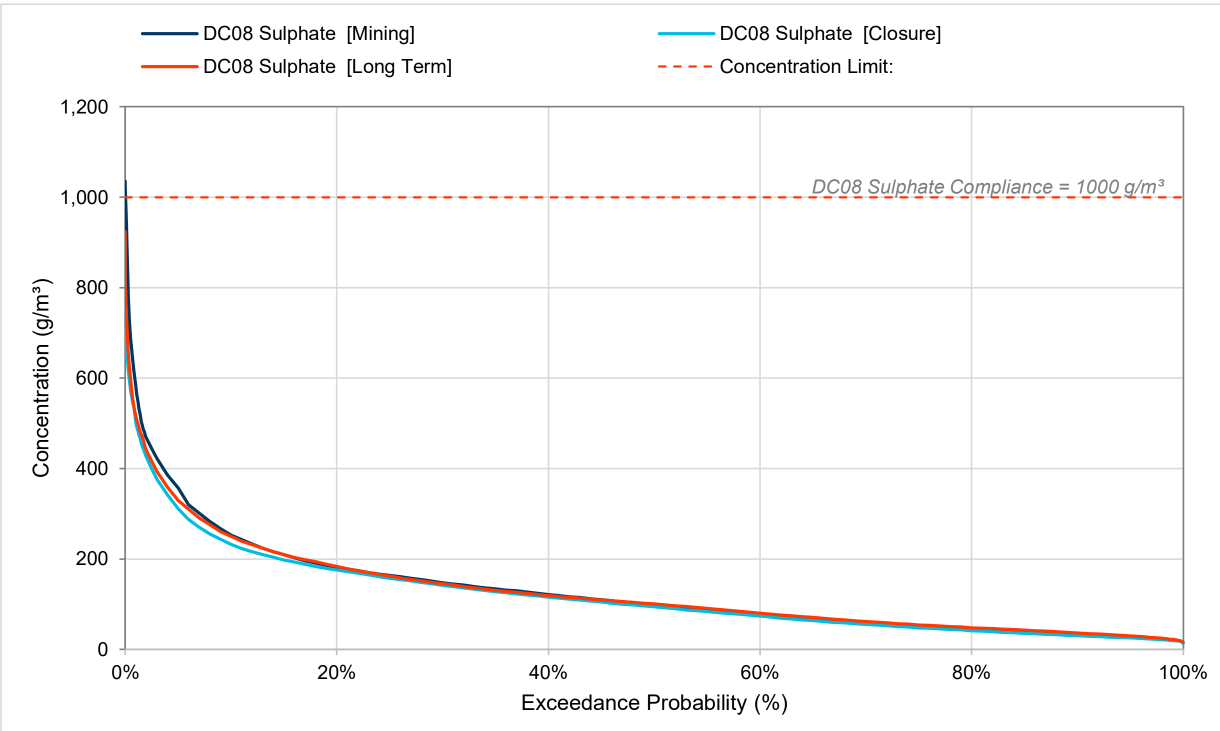


Figure 46 DC08 Sulphate – Modelled probability exceedance – Mitigation + Flow Augmentation

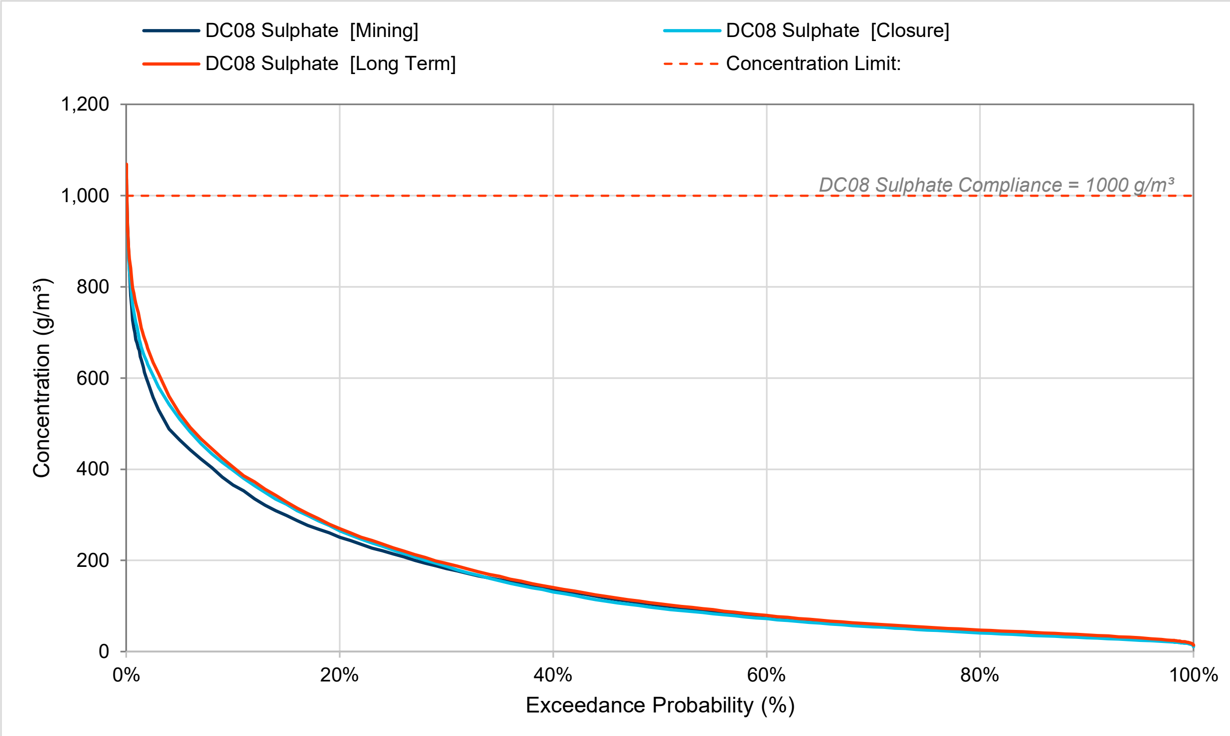


Figure 47 DC08 Sulphate – Modelled probability exceedance – Basecase + No Flow Augmentation

The modelled Ammoniacal N concentration exceedance curve for DC08 is shown in Figure 48 and Figure 49 for the scenarios with and without the flow augmentation operational. Concentrations are predicted to be the highest during mining and decrease at closure as surfaces are rehabilitated and the relative runoff concentrations decrease. There are no modelled exceedances for either scenario.

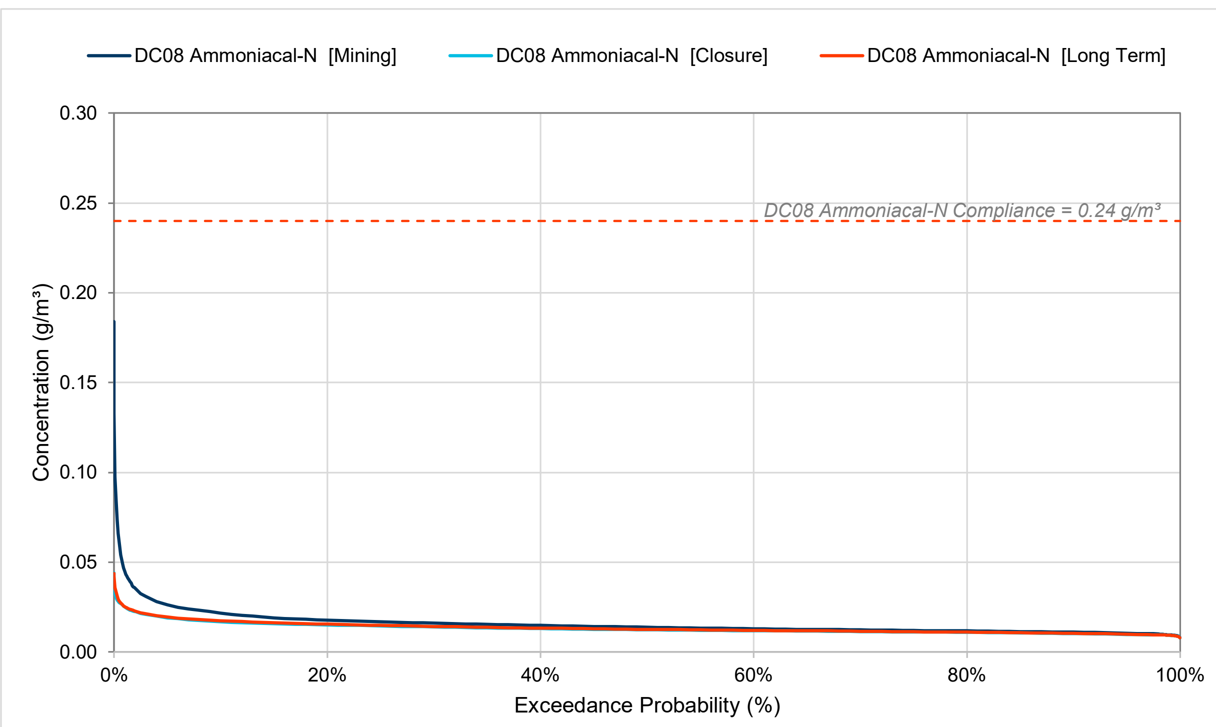


Figure 48 DC08 Ammoniacal N – Modelled probability exceedance – Mitigation + Flow Augmentation

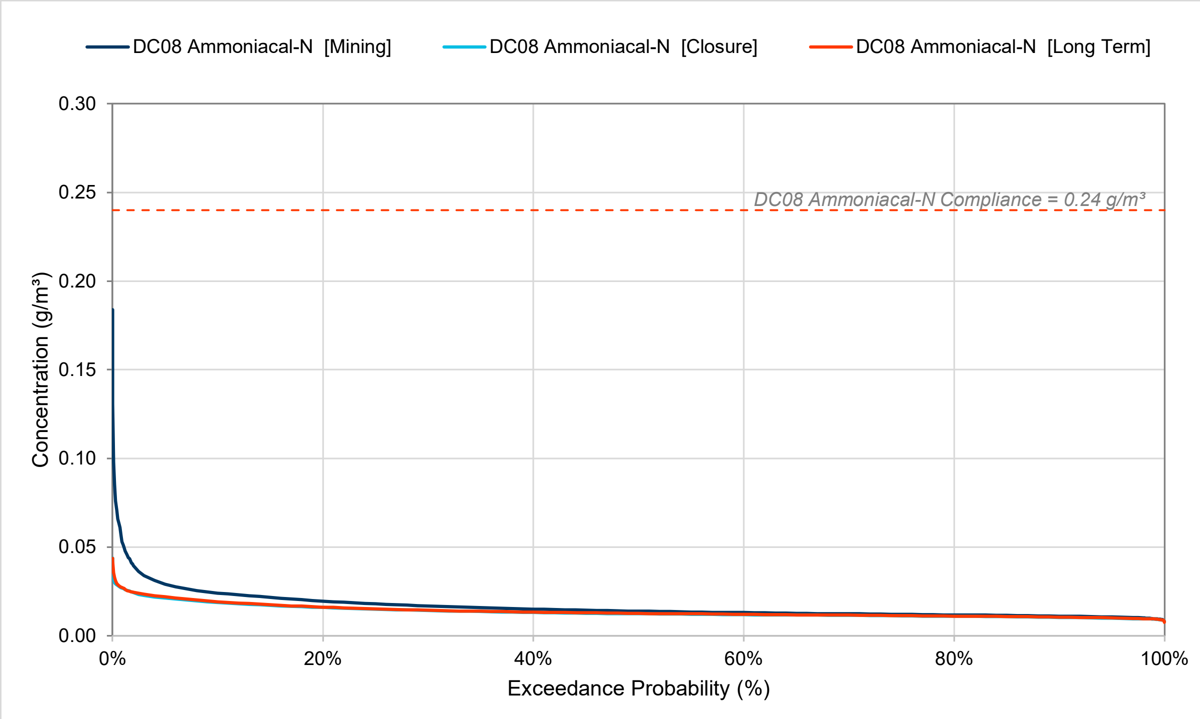


Figure 49 DC08 Ammoniacal N – Modelled probability exceedance – Basecase + No Flow Augmentation

The modelled Nitrate N concentration exceedance curves for DC08 are given in Figure 50 and Figure 51 for the three key phases considered for the scenarios with and without the flow augmentation operational. Concentrations are reasonably stable over all mining phases presented with a minor elevation noted during the mining phase in the Mitigation + flow augmentation scenario. This is result of the reservoir becoming operational part way through this period.

In terms of compliance with the annual median 2.4 mg/L and annual 95%ile 3.5 mg/L compliance limits, the water quality at DC08 is expected to be in compliance in the mitigation scenario with flow augmentation providing dilution water. The modelled exceedances of the 95th%ile 3.5 mg/L during the mining phase is likely to be within statistical limits of the 95%ile results over an annual period.

In the basecase scenario without the flow augmentation dilution water, exceedances of the 95%ile limit (3.5 mg/L) are modelled to occur approximately 5% of the time. This will likely result in exceedance of the 95% limit during prolonged low flow periods

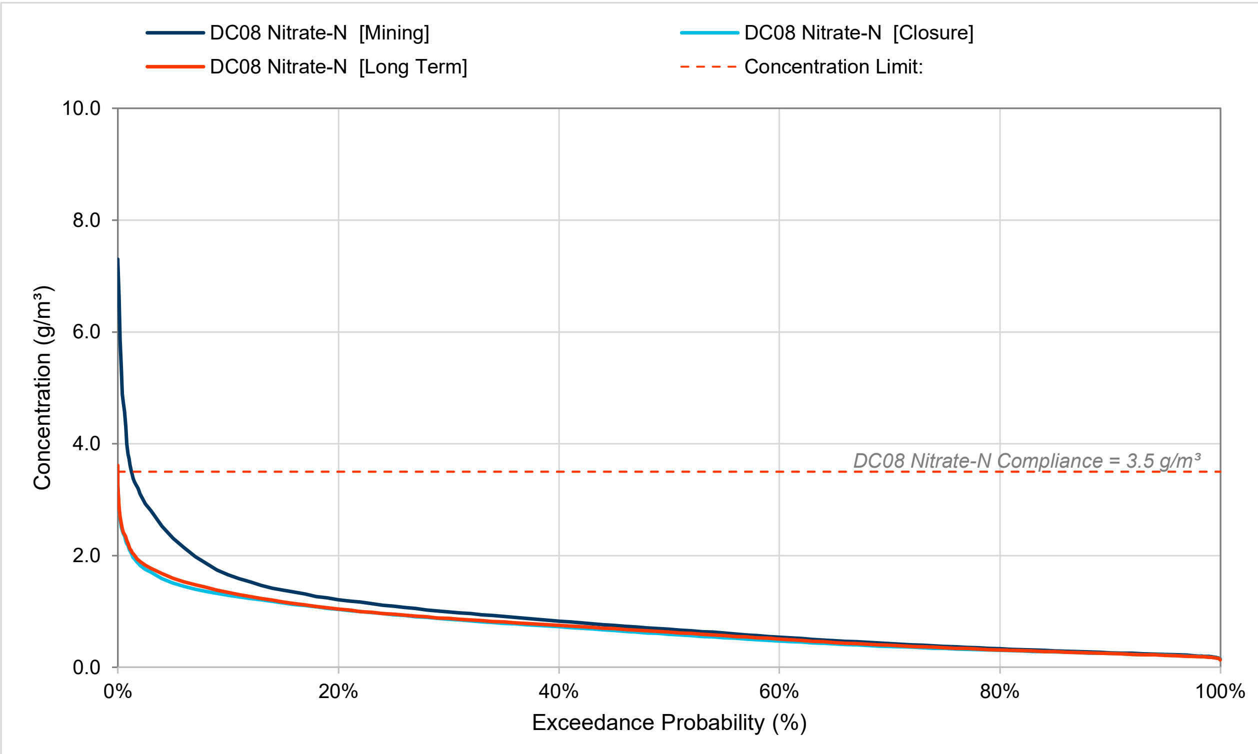


Figure 50 DC08 Nitrate N – Modelled probability exceedance – Mitigation + Flow Augmentation

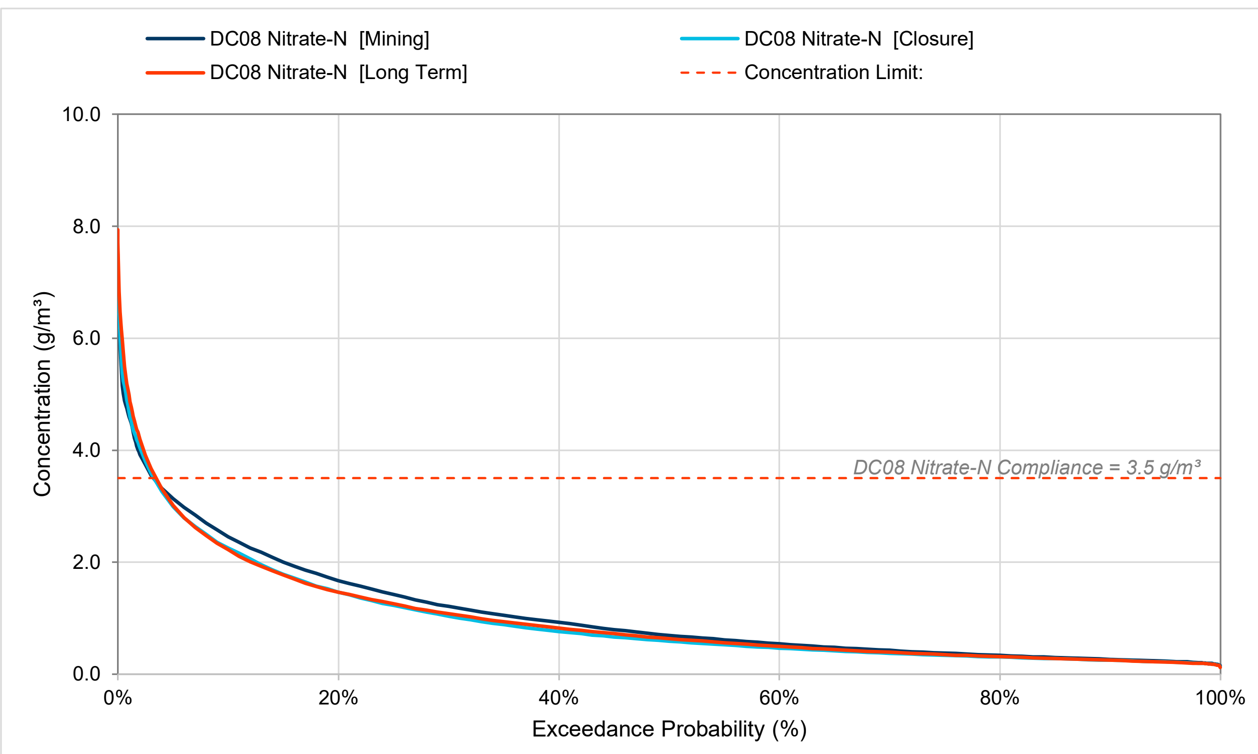


Figure 51 DC08 Nitrate N – Modelled probability exceedance – Basecase + No Flow Augmentation

The modelled Arsenic concentration exceedance curves for DC08 are given in Figure 52 and Figure 53 for the three key phases considered for the scenarios with and without the flow augmentation. Concentrations are reasonably similar between both scenarios with elevated concentrations of arsenic noted during the mining phase. In terms of compliance with the limit of 0.15 mg/L, the water quality at DC08 is expected to be compliant during mining and the long term with a low (<0.5%) risk of exceedance.

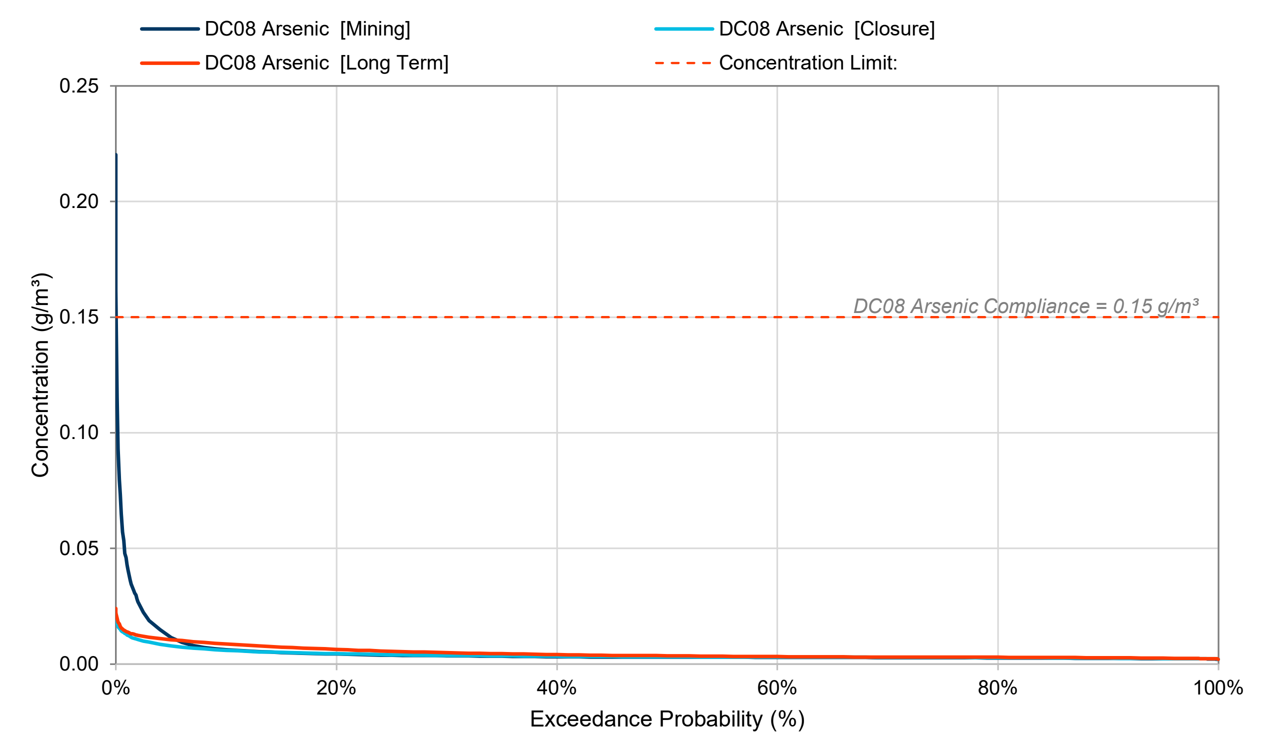


Figure 52 DC08 Arsenic – Modelled probability exceedance – Mitigation + Flow Augmentation

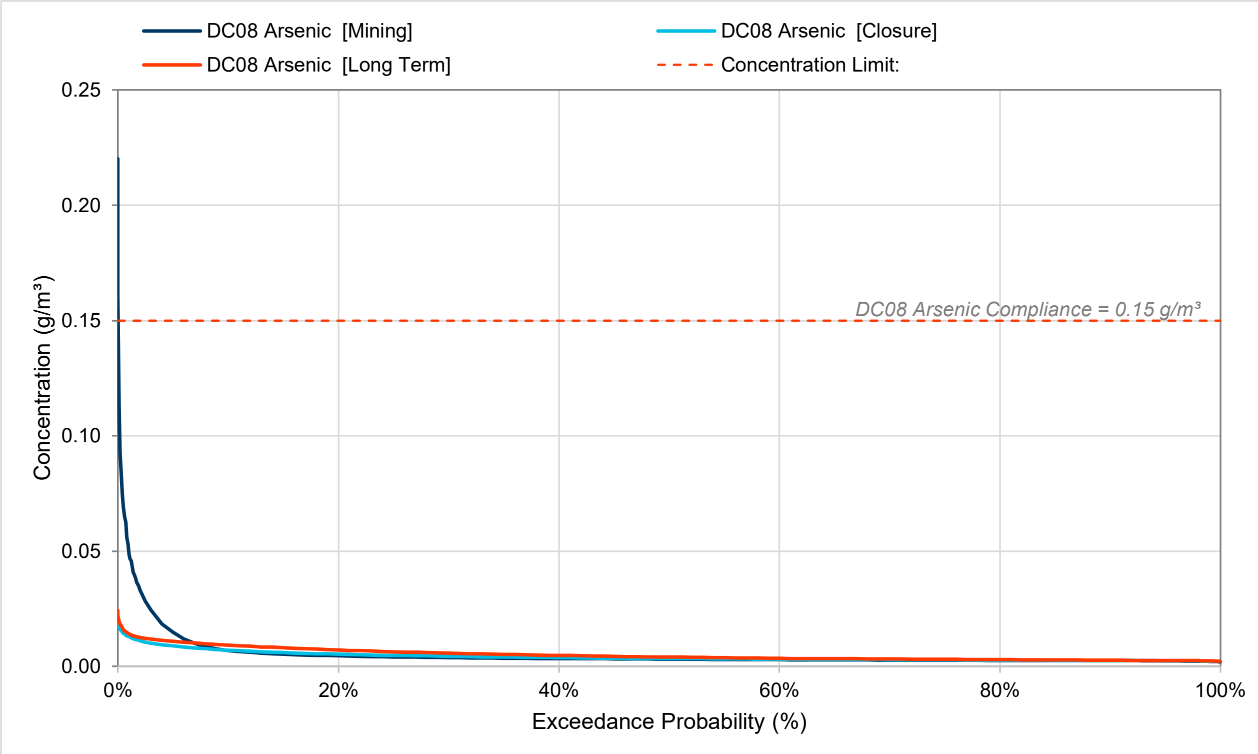


Figure 53 DC08 Arsenic – Modelled probability exceedance – Basecase + No Flow Augmentation

The modelled iron concentration exceedance curve for DC08 is given in Figure 54 and Figure 55 for the three key phases considered for the scenarios with and without the flow augmentation operational. Concentrations are reasonably similar between both scenarios with elevated concentrations of iron noted during the mining phase. In terms of compliance with the limit of 1.0 mg/L, the water quality at DC08 is expected to be compliant during mining and the long term with a low (<0.5%) risk of exceedance.

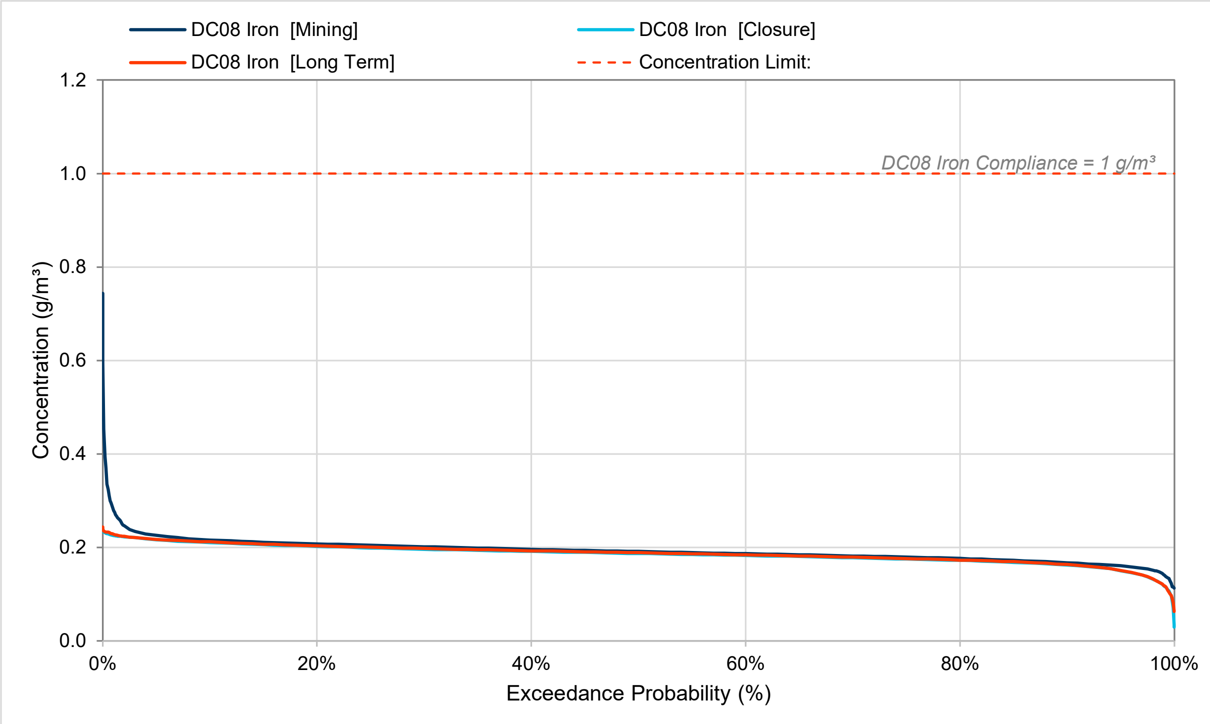


Figure 54 *DC08 Iron – Modelled probability exceedance – Basecase + Flow Augmentation*

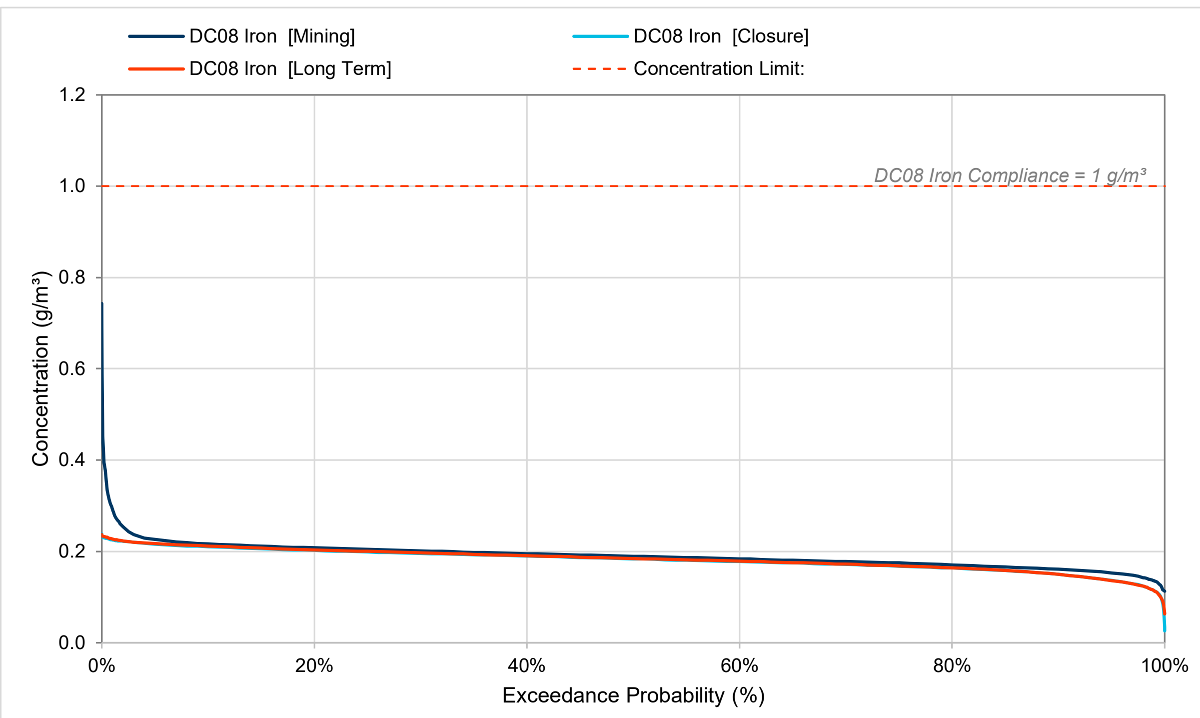


Figure 55 *DC08 Iron – Modelled probability exceedance – Basecase + No Flow Augmentation*

In general, the modelling shows that compliance with the DC07 and DC08 compliance criteria is high in the scenario that includes the construction and operation of the flow augmentation. The same can be said for the scenario where the flow augmentation is not constructed and operational, however expected concentrations at DC07 and DC08 (particularly during low - median flows) will likely be higher (compared to the scenario where the flow augmentation is operational) and some elements (eg. Nitrate N) do show an elevated chance of exceeding the water quality criteria. Furthermore, the basecase scenario (ie. no flow augmentation) assumes optimal operation of the Maori Tommy Silt and Battery Creek Silt Ponds (ie. no (or a very limited) spill waters to Deepdell Creek during low flow events). Spill events from these silt pond during low flow events could potentially result in sulphate concentrations in excess of 1,000 mg/L at DC07 and DC08 (and up to 1,500 mg/L) when no additional dilution is present (ie. No flow augmentation). It's (flow augmentation) construction and operation will therefore likely offer significant benefits in terms of the ability to provide contingency during periods of prolonged low flow and will result in less reliance on controlling the Maori Tommy and/or Battery Creek Silt Ponds overflow.

5.11.5 Shag River @ Loop Road

The modelled concentration exceedance curves for the mitigation scenario including the Flow augmentation for sulphate, Ammoniacal N, Nitrate N, arsenic and iron at the Shag @ Loop Road compliance location are shown in Figure 56, Figure 57, Figure 58, Figure 59, and Figure 60 respectively. The results largely mirror that as shown for DC08 (Figure 46 - Figure 54) and take into account the significant dilution downstream of the DC08. The basecase scenario (which does not include the addition of the flow augmentation) is not shown as it offers little benefit by way of dilution further down the Shag River catchment

Sulphate shows a low probability of exceeding the compliance limit of 250 mg/L post closure (<0.5%). Arsenic shows minor modelled exceedances during closure (<1%) with this probability reducing in the long term. Iron is modelled to exceed the compliance limit of 0.2 mg/L however these exceedances are largely driven by the assumed natural background concentration of iron being 0.2 mg/L (equal to the compliance limit at this location), the variation in predictions being due to the volume of WRS seepage, Coronation pit lake spill water and/or runoff from rehabilitated and non-rehabilitated WRSs. There is currently no available water quality data from the unimpacted Shag River catchment upstream of this compliance location, however water quality data from the compliance location suggests that iron concentrations in this unimpacted area are substantially below the assumed 0.2 mg/L (by an order of magnitude). The modelled exceedance of iron (approximately 50%) is therefore conservative and significantly over stated.

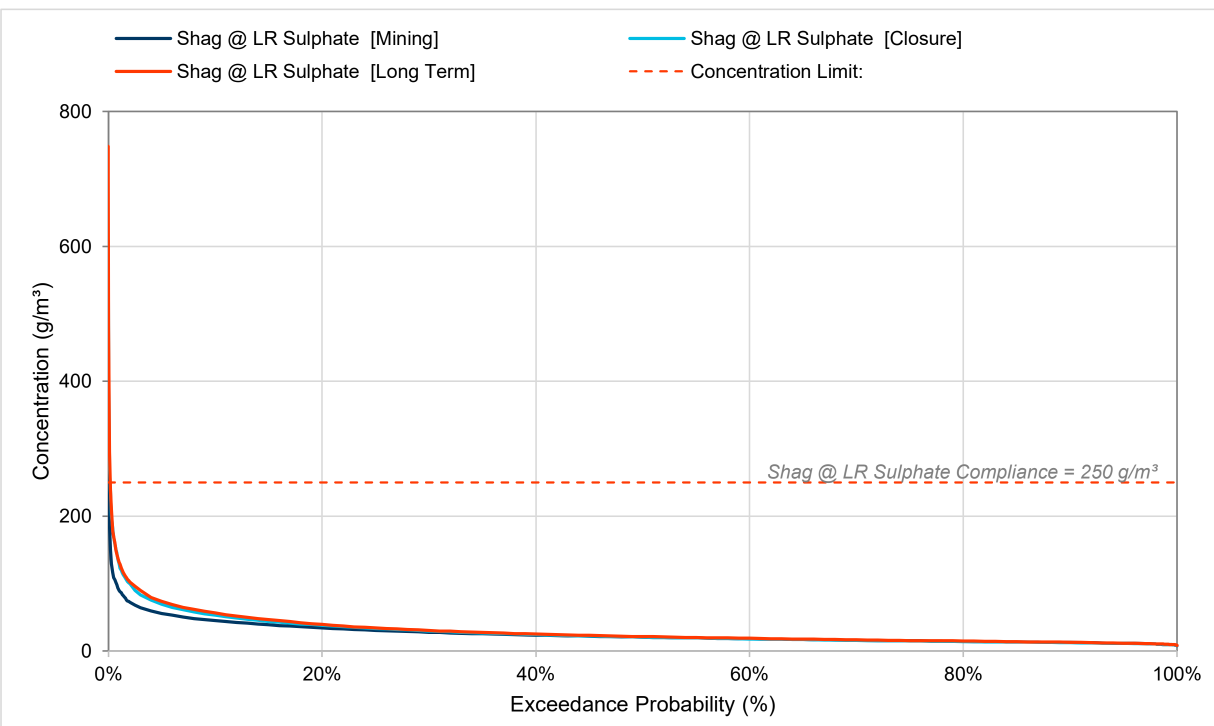
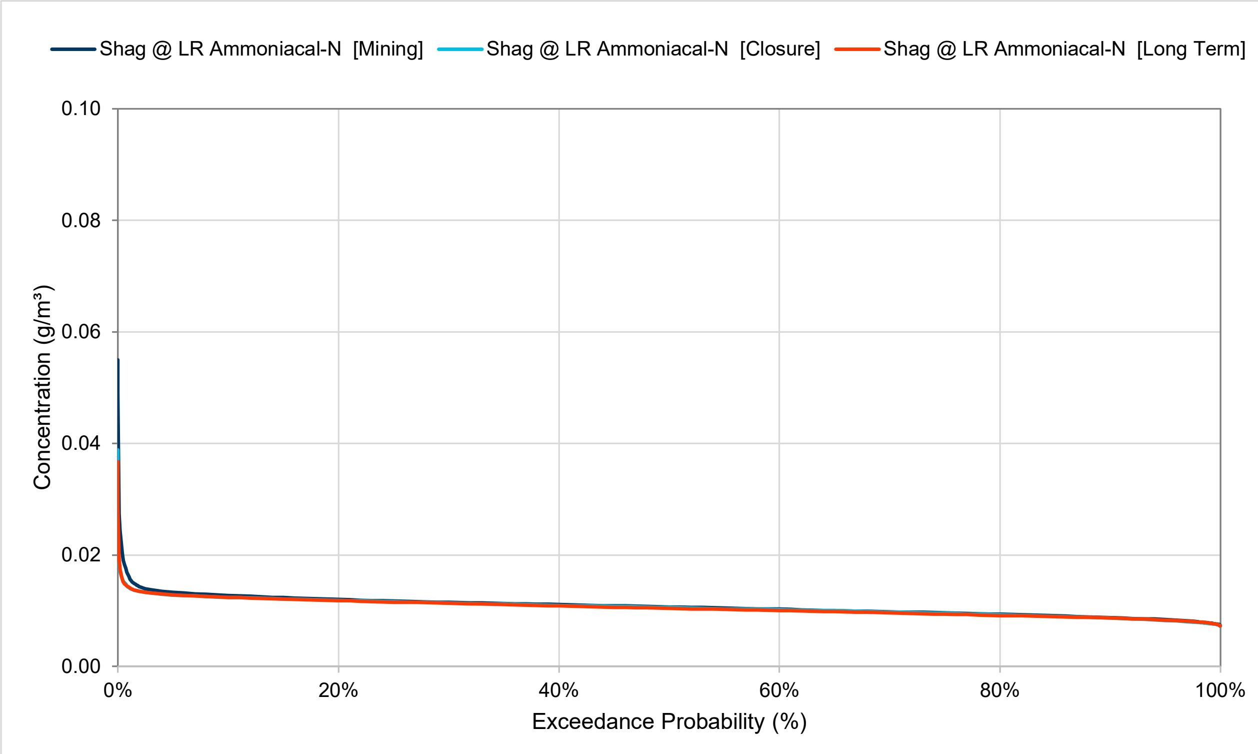
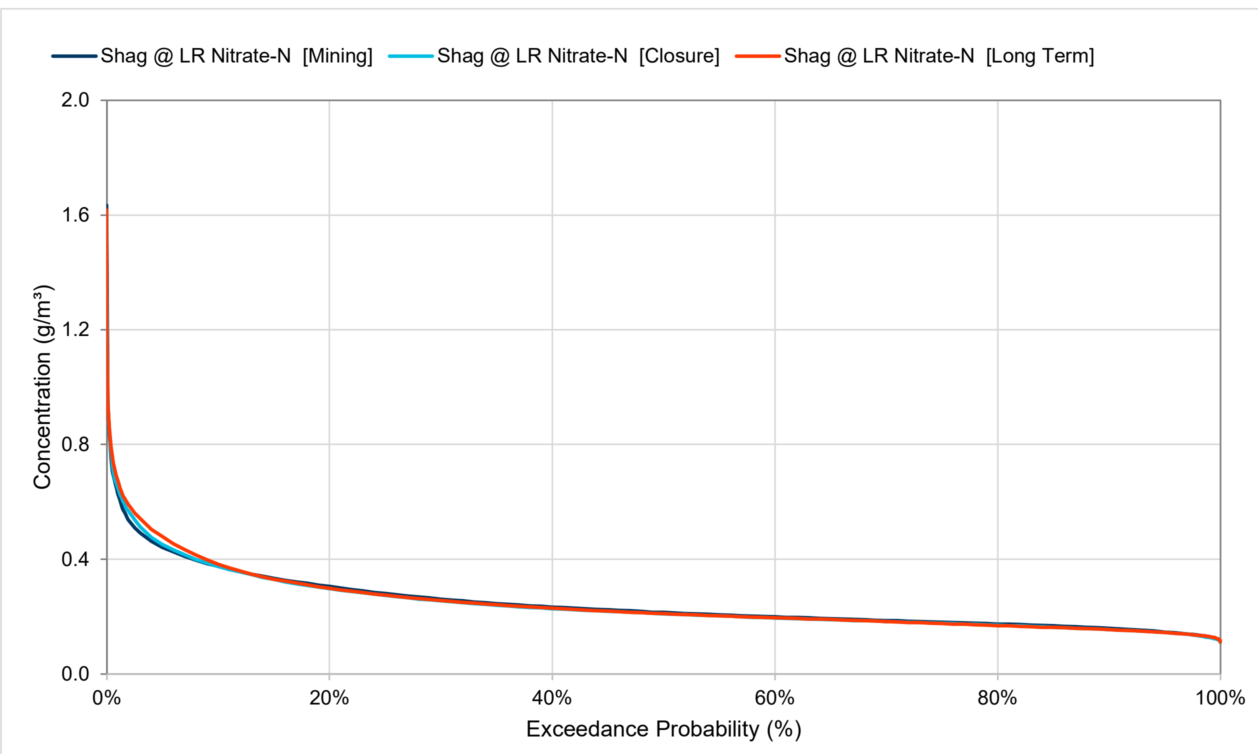


Figure 56 Shag River @ Loop Road Sulphate – Modelled probability exceedance – Mitigation + Camp Creek



* Note there is no compliance limit at this location.

Figure 57 Shag River @ Loop Road Ammoniacal N– Modelled probability exceedance – Mitigation + Camp Creek



* Note there is compliance limit at this location.

Figure 58 Shag River @ Loop Road Nitrate N – Modelled probability exceedance – Mitigation + Camp Creek

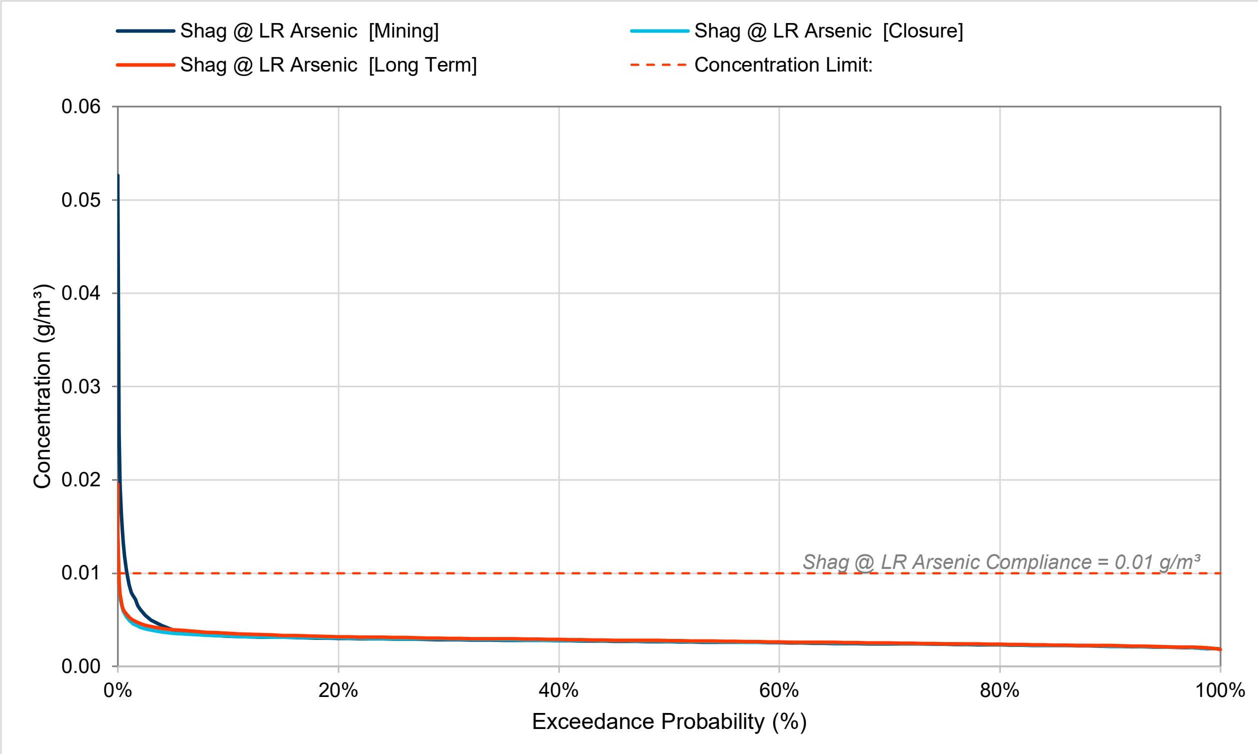


Figure 59 ***Shag River @ Loop Road Arsenic – Modelled probability exceedance – Mitigation + Camp Creek***

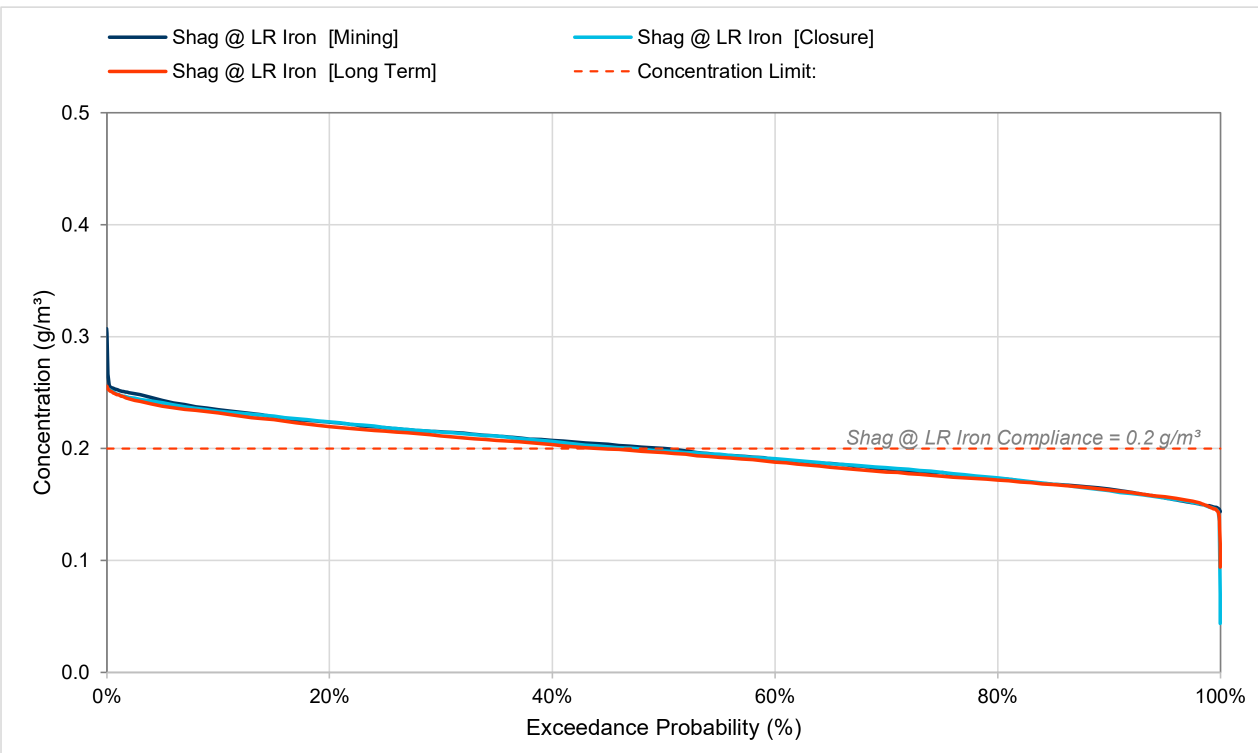


Figure 60 ***Shag River @ Loop Road Iron – Modelled probability exceedance – Mitigation + Camp Creek***

5.11.6 Shag River @ McCormicks

The modelled concentration exceedance curves for the mitigation scenario including the flow augmentation for sulphate, Ammoniacal N, Nitrate N, arsenic and iron at the Shag @ McCormicks compliance location are shown in Figure 61, Figure 62, Figure 63, Figure 64 and Figure 65 respectively. The results largely mirror that as shown for Shag @ Loop Road (Figure 56 - Figure 60). Additional dilution between Shag @ Loop Road and Shag @ McCormicks is taken into effect, however the compliance location also includes additional effects from the Tipperary catchment (refer GHD, 2022a). The basecase scenario (which does not include the addition of the flow augmentation) is not shown as it offers little benefit by way of dilution further down the Shag River catchment.

Generally, the consented parameters exhibit a low probability of exceeding the respective compliance limits. Iron (as at the Shag River @ Loop Road compliance location) is modelled to exceed the compliance limit of 0.2 mg/L largely as a result of the assumed natural background concentration of iron being 0.2 mg/L (equal to the compliance limit at this location). However as at the Shag River @ Loop Road compliance location water quality data from Shag @ McCormicks suggests that background iron concentrations are substantially below the assumed 0.2 mg/L (by an order of magnitude). The modelled exceedance of iron is therefore likely conservative and significantly over stated.

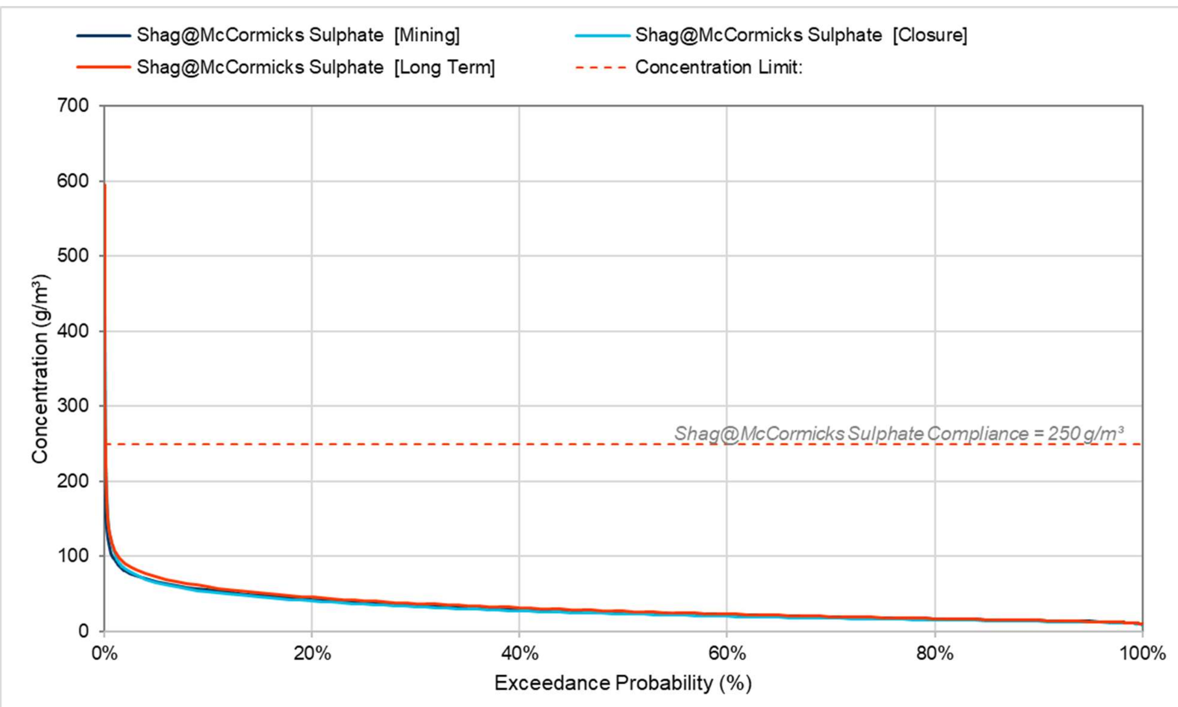
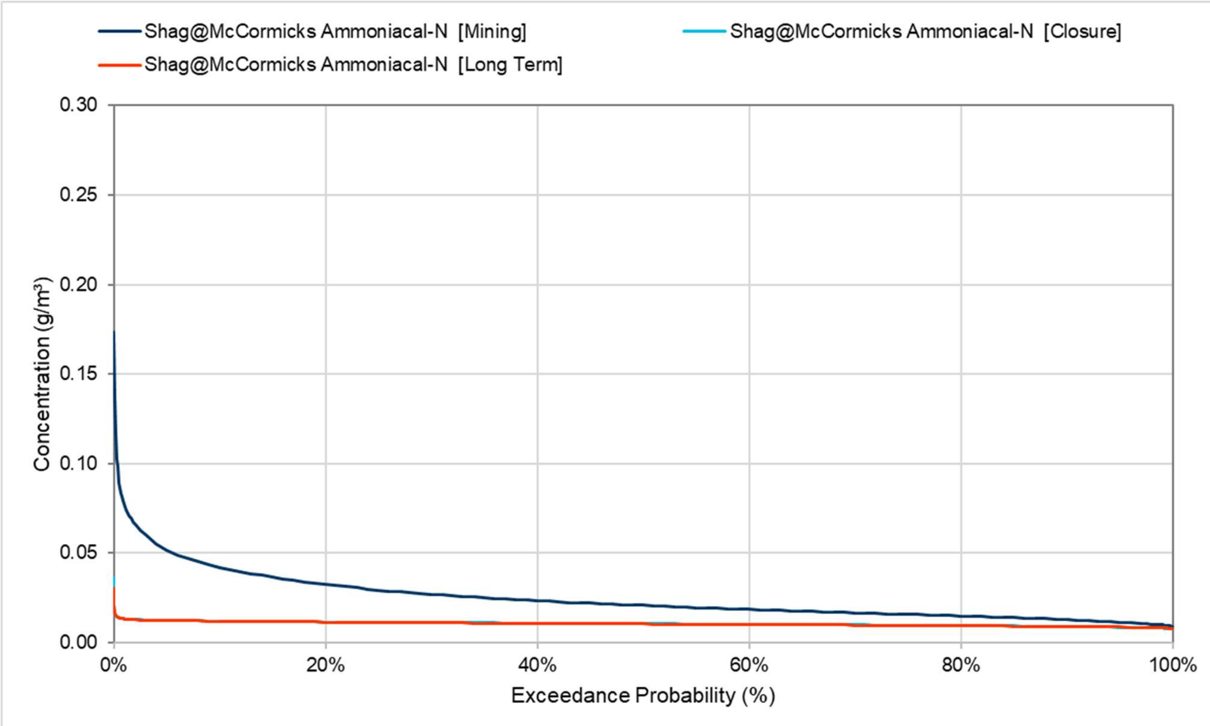
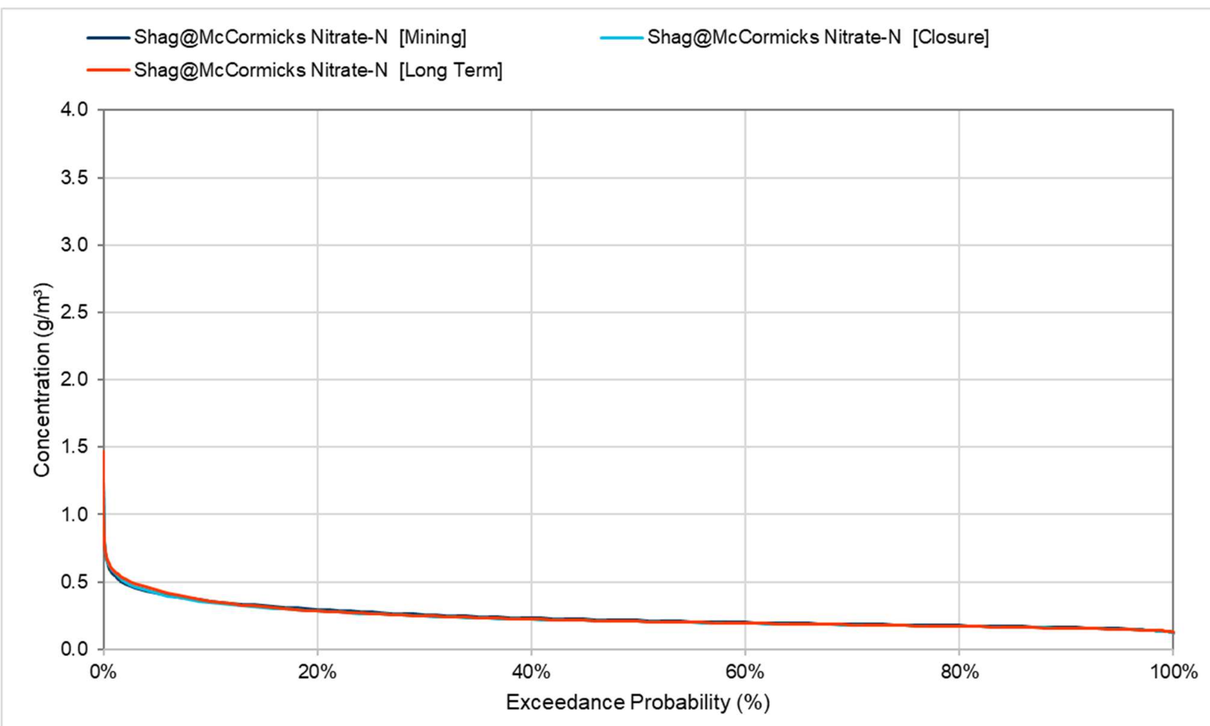


Figure 61 Shag River @ McCormicks Sulphate – Modelled probability exceedance – Mitigation + Camp Creek



* Note there is no compliance limit at this location.

Figure 62 Shag River @ McCormicks Ammoniacal N– Modelled probability exceedance – Mitigation + Camp Creek



* Note there is no compliance limit at this location.

Figure 63 Shag River @ McCormicks Nitrate N – Modelled probability exceedance – Mitigation + Camp Creek

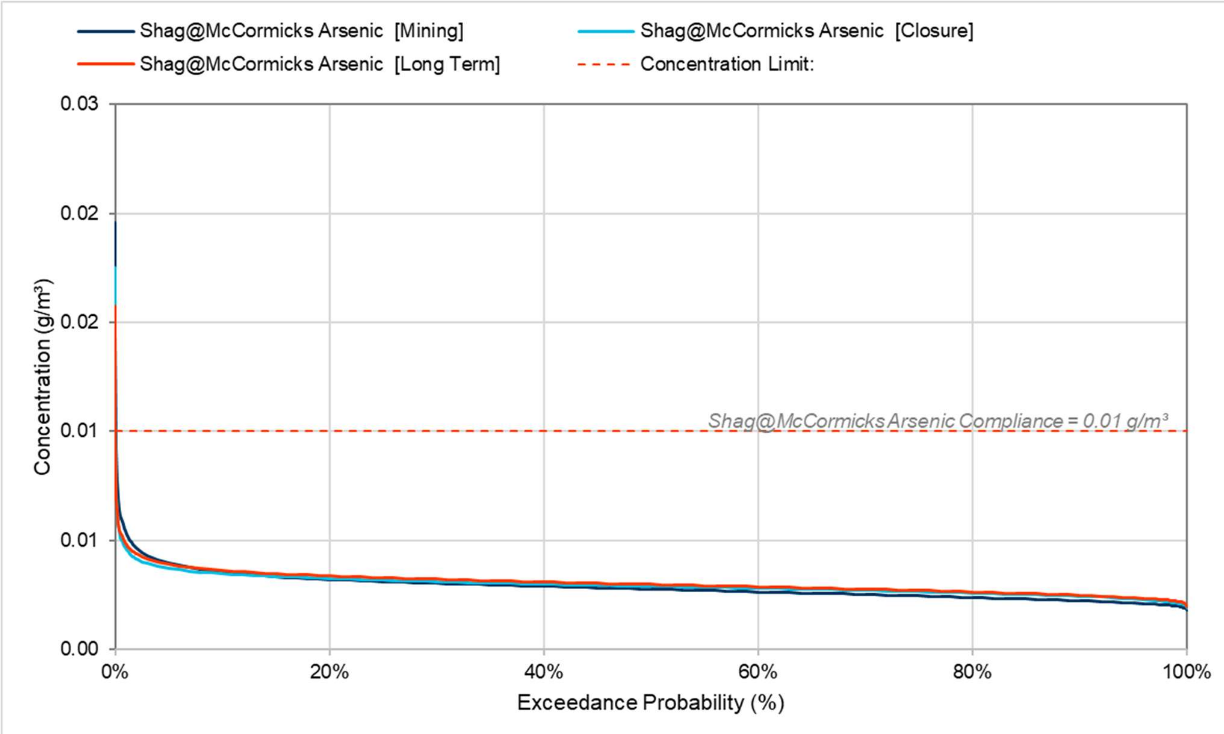


Figure 64 Shag River @ McCormicks Arsenic – Modelled probability exceedance – Mitigation + Camp Creek

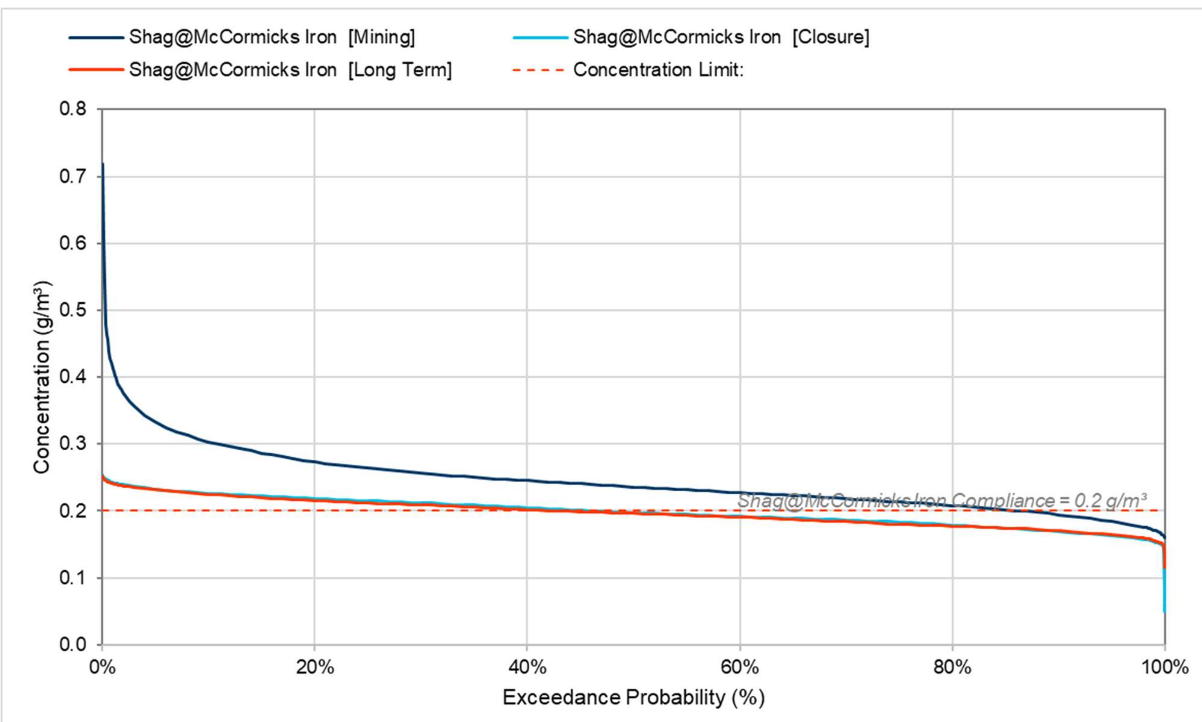


Figure 65 Shag River @ McCormicks Iron – Modelled probability exceedance – Mitigation + Camp Creek

5.12 Results – Water Quality – Waikouaiti River North Branch Catchment

The proposed MPIV project includes development of the IMOP Stages 9-10 extensions, Golden Bar Stage 2 Pit extension, waste disposal at Frasers backfill, Frasers WRS and Golden Bar WRS, the operation of the FTSF and formation of the FRIM and Golden Bar pit lakes within the headwaters of the NBWR. Surface water modelling is presented as a basecase scenario and a selected mitigation scenario.

The water quality results are presented at monitoring and compliance points NBWRRF, MC02 and NB03. Selected contaminants (comprising Sulphate, Ammoniacal N, Nitrate N, arsenic, iron and copper) predictions are presented for each location where they are considered key elements in terms of the current and predicted future impacts. The modelled results of these constituents are also within the range of consented limits applied to other surface water bodies within the wider MGP area. Other consented constituents (lead and zinc) are typically lower in the receiving water bodies and modelled concentrations are generally well below the stated compliance limits. Where there are existing consent limits applied in previous consents, these limits are displayed on the figures for reference. Selected modelled statistical results for the key elements are presented in **Appendix F** (for the selected mitigation scenario only).

Concentrations are presented as concentration exceedance curves based on statistics from multiple realisations of the model. With this approach, where an exceedance is rare, this exceedance may be a result of specific hydrological conditions that occur on a given day/s for a given model run, and does not always guarantee the outcome will occur. Where exceedances are more common, typically they occur across multiple iterations of the modelling and may last for discrete days or extended periods.

5.12.1 Basecase

The basecase scenario assumes the status quo controls are in place within the catchment and models current effects plus the additional effects associated with the development of MPIV. The assumed controls are:

– Murphys silt pond is pumped back to Frasers Pit in perpetuity;
– Frasers West and Clydesdale Silt Ponds discharge by overflow to the NBWR; and
– WRS seepage draining directly to NBWRTR is not collected and drains directly to the NBWR.

The scenario does not reflect any active management of discharges which are currently in place to mitigate potential compliance breaches.

5.12.2 Proposed Mitigation Options

Mitigation options for future application in the catchment are considered here. These mitigation options (Table 20) are applied in concept form and complete feasibility studies have not been undertaken to verify or refine the solutions. Therefore, there is scope to further optimise outcomes.

Table 20 Proposed water quality mitigation options for NBWR catchment

Option	Description	Potential application
Rehabilitation of WRSs	Current monitoring data indicates that seepage discharge rates from some WRSs exceed the typical value applied for most rehabilitated WRSs in the model. It is thought that these elevated seepage rates are caused by, (i) Unrehabilitated top surfaces of WRSs with long construction timeframes (e.g. Frasers West and South), and (ii) WRSs that promote flow though of waters captured on the upstream side (e.g. Clydesdale). Appropriate surface rehabilitation or shaping of these	Modelling assumes infiltration seepage rates of 29.2 mm/yr at all WRS's. This mitigation option would undertake physical works and monitoring to reduce and demonstrate reduction in these infiltration rates.

Option	Description	Potential application
	WRSs to reduce infiltration rates is expected to reduce seepage flow rates in the long term.	
Passive Treatment System (PTS)	Operational tTrials are being undertaken to prove the effectiveness of enhanced passive treatment systems suited at to the Macraes site (Christenson *et al.* 2022). Studies (at other sites) have indicated reductions (in sulphate concentrations) of up to 50%. A conservative reduction at this stage of development it is proposed to apply a (30% reduction in sulphate) employing and assuming inline PTS between the seepage discharge and silt ponds / sumps. The effect on secondary contaminants such as ammoniacal nitrogen, sulfide, DOC need to be resolved further to this this site trial study.	Modelling applies the utilisation of PTSs at the Frasers West Silt Pond and off-line at Clydesdale Silt Pond. Inclusion at the Murphys Creek Silt Pond is also considered where return pumping to Frasers Pit is not in place. It is also considered at the proposed NBWRTR sump. It is assumed that the PTSs are sized to treat the complete seepage flows and result in a consistent 30% reduction in sulphate concentrations.
Controlled Discharge	This option captures seepage waters in retention ponds and discharges these in a controlled manner during period of increased flow that provide suitable levels of dilution. Typically, these retention ponds would capture water during dry periods when stream flows are reduced, then discharge at an increased rate as flow and hence dilution capacity increases. Silt ponds are typically constructed on the mine site where the toes of the WRSs terminate within valleys. These locations correspond to where the bulk of the seepage water also discharges. Once the WRSs are rehabilitated these silt ponds are no longer required for their primary purpose of treating for TSS and surface runoff could be diverted passed the ponds. The available storage volume could then be repurposed as retentions ponds.	Modelling applies controlled discharges at the existing pond locations for Frasers West Silt Pond, Clydesdale Silt Pond, and Murphys Creek Silt Pond (where return pumping to Frasers Pit is not applied). A new pond and seepage interception drain is proposed upstream of the monitoring point NBWRTR to capture and manage seepage flows from the South-Western toe of the WRSs. All other WRS seepages discharging from Frasers West and Frasers South are to be captured and directed to Frasers West and Murphys silt ponds respectively. Discharge rates are controlled in order to reduce sulphate concentrations in the NBWR through low flow periods while minimising accumulated water in the ponds. The assumed rates versus the flow within NB03 are detailed in Figure 66.
Pumping	This option captures WRS seepage waters where concentrated at WRS toes in a sump, then pumps to a suitable location for long term accumulation or use. The aim of this is to minimise contaminant mass discharge from site.	Pumping and storage of WRS seepage is currently applied as a mitigation method on site at Murphys Creek Silt Pond, where water is pumped to Frasers Pit. Modelling assumes that return pumping of seepage at this location is retained long term. Modelling considers options for further implementation of seepage collection at the Murphys Creek Silt Pond as well as at the Frasers West Silt Pond, Murphys Creek Silt Pond, Clydesdale Silt Pond and proposed NBWRTR sump (refer to the Controlled Discharge mitigation measure), with waters being pumped to Frasers Pit Lake when the silt/collection ponds reach a capacity of 90% in order to prevent overtopping of the ponds during low flow events.

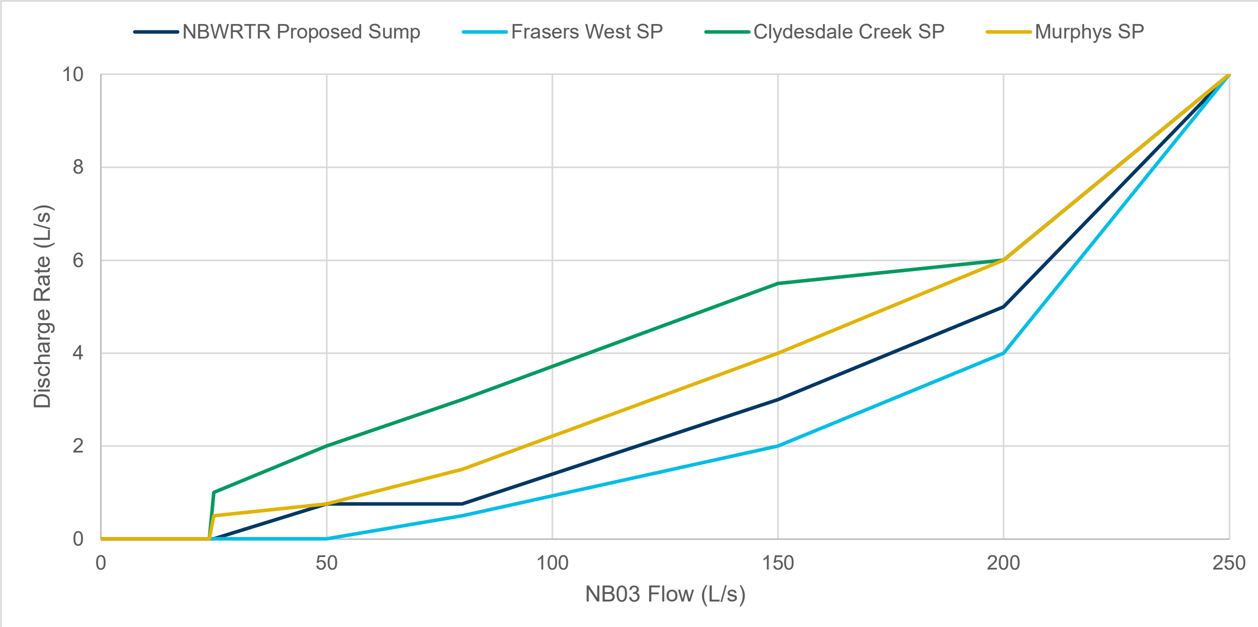


Figure 66 ***Controlled discharge rates from proposed sumps at NBWRTR, Frasers West SP and Clydesdale Creek SP with respect to NB03 flow rates***

5.12.3 Selected Mitigation Scenario

The selected mitigation scenario is based on a combination of the outlined proposed mitigation options that sufficiently addresses modelled exceedances in the basecase model run. The selected mitigation scenario is considered to address modelled compliance exceedance of the basecase scenario and consists of the following components:

– Rehabilitation of WRSs - The Frasers West / South and Golden Bar WRSs are rehabilitated to achieve an average annual infiltration (and seepage) rate reduction to 29.2 mm/year;
– Passive Treatment Systems – PTSs are capturing and treating all seepage water from the Frasers West, Frasers South and Golden Bar WRSs and reducing sulphate loads by 30% before discharge to the respective silt / collection ponds;
– Controlled Discharge - The Frasers West Silt Pond, Murphys and Clydesdale Silt Ponds are converted to sumps and discharge to the receiving surface water environment only at elevated flows. Discharge rating curves are as per Figure 66 which account for available storage in the sumps and reduce long term likelihood of over filling without the ability to discharge. The sumps are assumed to be fitted with high level alarms where capacity reaches 90%, above which emergency pumping or carting water back to Frasers Pit would occur; and
– A new sump capturing seepage from the Frasers West and South WRSs is constructed at or near the monitoring location NBWRTR. This sump will operate in a similar manner to the Frasers West and Clydesdale Silt ponds in terms of discharge to the NBWR and return to Frasers.

The mitigation scenario shows the results for the outlined controls / mitigation measures during all stages (mining, closure and long term) and where the outlined controls / mitigation measures are not applied in the mining phase.

5.12.4 Waikouaiti River North Branch– NBWRRF

The modelled concentration exceedance curve for sulphate, arsenic and iron at the NBWRRF compliance location for the basecase and selected mitigation scenario are shown in Figure 67 to Figure 72 respectively. Other compliance limits applicable to the location (copper, lead and zinc) are well below the respective compliance limits and modelled results are summarised in **Appendix F-3**.

The basecase sulphate results (Figure 67) show exceedance of the compliance limit (1000 mg/L) approximately 5-8% of the time and reflect the high loading of seepage draining to the catchment and frequent low flow periods offering little dilution. The selected mitigation scenario (Figure 68) shows a significant improvement in the compliance during closure and the long term and is a reflection of the reduced load to the catchment (due to the presence of the PTSs) and the controlled discharge of collected seepage minimising discharge of elevated sulphate mass during low flow conditions. The mining phase still shows exceedance of the sulphate limit approximately 8% of the time (when the assumed mitigation measures are not implemented) and a significant improvement during mining when the mitigation measures are applied. Early implementation of the outlined mitigation measures (i.e during mining) is recommended based on these predictions.

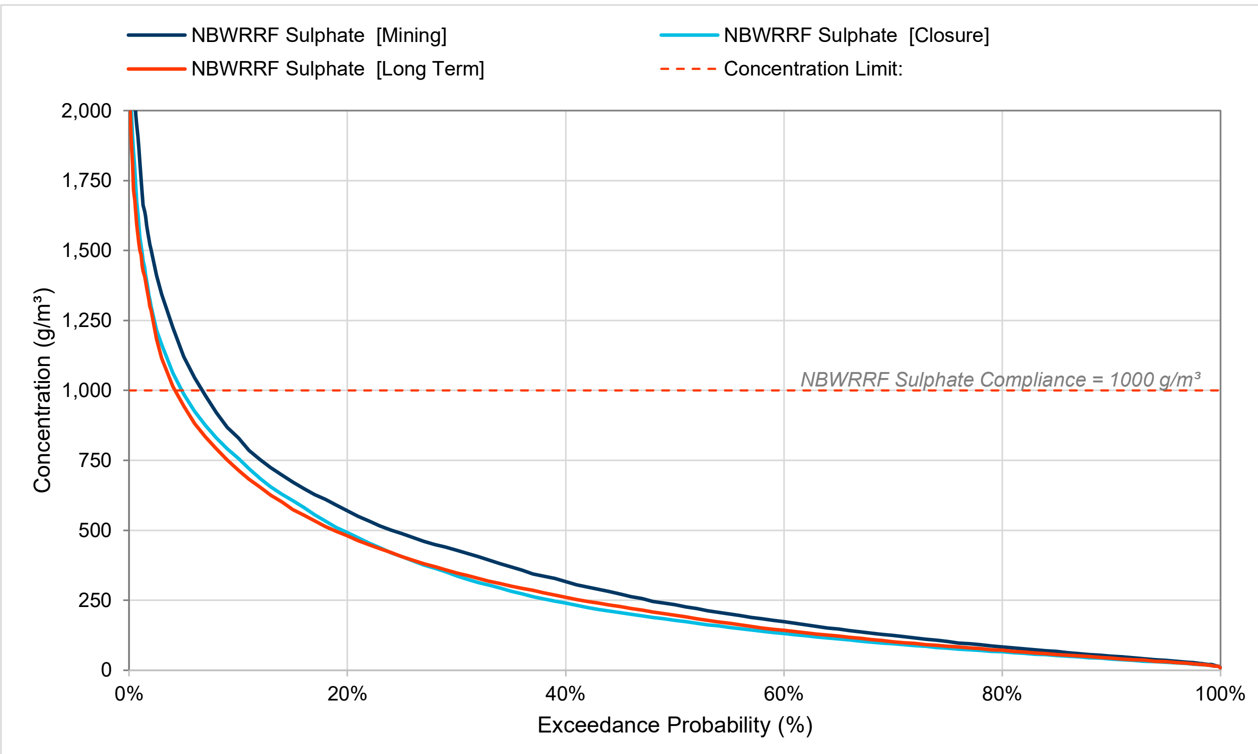


Figure 67 ***NBWRRF Sulphate – Modelled probability exceedance (Basecase)***

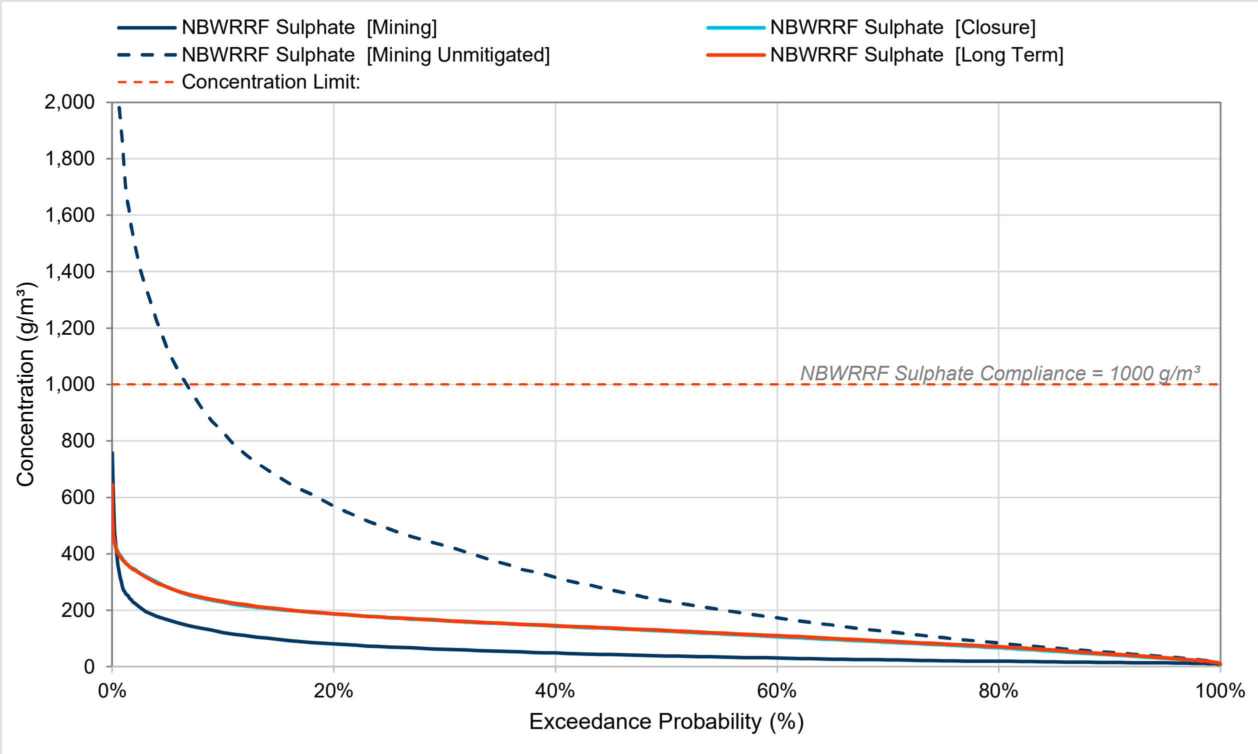


Figure 68 NBWRRF Sulphate – Modelled probability exceedance (Selected Mitigation)

Modelled arsenic and iron concentrations for the basecase and selected mitigation scenario are well below the applicable compliance limits at NBWRRF (Figure 69 - Figure 72).

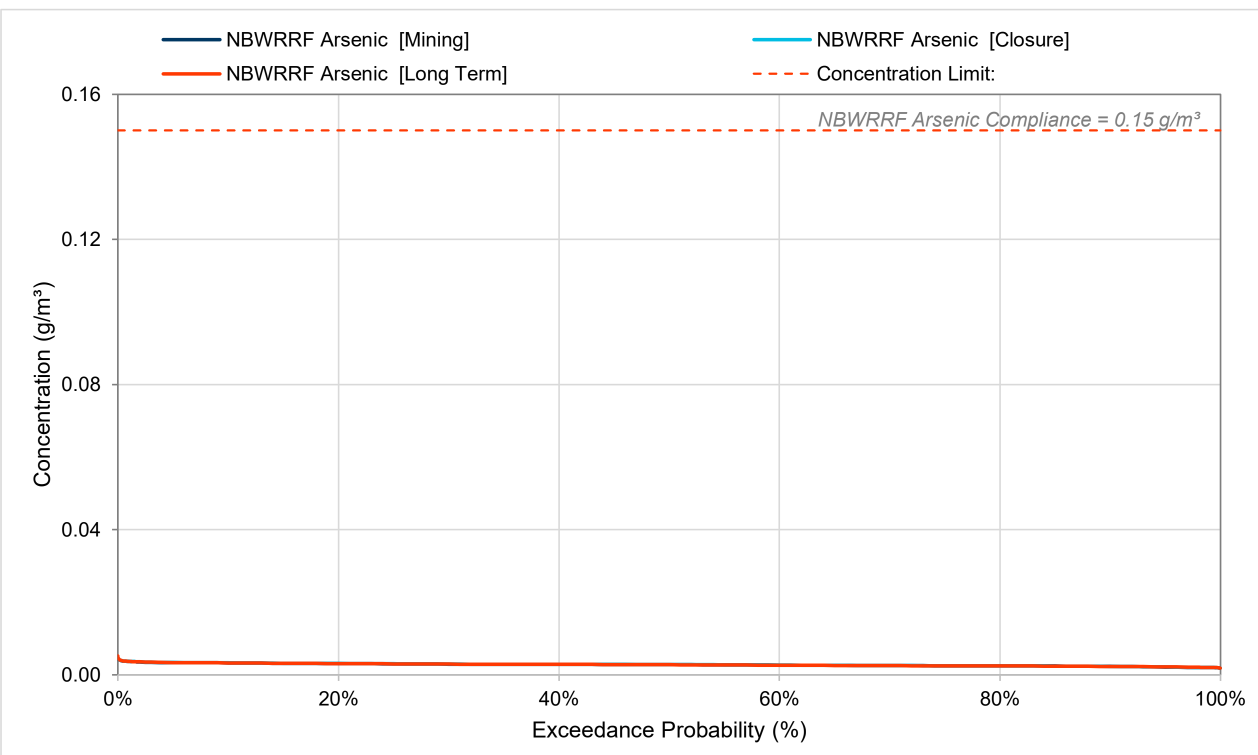


Figure 69 NBWRRF Arsenic – Modelled probability exceedance (Basecase)

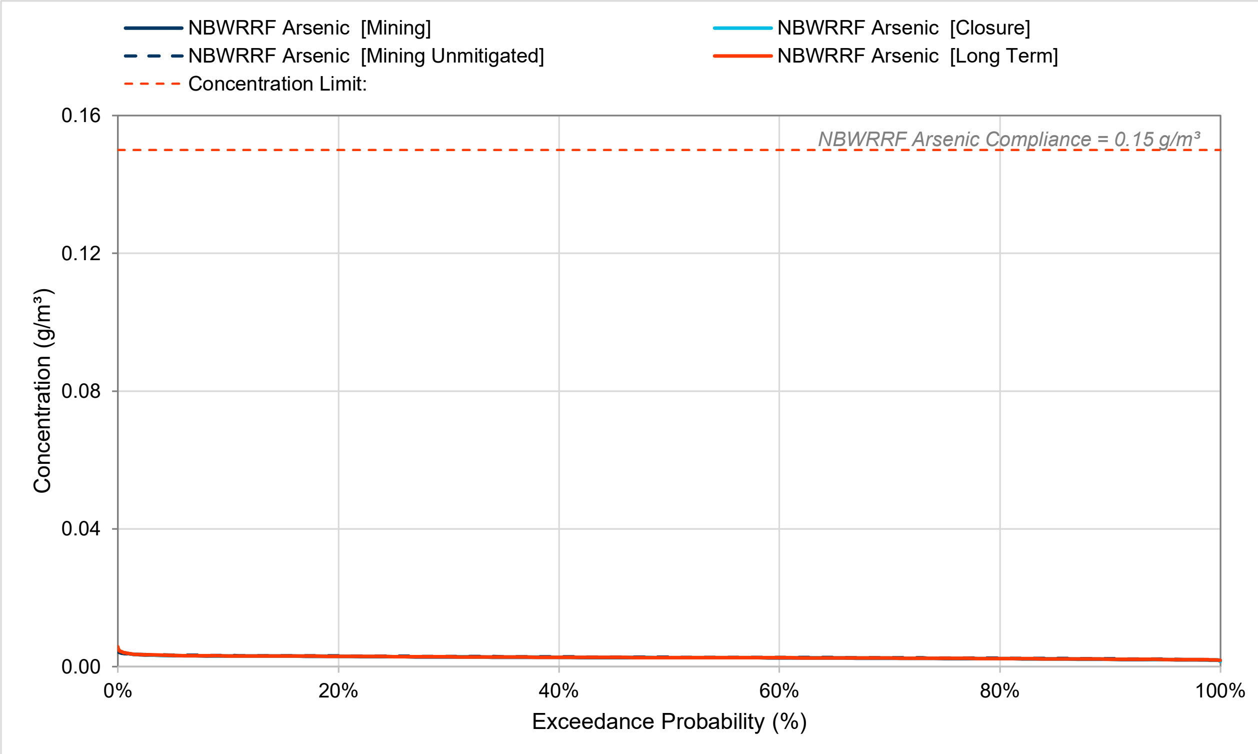


Figure 70 ***NBWRRF Arsenic – Modelled probability exceedance (Selected Mitigation)***

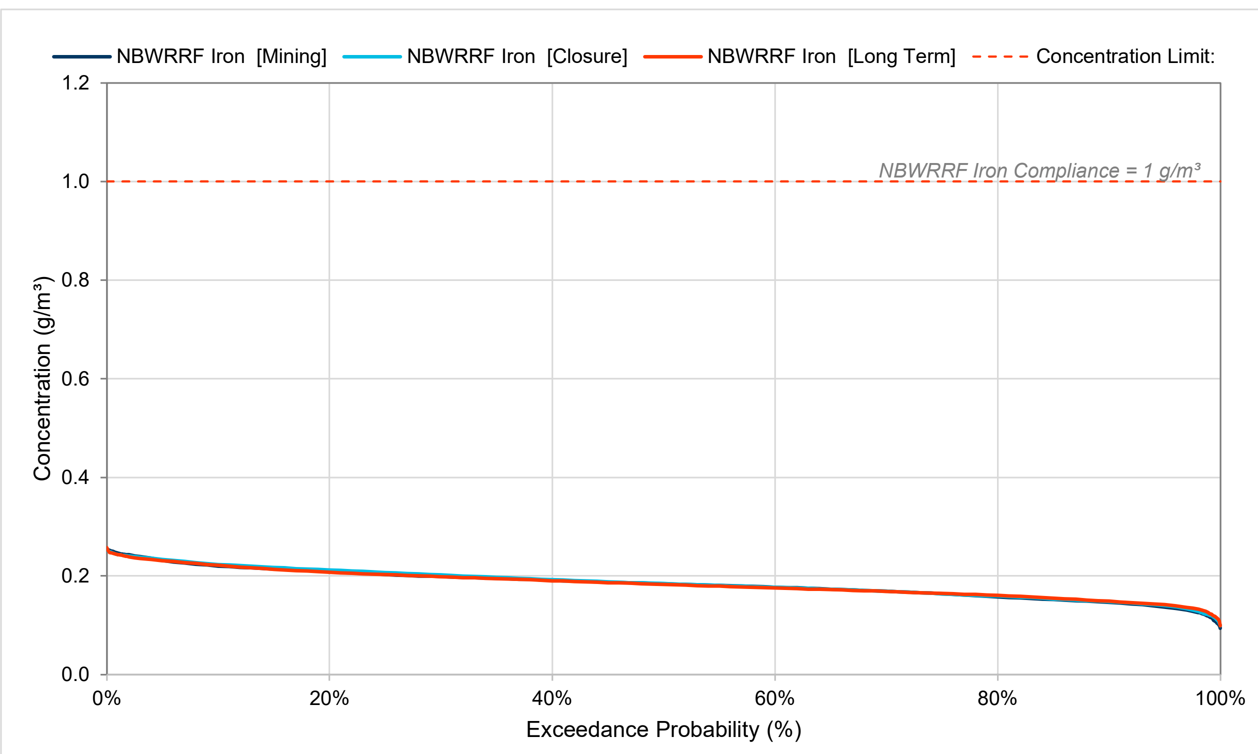


Figure 71 ***NBWRRF Iron – Modelled probability exceedance (Basecase)***

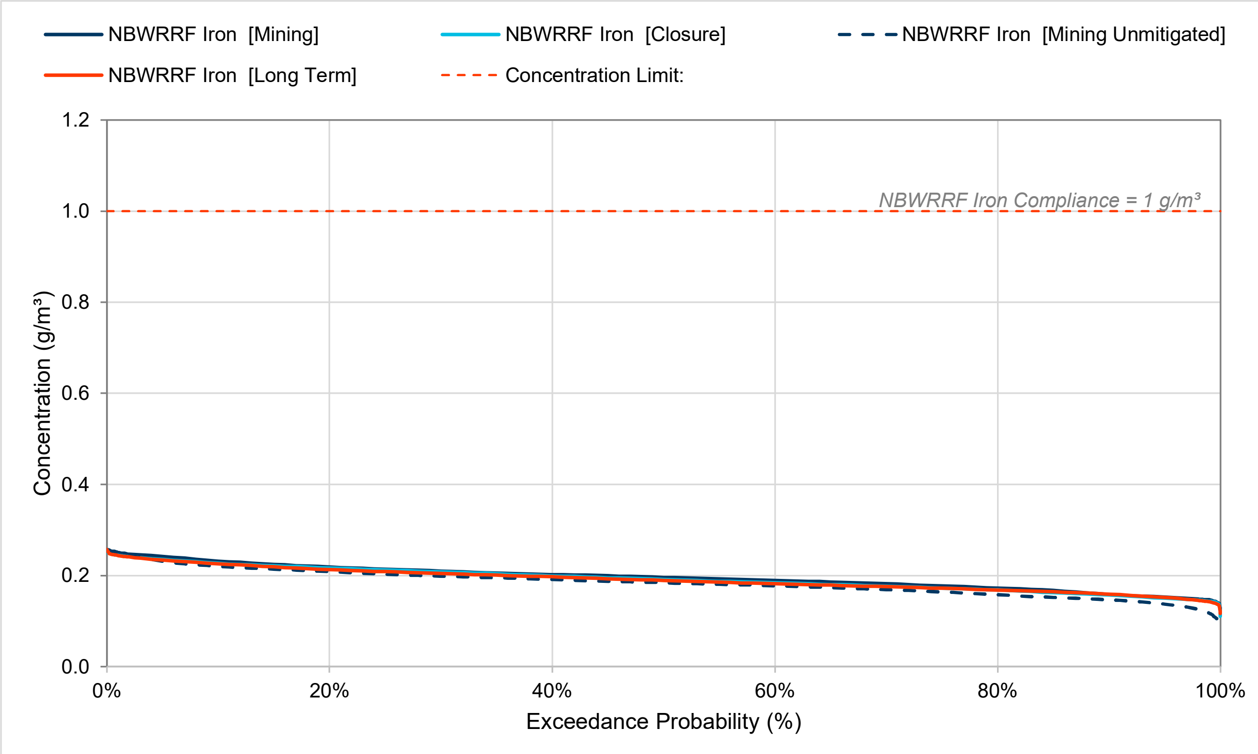


Figure 72 NBWRRF Iron – Modelled probability exceedance (Selected Mitigation)

5.12.5 Waikouaiti River North Branch– MC02

The modelled concentration exceedance curve for sulphate, arsenic, iron and copper at the MC02 compliance location for the selected mitigation scenario are shown in Figure 73 to Figure 76 respectively. The basecase results are shown for the mining phase. It is noted that mitigation is currently applied where Murphys Silt Pond is pumped back to FROP. It is assumed this will continue until mine closure or the implementation of controlled release from this location in addition to controls being placed on releases from Clydesdale Silt Pond. Other compliance limits applicable to the location (lead and zinc) are well below the respective compliance limits and modelled results are summarised in **Appendix F-3**.

The results show no exceedance of the applicable compliance limits except for copper which models a compliance exceedance approximately 8-9% of the time. These modelled compliance exceedances do not consider hardness and the 0.009 mg/l copper limit assumes a hardness of 100 mg/L. The modelled elevated copper concentrations are modelled with an associated elevated hardness (in excess of 400 mg/L). Based on the hardness related compliance criteria, the adjusted hardness related copper compliance limit would be 0.035 mg/L, therefore the water quality at MC02 is expected to be within the consented limits.

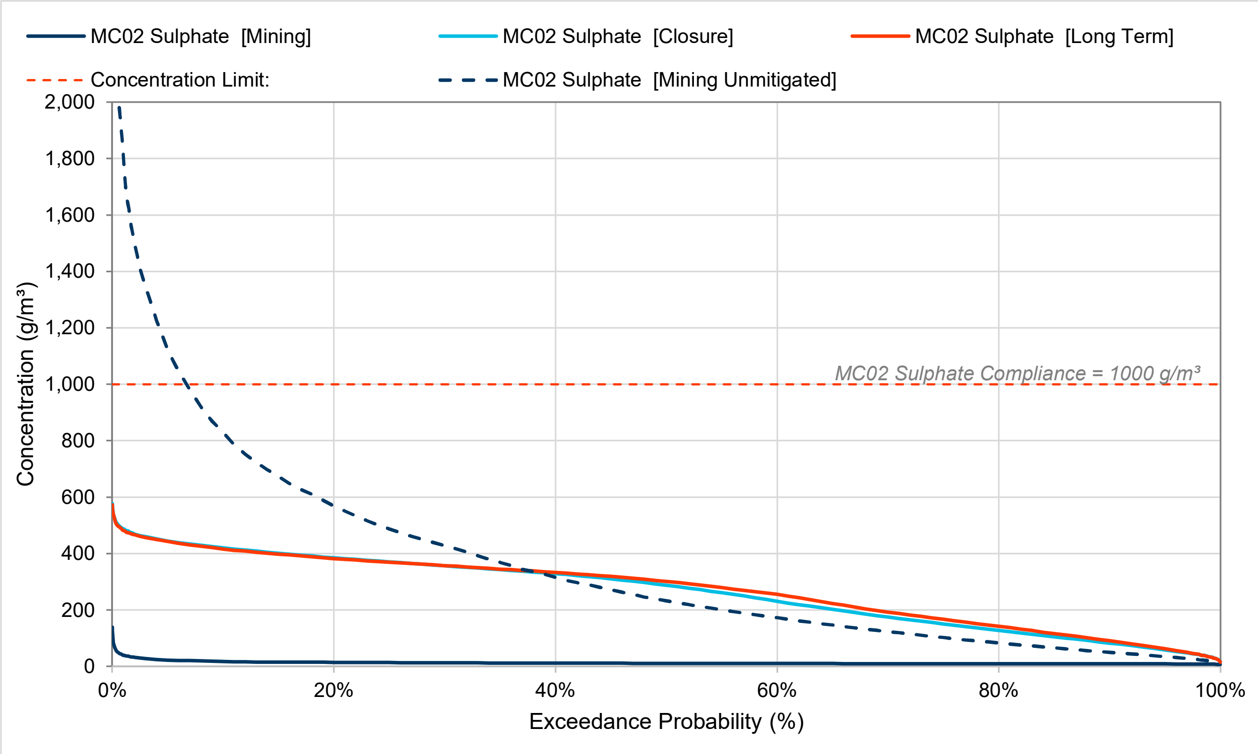


Figure 73 ***MC02 Sulphate – Modelled probability exceedance (Selected Mitigation)***

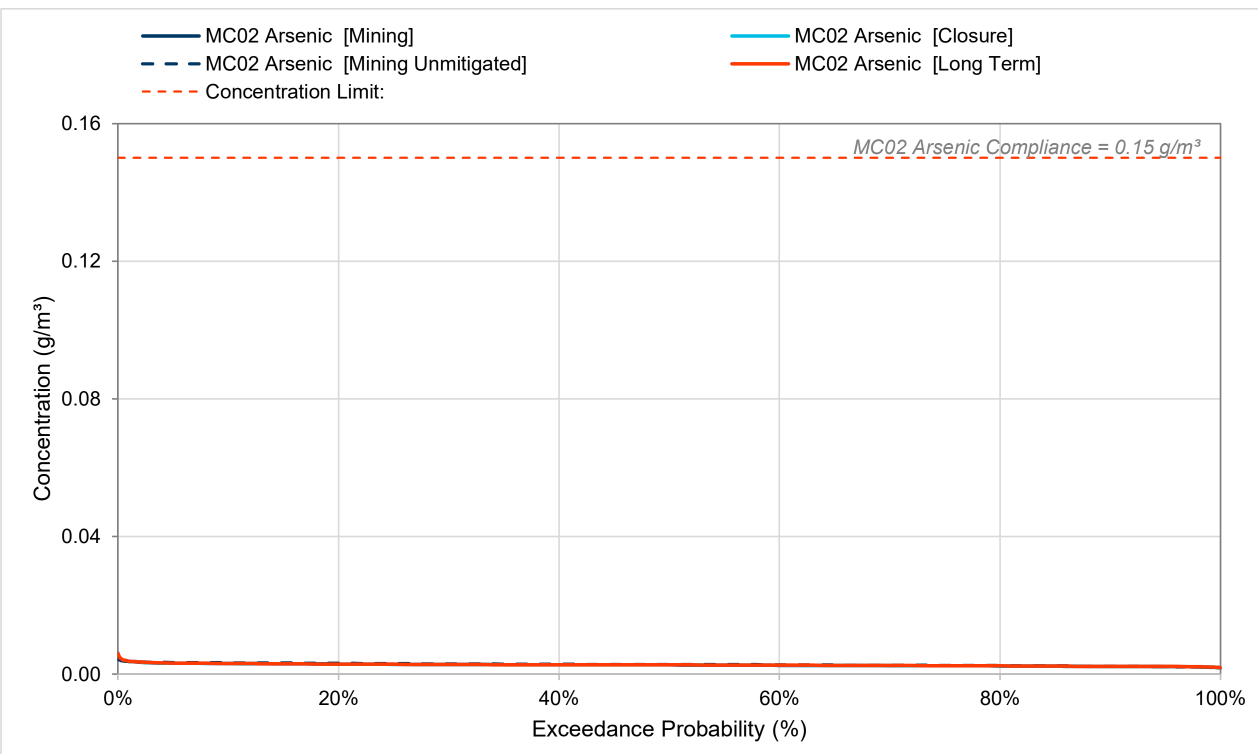


Figure 74 ***MC02 Arsenic – Modelled probability exceedance (Selected Mitigation)***

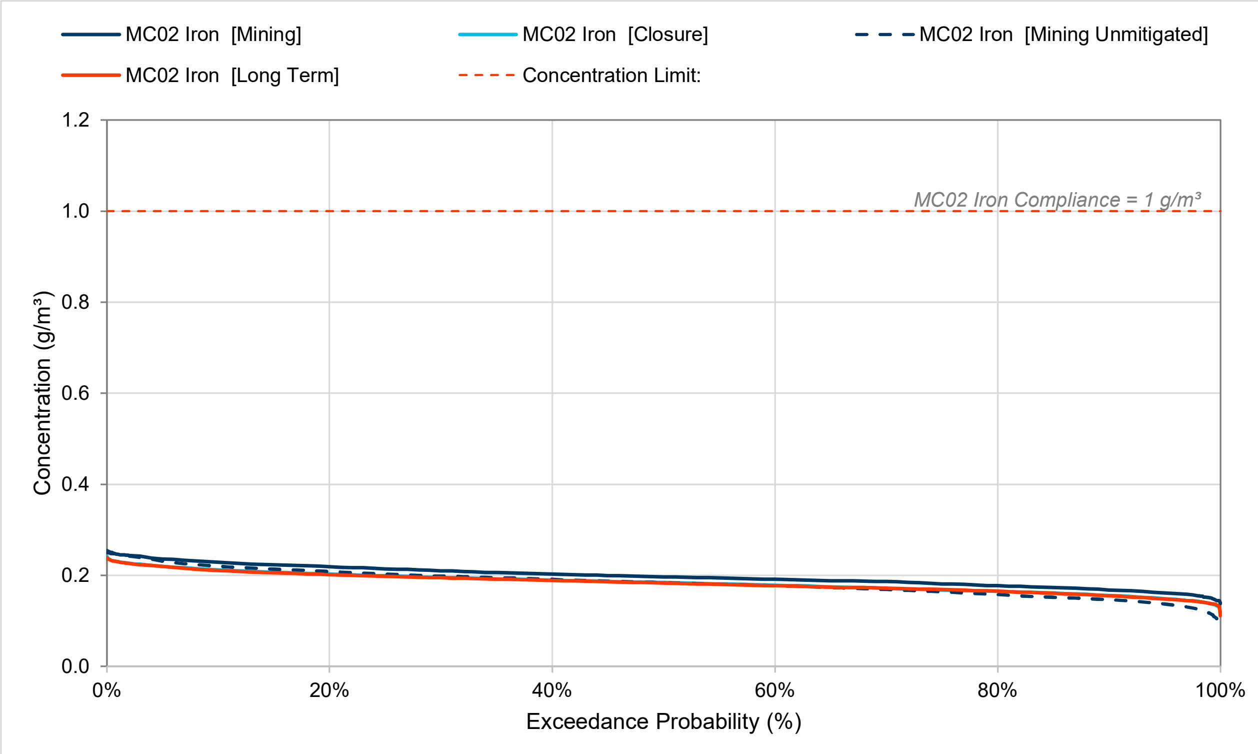


Figure 75 ***MC02 Iron – Modelled probability exceedance (Selected Mitigation)***

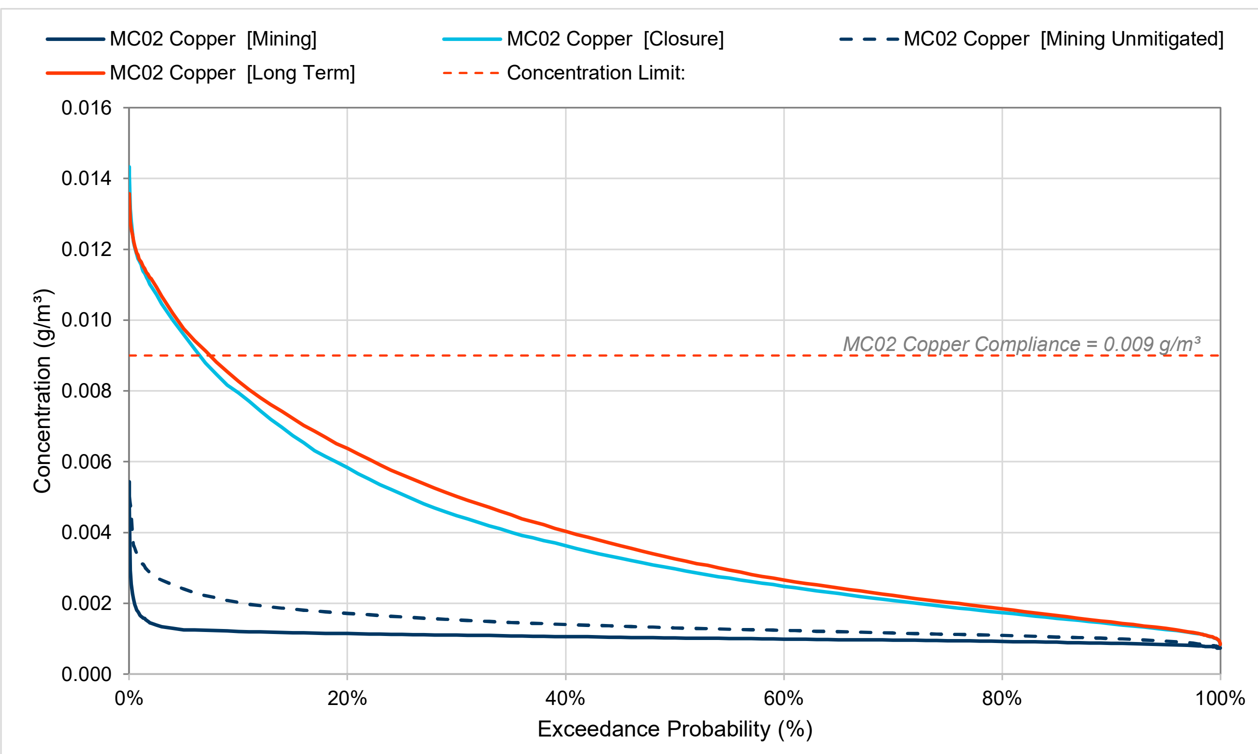


Figure 76 ***MC02 Copper – Modelled probability exceedance (Selected Mitigation)***

5.12.6 Waikouaiti River North Branch– NB03

The modelled concentration exceedance curve for sulphate, Ammoniacal N, Nitrate N, arsenic, iron and copper at the NB03 compliance location for the basecase and selected mitigation scenario are shown in Figure 77 to Figure 88 respectively.

The basecase sulphate results (Figure 77) show exceedance of the compliance limit (250 mg/L) approximately 15-20% of the time and reflect the high loading of seepage draining to the catchment and frequent low flow periods offering little dilution. The selected mitigation scenario (Figure 78) shows a significant improvement in the compliance during closure and the long term (exceedance < 1%) and is a reflection of the reduced load to the catchment (due to the presence of the PTSs) and the controlled discharge of collected seepage minimising discharge of elevated sulphate mass during low flow conditions. The mining phase shows exceedance of the sulphate limit approximately 18% of the time if the outlined mitigation measures are not implemented as soon as practicable. Significant improvement is secured during mining when the mitigation measures are applied..

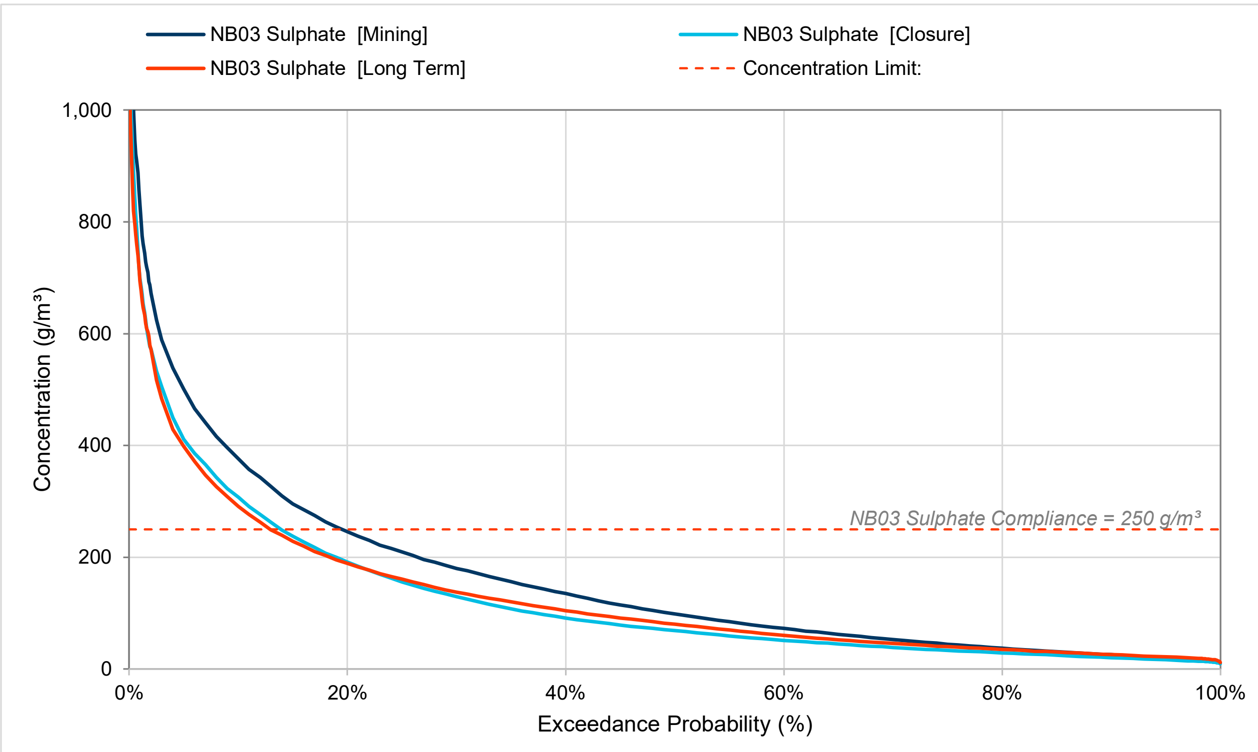


Figure 77 NB03 Sulphate – Modelled probability exceedance (Basecase)

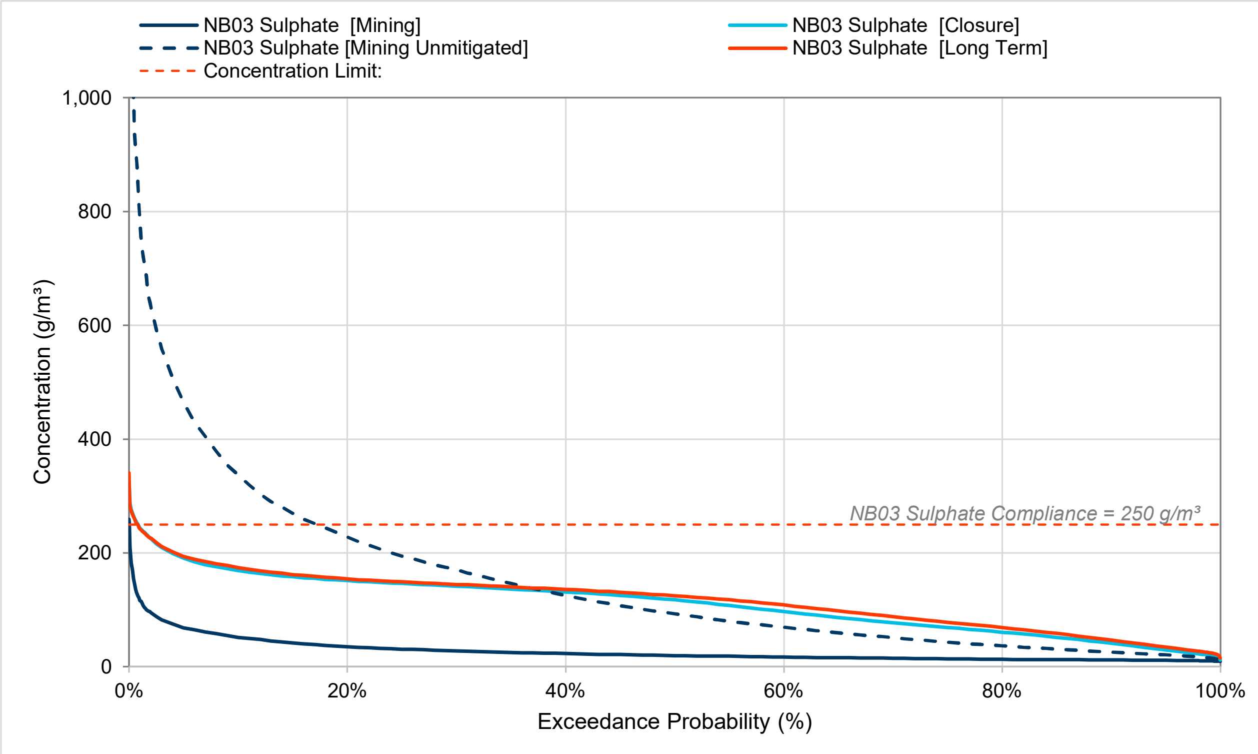
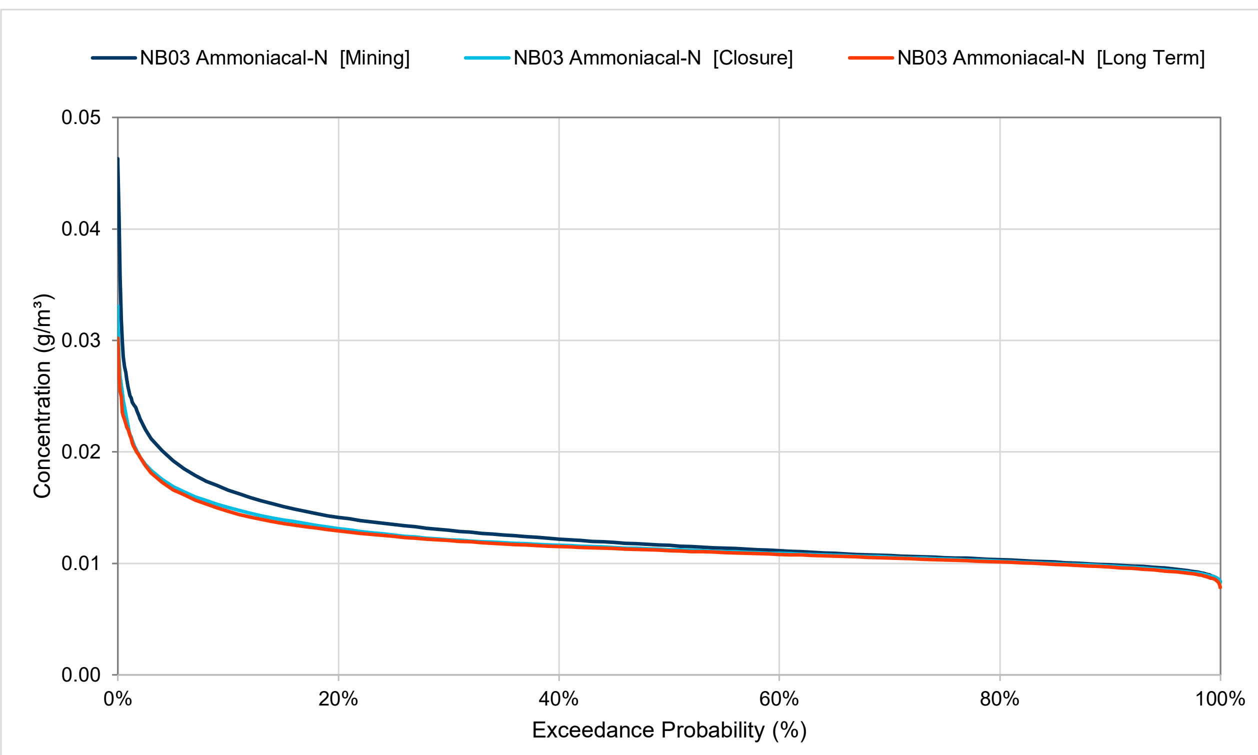


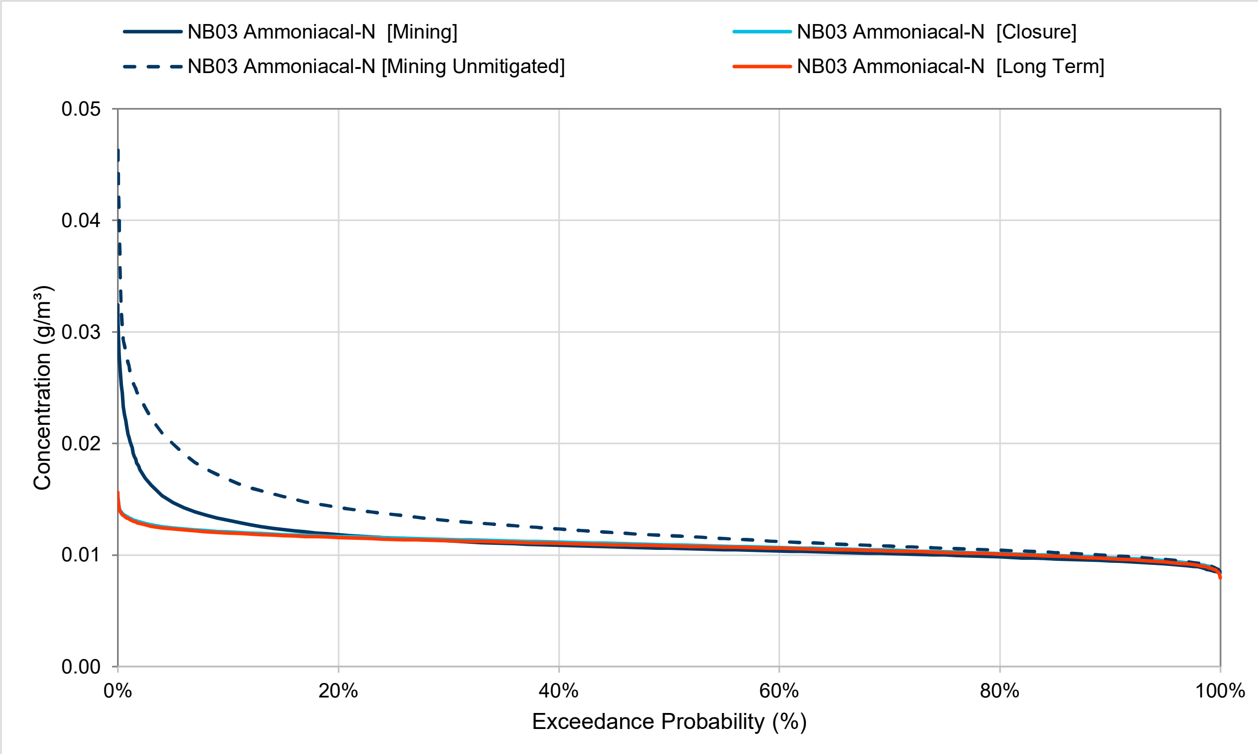
Figure 78 NB03 Sulphate – Modelled probability exceedance (Selected Mitigation)

Ammoniacal N concentrations are expected to be well below the implied compliance limit at NB03 (median concentration of 0.24 mg/L) in all phases of mining in both presented scenarios (Figure 79 and Figure 80).



*The implied Ammoniacal N compliance limit of 0.24 mg/L is off the scale of the figure

Figure 79 NB03 Ammoniacal N– Modelled probability exceedance (Basecase)



*The implied Ammoniacal N compliance limit is 0.24 mg/L

Figure 80 ***NB03 Ammoniacal N– Modelled probability exceedance (Selected Mitigation)***

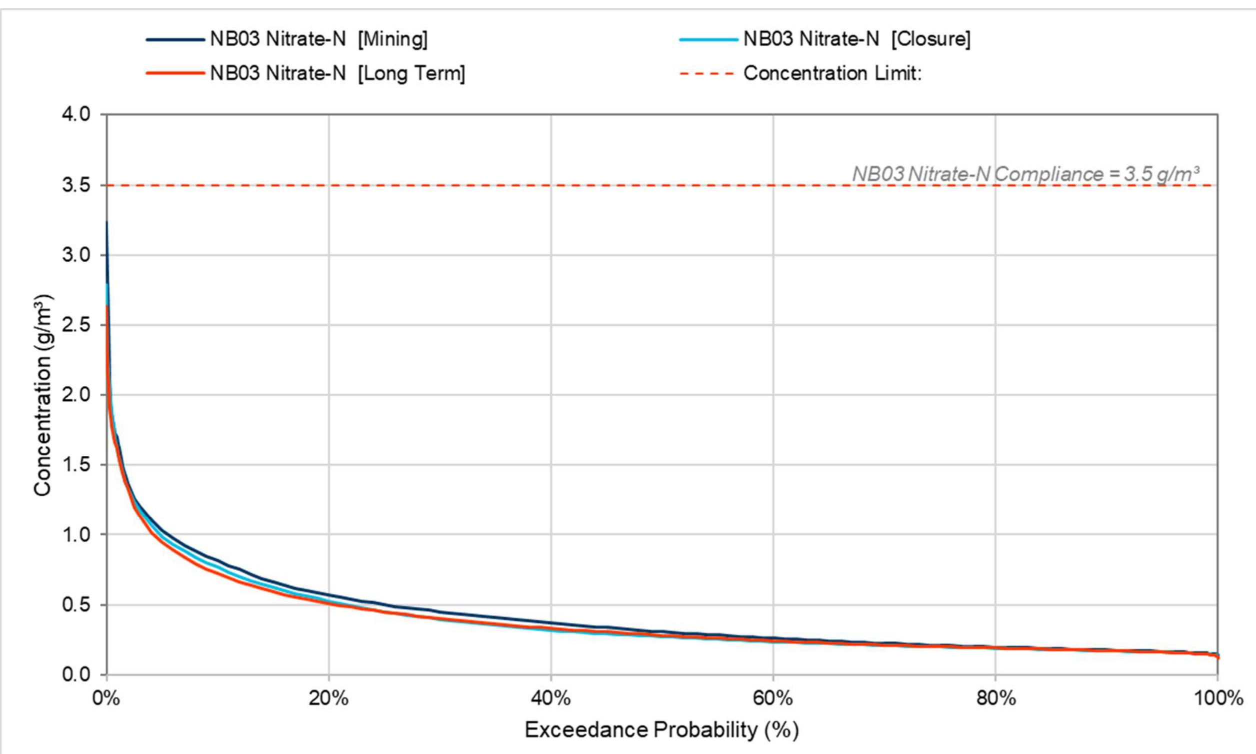


Figure 81 ***NB03 Nitrate N – Modelled probability exceedance (Basecase)***

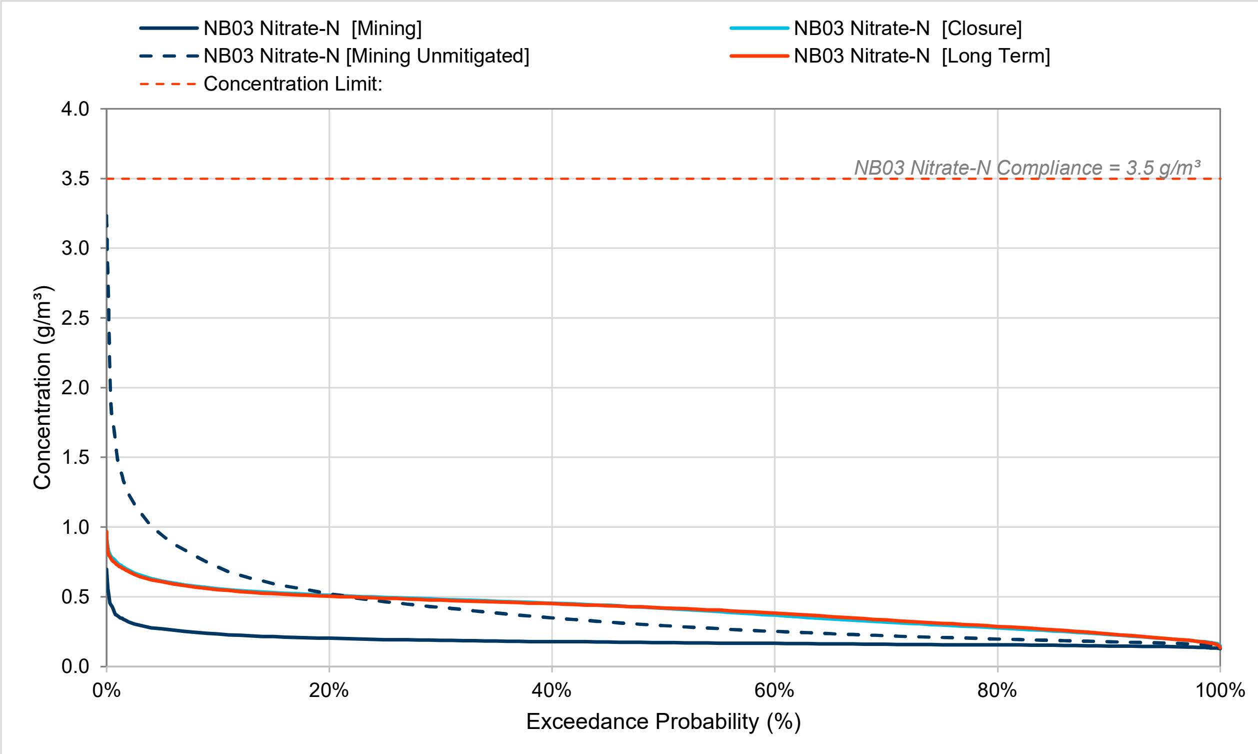


Figure 82 NB03 Nitrate N – Modelled probability exceedance (Selected Mitigation)

Modelled Arsenic concentrations show increased concentrations during the mining and long term phases compared to the closure phase in both scenarios (Figure 83 and Figure 84). The elevated levels during closure (and for some of the mining phase) are the result of Golden Bar pit spill waters influencing NB03 and result in estimated exceedance of the 0.01 mg/L compliance limit approximately 3% of the time in both scenarios. The control of the Golden Bar Pit overflow and/or dosing of the Golden Bar Pit Lake (eg. dosing with Ferric Chloride) could potentially be utilised to reduce pit lake arsenic concentrations and prevent compliance exceedance at NB03. The modelled mining phase exceedances are a result spill waters before dewatering and prior to the commencement of GB2 development.

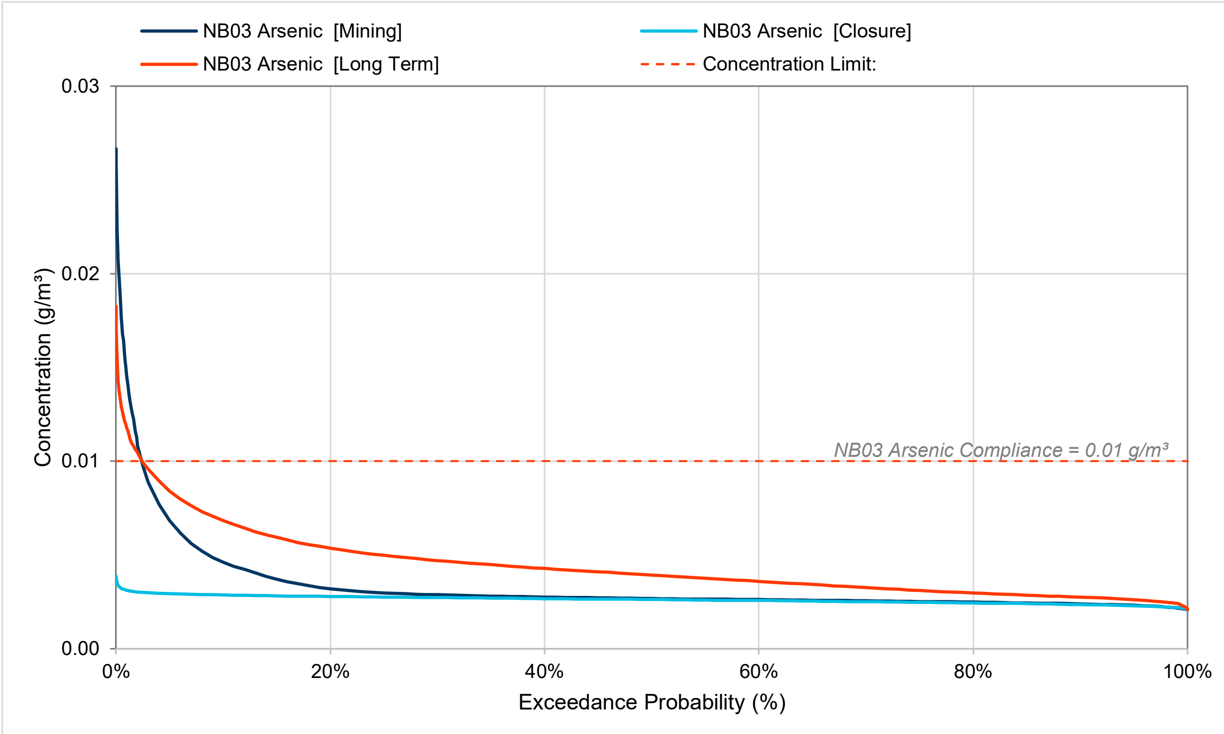


Figure 83 ***NB03 Arsenic – Modelled probability exceedance (Basecase)***

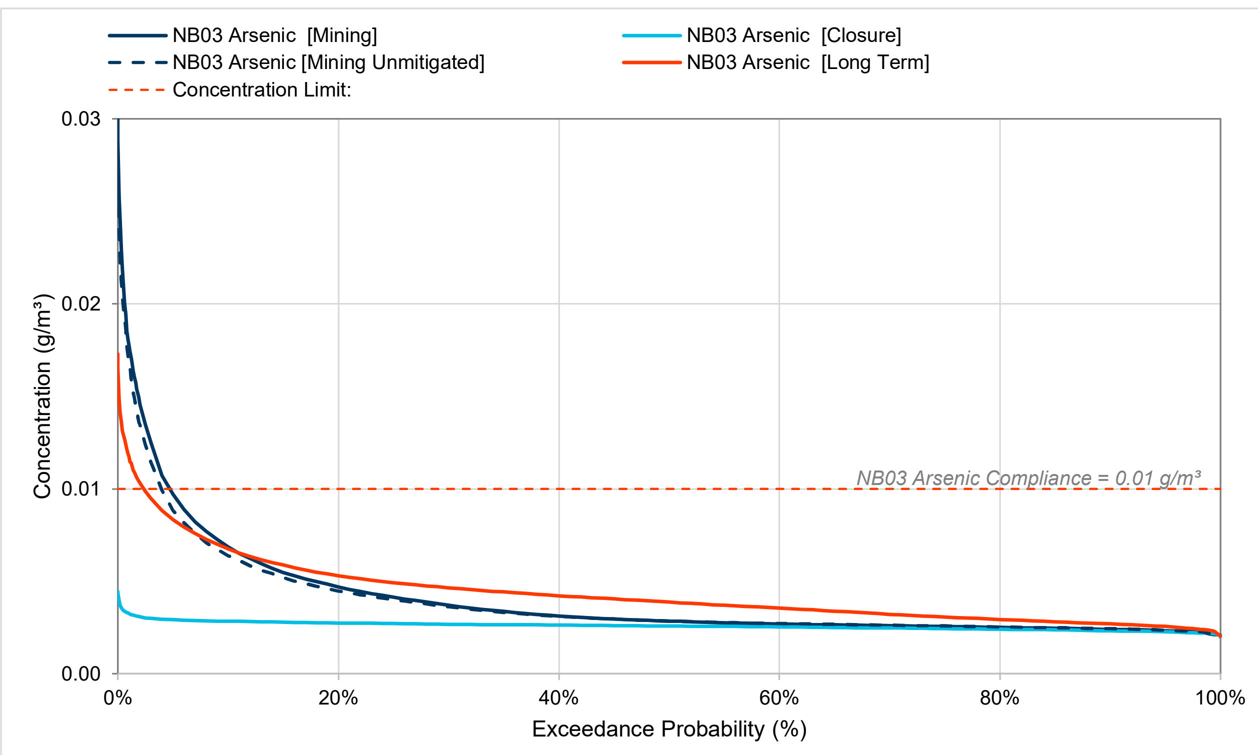


Figure 84 ***NB03 Arsenic – Modelled probability exceedance (Selected Mitigation)***

Modelled iron concentrations show a slightly elevated iron concentration and elevated chance of exceedance in the selected mitigation scenario (compared to basecase). This is a result of the assumed elevated iron concentration in the unimpacted catchment (0.2 mg/L) which is equal to the compliance limit. However water quality data from the compliance location suggests that iron concentrations in the unimpacted area are substantially below the assumed 0.2 mg/L (by an order of magnitude). The modelled exceedance of iron (approximately 25%) is therefore to conservative and likely significantly over stated.

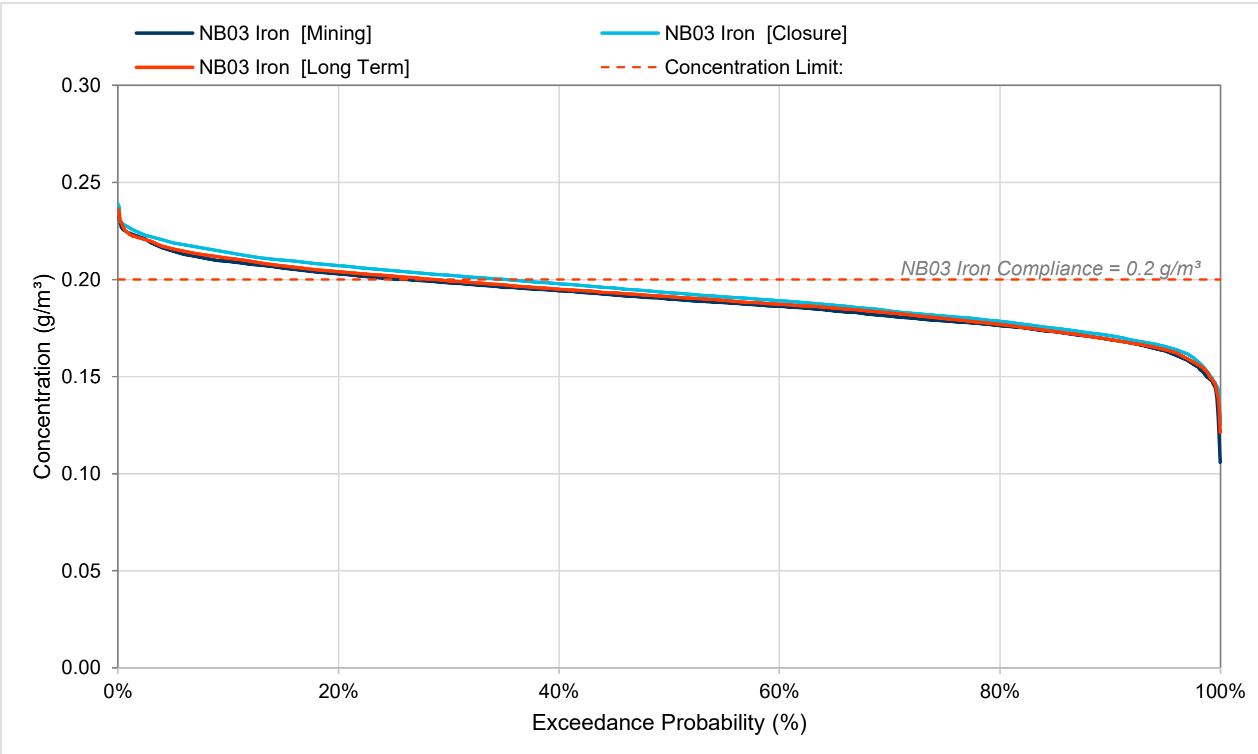


Figure 85 NB03 Iron – Modelled probability exceedance (Basecase)

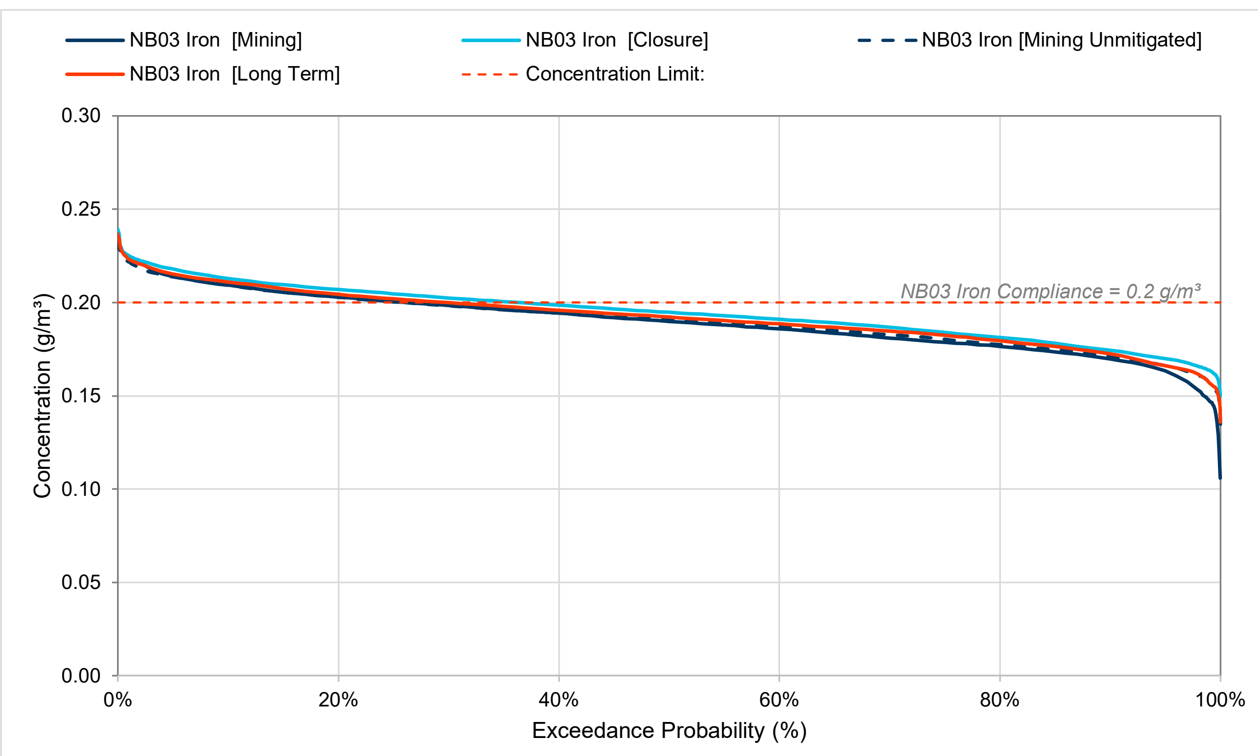


Figure 86 NB03 Iron – Modelled probability exceedance (Selected Mitigation)

Modelled copper concentrations show exceedances of the compliance limit (0.009 mg/L) approximately 3 % of the in the basecase scenario (Figure 87). These modelled compliance exceedances do not consider hardness and the 0.009 mg/l copper limit assumes a hardness of 100 mg/L. The elevated copper concentrations are all modelled with an associated elevated hardness (in excess of 400 mg/L). Based on the hardness adjusted compliance criteria (0.035 mg/L) the results presented are expected to be within the compliance limits.

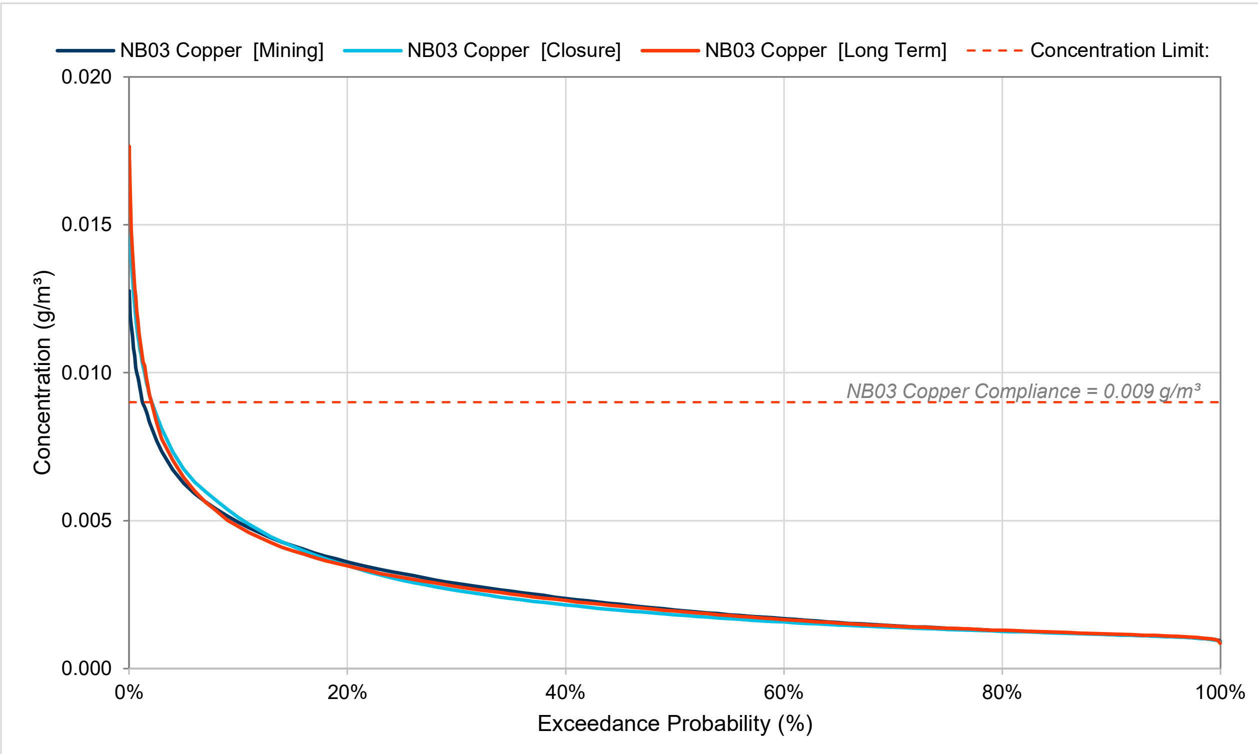


Figure 87 ***NB03 Copper – Modelled probability exceedance (Basecase)***

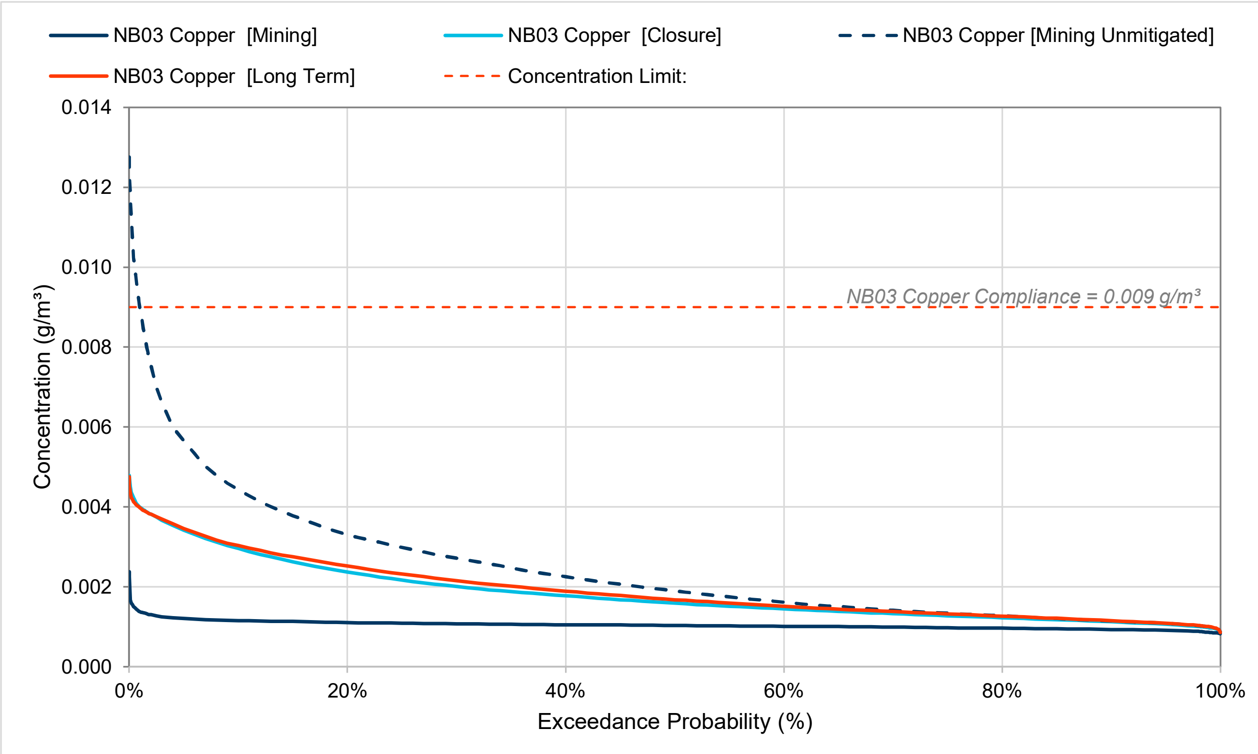


Figure 88 NB03 Copper – Modelled probability exceedance (Selected Mitigation)

5.13 Surface Water Summary

The WBM indicates that the top of the FRBF could be reached after approximately 51 years post closure (year 2081), following which water from FROP will spill into the IMOP for a period (33 years based on the mean estimate) until lake levels equalise. The combined FRIM Pit Lake is modelled to reach a long term equilibrium level of between 486 and 494 m RL. It is considered unlikely that the pit spill level (of 497 m RL) in the northwest will be reached based on the modelling undertaken.

FRIM pit water levels above 487 m RL will potentially result in increased seepage through to Murphys Silt Pond (as a result of pit water draining through the Frasers South WRS). This seepage is assumed captured and is pumped back to FRIM. Therefore, although an increased volume of water through this pathway is anticipated, no net effect on discharge volumes to the receiving environment is expected.

Sulphate concentrations within Deepdell Creek are expected to increase post closure as a result of an increase in sulphate concentration and mass from seepage waters (associated with WRS development), Coronation pit lake spill waters and seepage through the underlying schist into Deepdell Creek. Concentrations of Ammoniacal N, Arsenic and Iron are generally expected to improve post closure as modelled overflow from Maori Tommy and Battery Creek Silt Ponds is reduced during low flow periods. Generally, modelled concentrations are within the compliance limits with the model scenario excluding the flow augmentation showing a minor increase in modelled exceedance in some cases. The inclusion of the flow augmentation however offers benefits in reducing low flow concentrations within Deepdell Creek and providing contingency during periods of prolonged low flow. Furthermore, the basecase scenario (which does not include the flow augmentation) is optimised and assumes that Maori Tommy and Battery Creek Silt Ponds operate so that no (or a very limited) volume of water spills to Deepdell Creek during low flow events (i.e. there would be a high reliance on how these silt ponds operate post closure). Spill events from these silt pond during low flow events could potentially result in sulphate concentrations up to 1,500 mg/L at DC08 when no additional dilution is present (i.e. No flow augmentation).

Modelled exceedances of iron within the Shag River and primarily a result of the assumed basecase water quality and are likely conservative and significantly over-stated.

Basecase modelling of the NBWR shows compliance exceedance at the surface water compliance locations NBWRRF and NB03. By implementing a selected range of mitigation measures within the catchment (rehabilitation of WRS, implementation of the PTS, collection and controlled release of all seepage from the Frasers West, South and Golden Bar WRSs and, selective pumping of waters back to Frasers Pit), the risk of compliance exceedance is significantly reduced with concentrations of sulphate, Nitrate N, Ammoniacal N and copper below the stated compliance limits. Elevated arsenic at compliance location NB03 is a result of the Golden Bar pit spill and could be managed by controlled discharge (during high flows) and/or treatment (e.g. dosing the pit lake with Ferric Chloride). As in the Shag River catchment, modelled concentrations of iron are primarily a result of the assumed basecase water quality and modelled exceedances of iron are likely conservative and significantly over stated.

6. Conclusions

Groundwater modelling results indicate that groundwater flow into and out of the existing and proposed Pits, as well as groundwater seepage from site WRSs and Pit lakes are expected to move laterally within the weathered schist and be captured in silt ponds and/or report to the receiving surface water catchments.

The groundwater contaminant plume is modelled to primarily impact Deepdell Creek (from a combination of WRS seepage through the natural schist) with an estimated sulphate seepage flux of between 24 and 861 kg/day (20 and 200 years post closure respectively). The Waikouaiti River North Branch is modelled to receive an estimated sulphate seepage flux of between 5 and 117 kg/day (20 and 200 years post closure respectively) with the majority of the mass sourced directly from WRS seepage.

The WBM indicates that the combined FRIM Pit Lake is unlikely to spill into the NBWR via the low point on the pit rim in the northwest (497 m RL) and that a stabilised pit lake water level of between 486 and 494 m RL is likely to form in the long term (ca. 200 years+). Increased seepage through to Murphys Silt Pond in the south is expected in pit water levels above 487 m RL.

The WBM shows that in general, sulphate concentrations within the receiving environment in Deepdell Creek and the Shag River are predicted to increase post closure relative to the mining phase due to the relative greater increase in concentration and mass from seepage water (from WRSs) and Coronation Pit Lake overflow. Ammoniacal N and Nitrate N, arsenic and iron concentrations in Deepdell Creek and the Shag River are generally predicted to remain similar post closure relative to the mining phase. Through the mining phase, elevated levels for some of these contaminants are shown in the modelling and are primarily due to modelled overflow from operational and non-rehabilitated areas, including Maori Tommy and Battery Creek Silt Ponds. Active management to reduce the impact of these overflows during operation would be expected to reduce these overflows (and modelled compliance exceedances where they exist). Post closure the increased presence of rehabilitated surfaces and lower volumes of water reporting to these ponds, are expected to decrease the spill volumes and improve overall water quality.

Modelling indicates a low risk of exceeding compliance with the current consented criteria within Deepdell Creek and the Shag River. Iron is modelled as exceeding the compliance limits within the Shag River (@ Loop Road) due to the assumed natural background concentrations for iron equalling the compliance limit however this is considered conservative and significantly over stated.

The presence of the flow augmentation has a small impact on the predicted level of compliance but does reduce concentrations (particularly of sulphate) in Deepdell Creek during low flows. However, the operation of the Maori Tommy and Battery Creek Silt Ponds within the WBM are optimised so that no (or a very limited) volume of water spills to Deepdell Creek during low flow events (ie. there would be a high reliance on how these silt ponds operate post closure). Spill events from these silt pond during low flow events could potentially result in sulphate concentrations up to 1,500 mg/L at DC07 and DC08 when no additional dilution is present (ie. no flow augmentation). The inclusion of the flow augmentation therefore offers benefits in reducing low flow concentrations within the Deepdell Creek enabling receiving water compliance to be met and provides contingency during periods of prolonged low flow.

In the NBWR, basecase modelling shows compliance exceedance at the surface water compliance locations NBWRRF and NB03. By implementing a package of selected mitigation measures within the catchment (rehabilitation of WRS, implementation of PTSs, collection and controlled release of all seepage from the Frasers West, South and Golden Bar WRSs and, selective pumping of waters back to Frasers Pit), the risk of compliance exceedance is largely removed with concentrations of sulphate, Nitrate N, Ammoniacal N and copper substantially reduced. Modelled elevated arsenic at compliance location NB03 as a result of the Golden Bar pit spill could be managed by controlled discharge (during high flows) and/or treatment (eg. dosing the pit lake with Ferric Chloride). As in the Shag River catchment, modelled concentrations of iron are primarily a result of the assumed basecase water quality and modelled exceedances of iron are likely conservative and significantly over stated.

Overall the results of the groundwater and surface water modelling suggest that the proposed development can be undertaken within the currently consented surface water compliance criteria limits with the assumptions that:

- The consented Camp Creek Dam (or an alternative source of augmentation water) is available and can augment Deepdell Stream flow to provide dilution against elevated concentrations at DC07 and DC08 during low flow conditions;
- The Back Road WRS (BRWRS) is not utilised during MPIV mine life;
- The Frasers West / South and Golden Bar WRSs are rehabilitated so that infiltration (and seepage) reduces to a rate of 29.2 mm/year;
- Passive Treatment Systems are capturing and treating all seepage water from the Frasers West, Frasers South and Golden Bar WRS and reducing sulphate loads by 30% before discharge to the respective silt / collection sumps;
- The Frasers West Silt Pond, Clydesdale Silt Ponds and Murphys Silt Ponds are converted to sumps and discharge to the receiving surface water environment only at elevated flows. The ponds are equipped with a system that ensures excess water is returned back to Frasers Pit toavoid uncontrolled overflow;
- A new collection sump capturing seepage from the Frasers West and South WRSs is constructed at or near the monitoring location NBWRTR. This sump will operate in a similar manner to the Frasers West, Clydesdale and Murphys Silt ponds in terms of discharge to the NBWR and return to Frasers; and
- Suitable operational controls and adaptive management processes are developed and implemented during mining and in the early stages of closure.

Other options to either limit and /or decrease the leachate volumes and loadings entering the surface water receiving environment together with potential remedial measures could be considered as part of the Macraes water management plan. These options include but are not necessarily limited to the following:

- Installation of flow monitoring on the Waikouaiti River North Branch to support design, construction and operation of discharge controls;
- Alternative WRS construction methodologies and/or reduced heights could be considered to reduce the sulphate and trace element loadings entering the surface water environment from seepage waters;
- Targeted passive and/or active treatment of sources could be investigated and implemented in areas where the discharge loadings are elevated; and
- Further optimisation of flow augmentation from Camp Creek reservoir (and/or other potential dilution sources) to Deepdell Creek can be carried out to ensure there is sufficient dilution water available during low flow periods.

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Appendices

Appendix A

Water Balance Model Build Report

A-1 Model Inputs

Key inputs into the Water Balance Model as outlined as provided.

– Stage volume area table for FROP, IMOP and Golden Bar deposition
– Measured site data
– Mine area and waste rock stack plans – current / closure
– Catchment runoff plans – current / closure

The overflow levels for the pits are as follows based on the information provided by OGNZL:

- FRIM Pit overflow 497 mRL

The overflow has been modelled to mimic a rectangular weir and a v-notch weir. When the pit starts overflowing below a certain water level the overflow acts as a v-notch weir. For periods of high overflow, when the pit water level reaches a certain height, the overflow acts as a rectangular weir.

The pit stage volume area relationships represented in the model accounts for the voids in the pit backfills. The voids are accounted for with a void ratio which is removed from the cumulative backfill volume to account for water seeping into the voids as the pit fills.

The silt ponds in the water balance model are represented with stage volume area curves to model the filling and release of the ponds.

A-1-1 Pit and Pond Discharge Hydraulics

Pits and freshwater dams discharge from overtopping flows are represented by a compound triangular-rectangular sharp crested weir (CTRSC) in the WBM unless otherwise specified. This arbitrary weir is defined with a width of 6 m and a 0.5 m deep v-notch.

Smaller silt ponds operate on the assumption that they have little buffering capacity and daily inflows match outflows where the pond is at the overflow level.

Table A-1 Stage volume curve for proposed Frasers Pit Lake

RL	Water Volume (m³)	Area (m²)
420	2,873,263	561,399
425	3,162,823	606,194
430	3,356,070	648,831
435	3,618,486	699,521
440	3,880,805	743,689
445	4,307,804	789,190
450	4,568,193	835,928
455	4,827,830	877,240
460	5,064,624	915,376
465	5,308,452	1,012,056
470	5,618,746	1,075,993
475	5,910,534	1,136,587
480	6,362,280	1,234,522
485	6,864,095	1,346,409
490	7,316,652	1,444,375
495	7,582,774	1,500,891
500	7,851,984	1,551,628

*Volume above Tailings Only, inclusive of pore water in embankment

Table A-2 Stage volume curve for proposed IM Pit

RL	Water Volume (m³)	Area (m²)
330	13,271	13,119
335	72,620	14,825
340	101,350	21,406
345	140,318	29,529
350	172,096	36,046
355	202,252	41,844
360	262,207	53,840
365	323,824	67,023
370	362,284	73,379
375	409,282	82,644
380	457,768	92,189
385	510,171	103,448
390	572,545	116,464
395	642,390	132,155
400	701,222	142,798
405	774,907	156,522
410	836,533	169,793
415	888,950	180,182
420	1,179,806	197,411
425	1,263,917	217,449
430	1,351,458	233,696
435	1,455,932	259,329
440	1,538,785	275,397
445	1,522,177	289,829
450	1,631,495	313,073
455	1,730,300	334,278
460	1,813,841	350,227
465	1,929,242	375,504
470	2,037,237	401,156
475	2,152,899	423,224
480	2,337,270	455,981
485	2,556,113	513,396
490	2,730,197	555,604
495	2,832,565	577,344
500	2,936,122	596,861

*Volume above Tailings Only, inclusive of pore water in embankment

Table A-3 Deepdell North Pit Stage Volume relationship

RL	Water Volume (m³)	Area (m²)
367.5	7941.6	3200
370.0	16931.14	3600
372.5	49131.95	12900
375.0	91654.54	17000
377.5	143770.2	20800
380.0	203340.1	23800
382.5	278307.4	30000
385.0	377976.7	39900
387.5	521881.1	57600
390.0	682238.6	64100
392.5	861216.7	71600
395.0	1055523	77700
397.5	1258169	81100
400.0	1470574	85000
402.5	1736735	106500
405.0	2020170	113400
407.5	2320733	120200
410.0	2634680	125600
412.5	2956486	128700
415.0	3287602	132400
417.5	3673427	154300
420.0	4071572	159300
422.5	4478681	162800
425.0	4899850	168500
427.5	5329308	171800
430.0	5768182	175500
432.5	6249804	192600
435.0	6739444	195900
437.5	7237251	199100
440.0	7748330	204400
442.5	8268810	208200
445.0	8800220	212600
447.5	9375957	230300
450.0	9962151	234500
452.5	10565638	241400
455.0	11188745	249200

Table A-4 Coronation Pit Stage Volume relationship

RL	Water Volume (m³)	Area (m²)
552.5	3746.765	1500
555.0	8808.889	2000
557.5	23125.47	5700
560.0	46226.75	9200
562.5	76142.23	12000
565.0	114808.3	15500
567.5	164329.6	19800
570.0	228424.4	25600
572.5	314544.6	34400
575.0	418307.1	41500
577.5	541485.8	49300
580.0	678722.1	54900
582.5	850434.2	68700
585.0	1036337	74400
587.5	1275700	95700
590.0	1553974	111300
592.5	1864720	124300
595.0	2193360	131500
597.5	2539424	138400
600.0	2902656	145300
602.5	3304351	160700
605.0	3720905	166600
607.5	4154321	173400
610.0	4620337	186400
612.5	5104550	193700
615.0	5603991	199800
617.5	6139738	214300
620.0	6688591	219500
622.5	7251852	225300
625.0	7830462	231400
627.5	8425517	238000
630.0	9038961	245400
632.5	9709698	268300
635.0	10406262	278600
637.5	11119168	285200
640.0	11853154	293600
642.5	12619726	306600
645.0	13416979	318900
647.5	14276638	343900
650.0	15182928	362500

RL	Water Volume (m³)	Area (m²)
652.5	16146757	385500
655.0	17201986	422100
657.5	18294126	436900
660.0	19426231	452800
662.5	20631077	481900
665.0	21891485	504200
667.5	23210340	527500

Table A-5 Golden Bar Pit Stage Volume relationship

RL	Water Volume (m³)	Area (m²)
420	2162.463	900
422.5	6798.064	1900
425	17538.12	4300
427.5	33974.97	6600
430	54606.43	8300
432.5	85596.36	12400
435	123227.9	15100
437.5	165226.9	16800
440	214606.9	19800
442.5	273636.5	23600
445	339939	26500
447.5	423559.6	33400
450	512119.3	35400
452.5	610185.7	39200
455	723842.3	45500
457.5	843507.9	47900
460	973148.3	51900
462.5	1130133	62800
465	1301276	68500
467.5	1483324	72800
470	1679742	78600
472.5	1884572	81900
475	2096683	84800
477.5	2336623	96000
480	2589038	101000
482.5	2850700	104700
485	3127479	110700
487.5	3413583	114400
490	3711488	119200
492.5	4054158	137100
495	4406772	141000
497.5	4768230	144600

A-2 Australian Water Balance Model (AWBM) Calibration

A-2-1 Deepdell Creek

For flows from un-effected catchments an AWBM is calibrated to gauging undertaken on Deepdell Creek at DC03 (immediately upstream of DC04 and the haul road crossing Deepdell Creek) between 1991 and 2018. This gauging site has a contributing catchment area of 4,200 ha. Golden Point rainfall and evaporation records are applied in calibration of the AWBM. The calibrated runoff model predicts both surface runoff and total runoff including base flow recharge, where total runoff is applied to model stream flows. The statistical comparison between gauge and calculated flows is shown in Figure A-1. The model calibration has a slight bias for underestimating natural catchment flows which is seen as conservative for assessing water quality effects following mass load contributions. This is not true for the driest 1% of flows (i.e. measured flows below 1 L/s), where measured data indicates that flow reduces at a relatively higher rate than predicted.

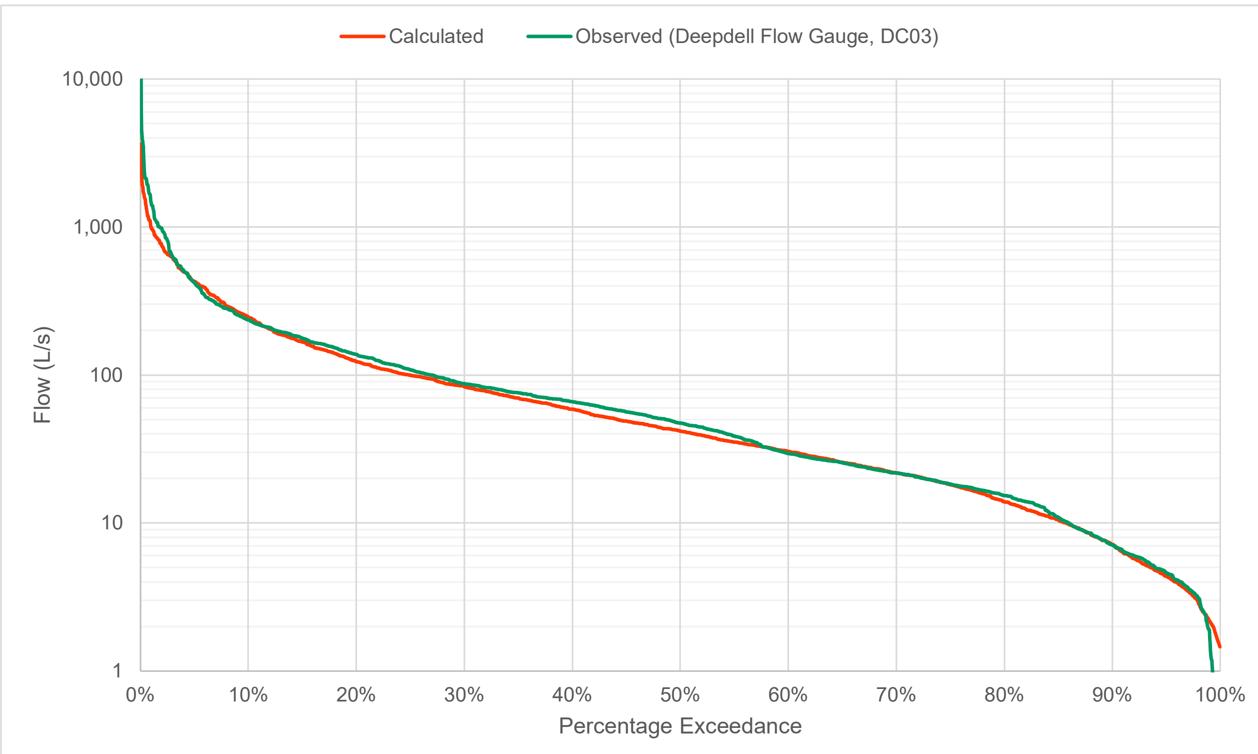


Figure A-1 Calibration of the Deepdell Creek AWBM

A-2-2 Waikouaiti River North Branch

For flows from un-effected catchments in the upper regions of the Waikouaiti River North Branch an AWBM is calibrated to gauging undertaken on the Waikouaiti River North Branch at Golden Bar Road and Gifford Road gauges (NBGR) between 1991 and 1998. These two gauging sites are estimated to have reporting catchments of 250 ha and 640 ha respectively. Golden Point rainfall and evaporation records are applied in calibration of the AWBM. The calibrated runoff model predicts both surface runoff and total runoff including base flow recharge as shown in Figure A-2, with these two outputs closely representing the statistical flows at the respective gauging sites. Given the specific runoff calculated at the lower gauging site – (NBGR) is lower and potentially unconservative, the total specific runoff model output is applied to the WBM for the purpose of pit lake filling projections.

Gauged flows above 10 L/s are estimates only, equivalent to a specific flow of 0.35 mm/d at Gifford Road and 0.135 mm/d at NBGR, corresponding to approximately the highest 15% of flows.

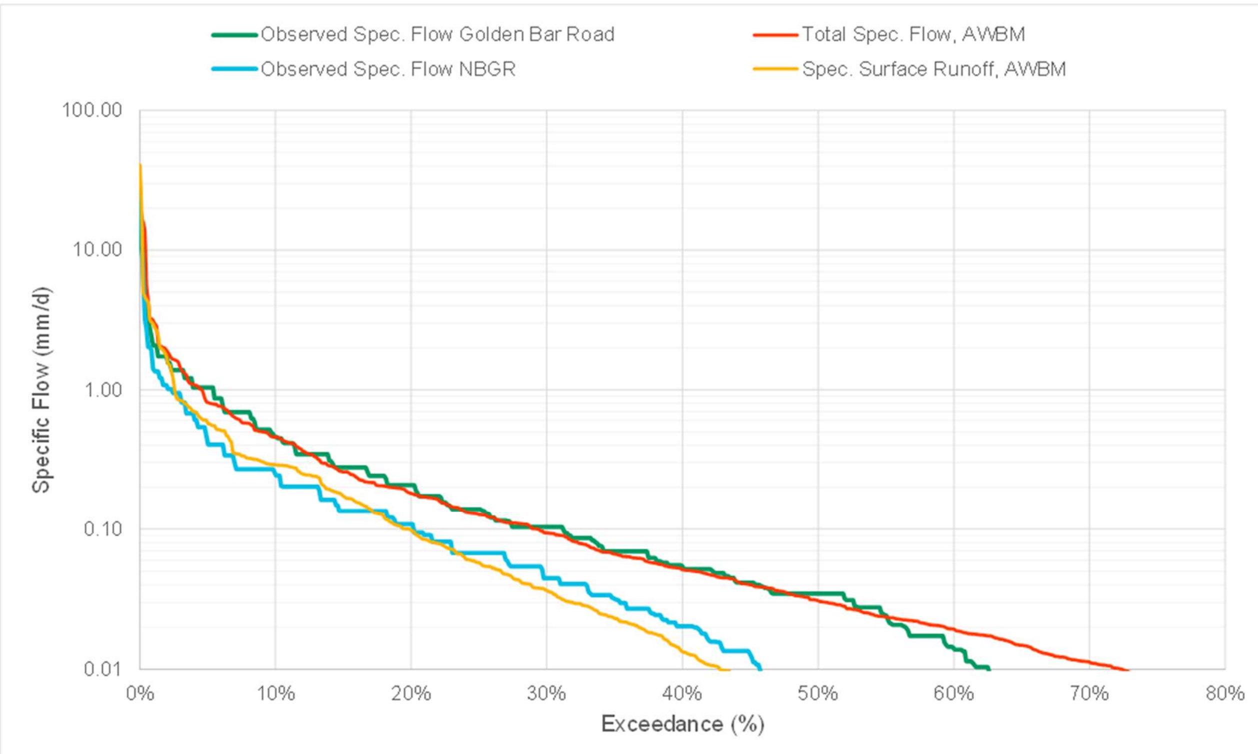


Figure A-2 Calibration of the Waikouaiti River North Branch AWBM

A-3 Catchment Maps for the Proposed Developments

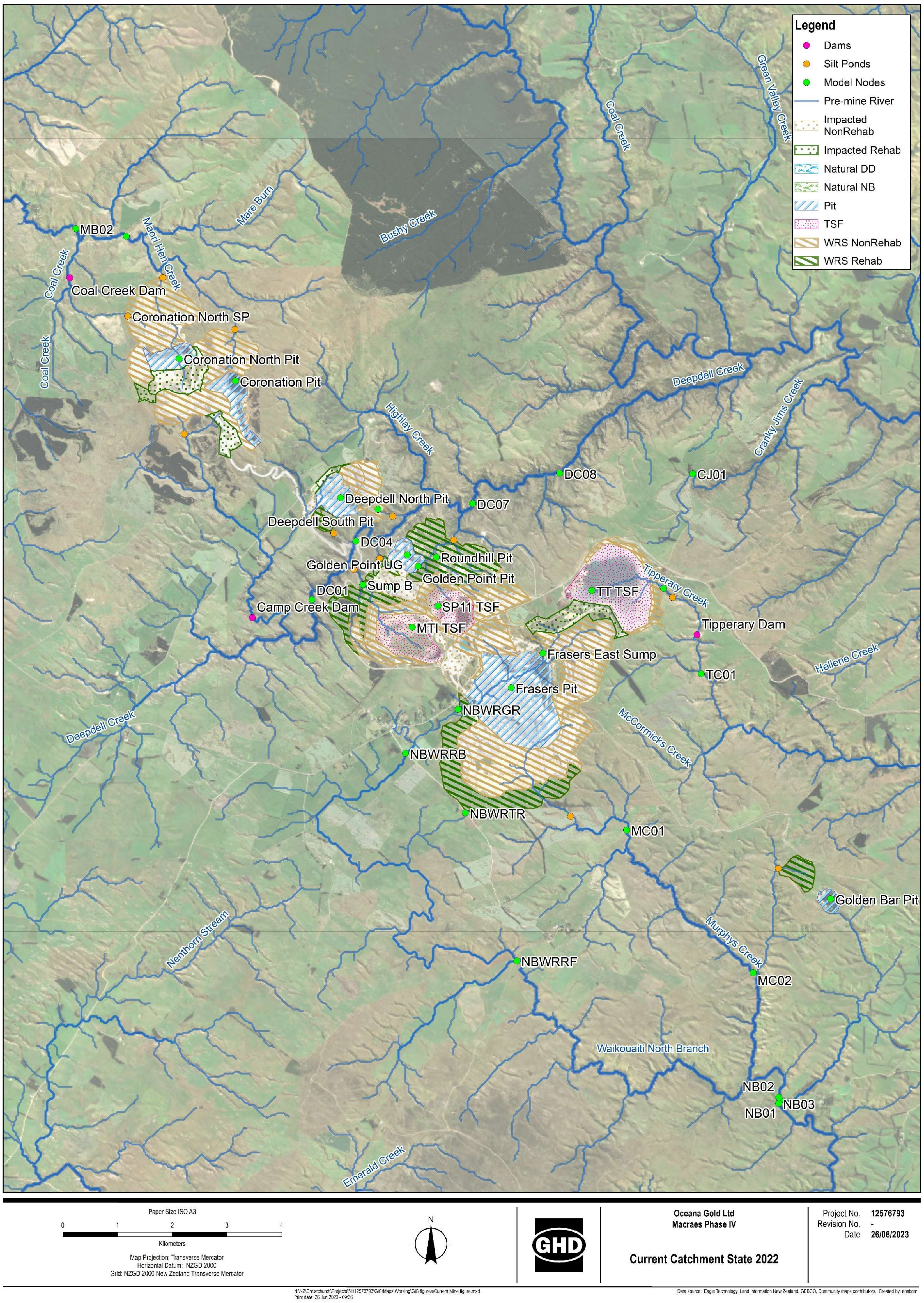


Figure A-3 Model Domain showing active mining surfaces

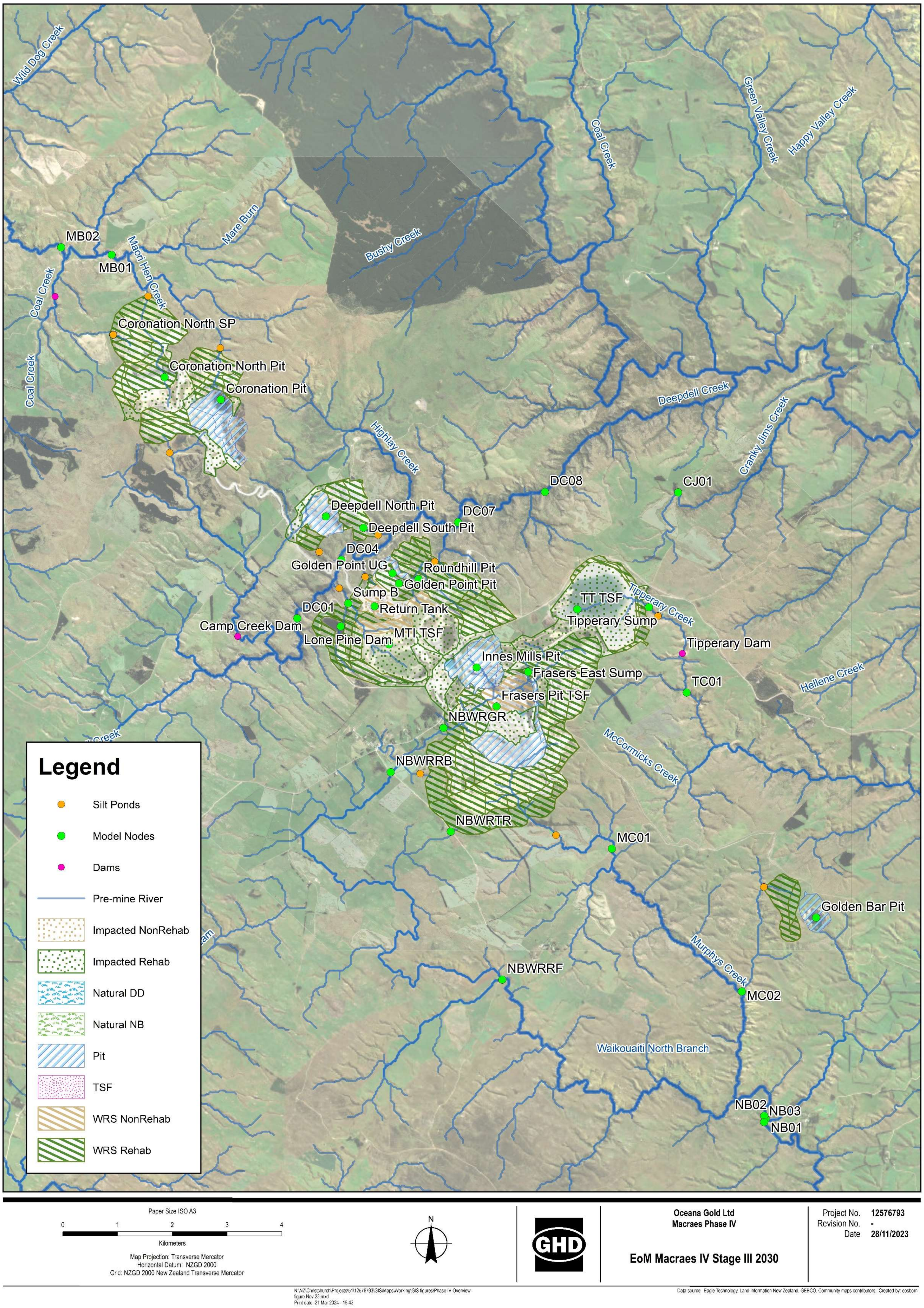


Figure A-4 Model Domain showing closure surface

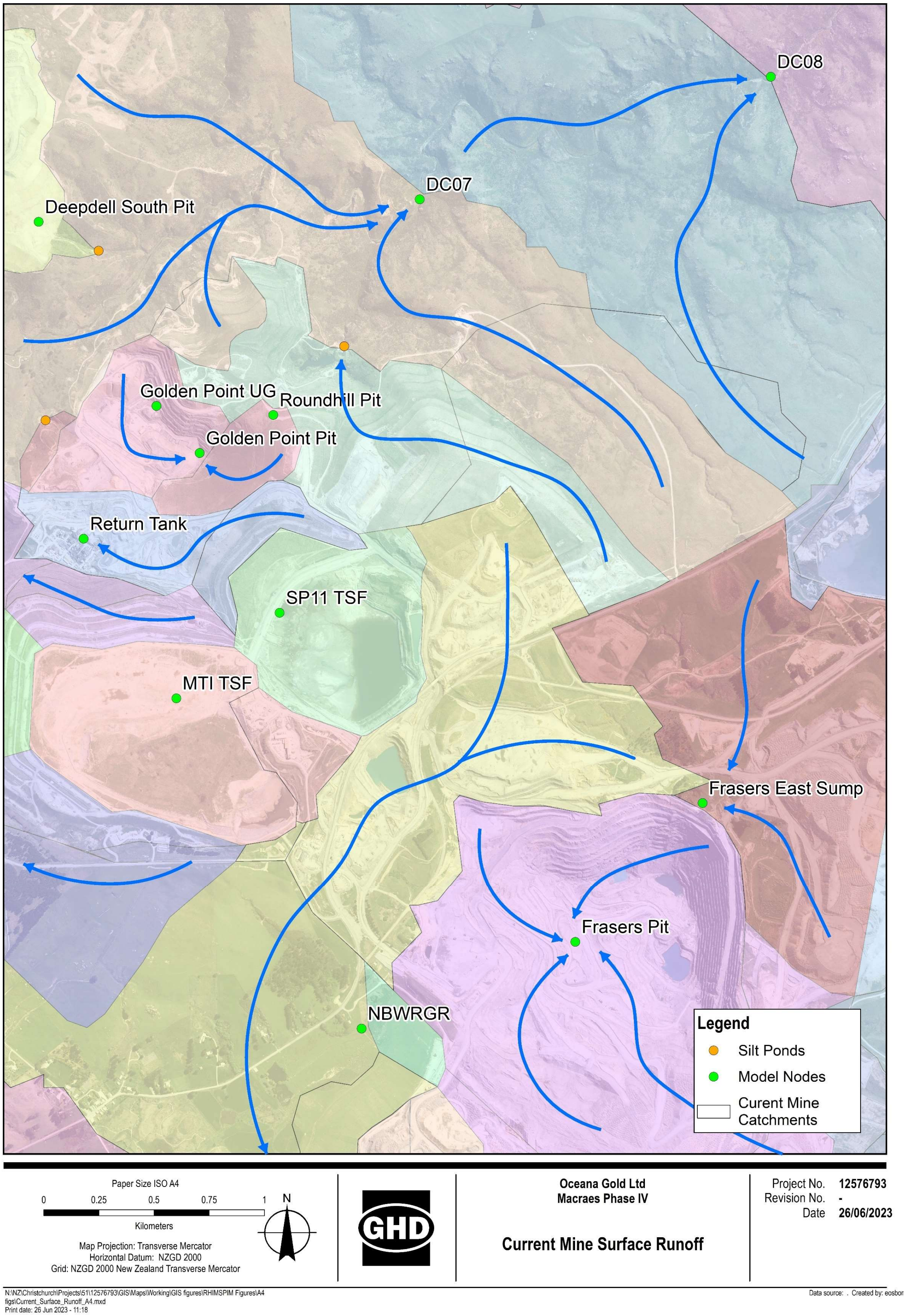


Figure A-5 Current Mine Surface Runoff

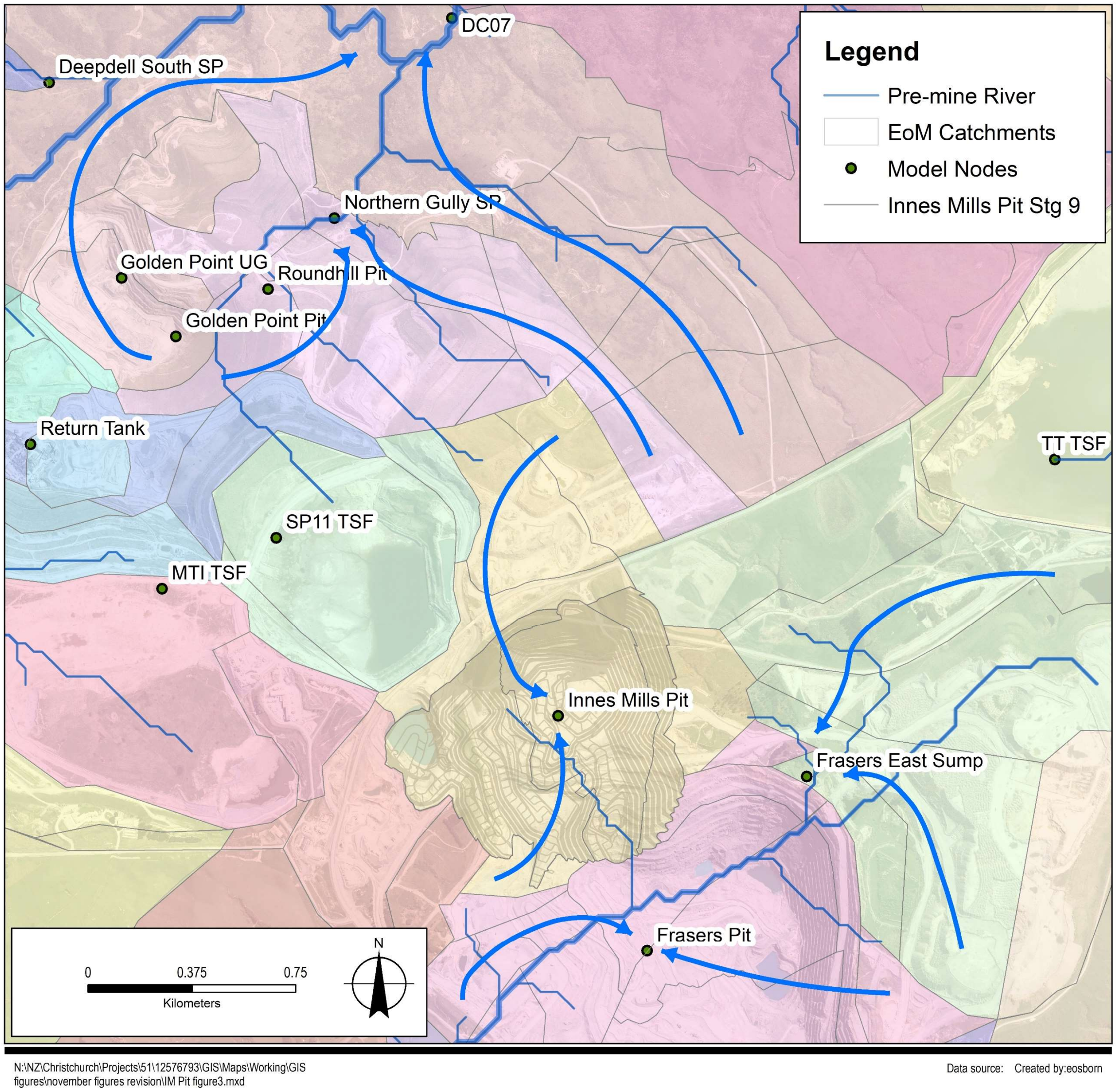
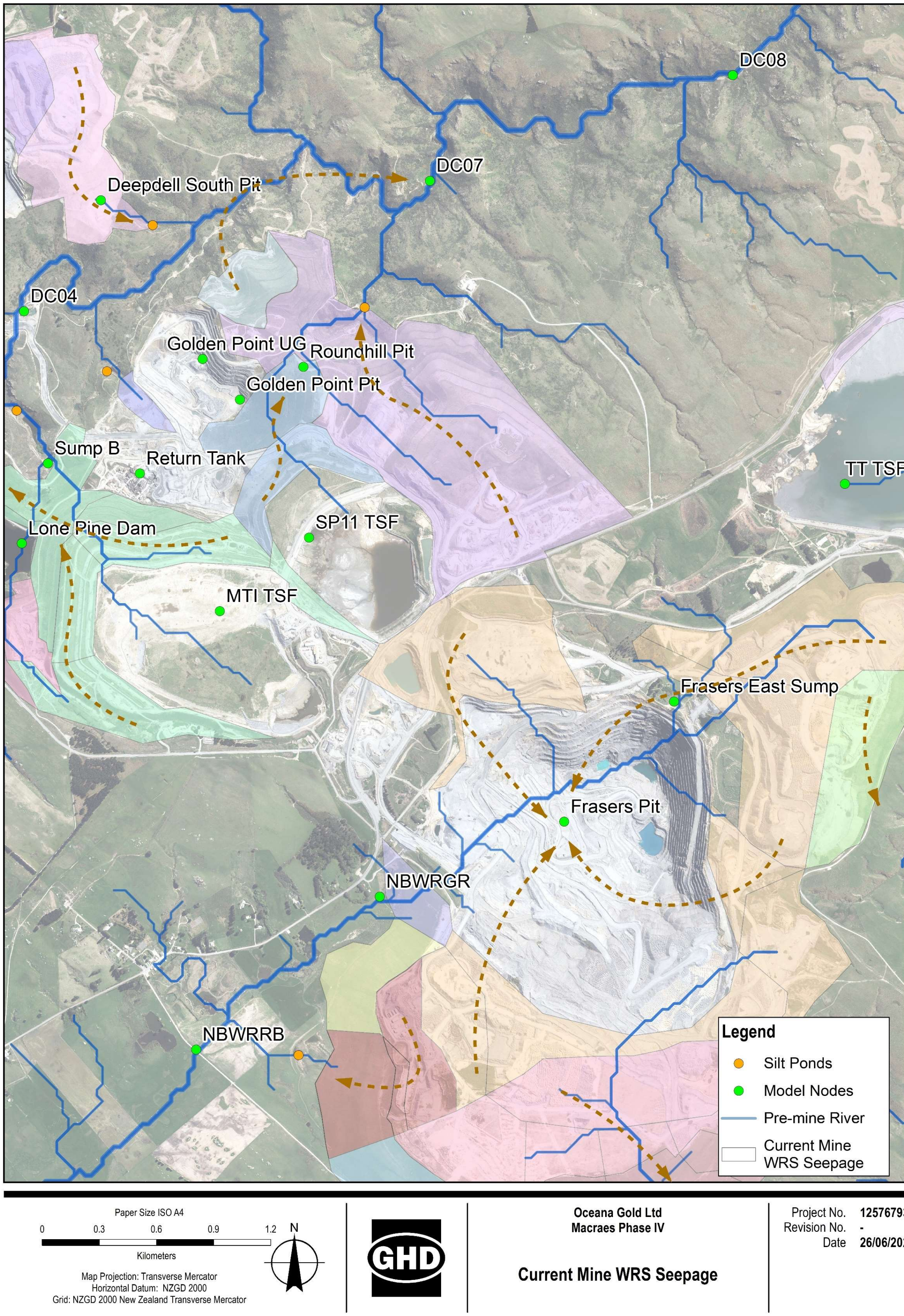


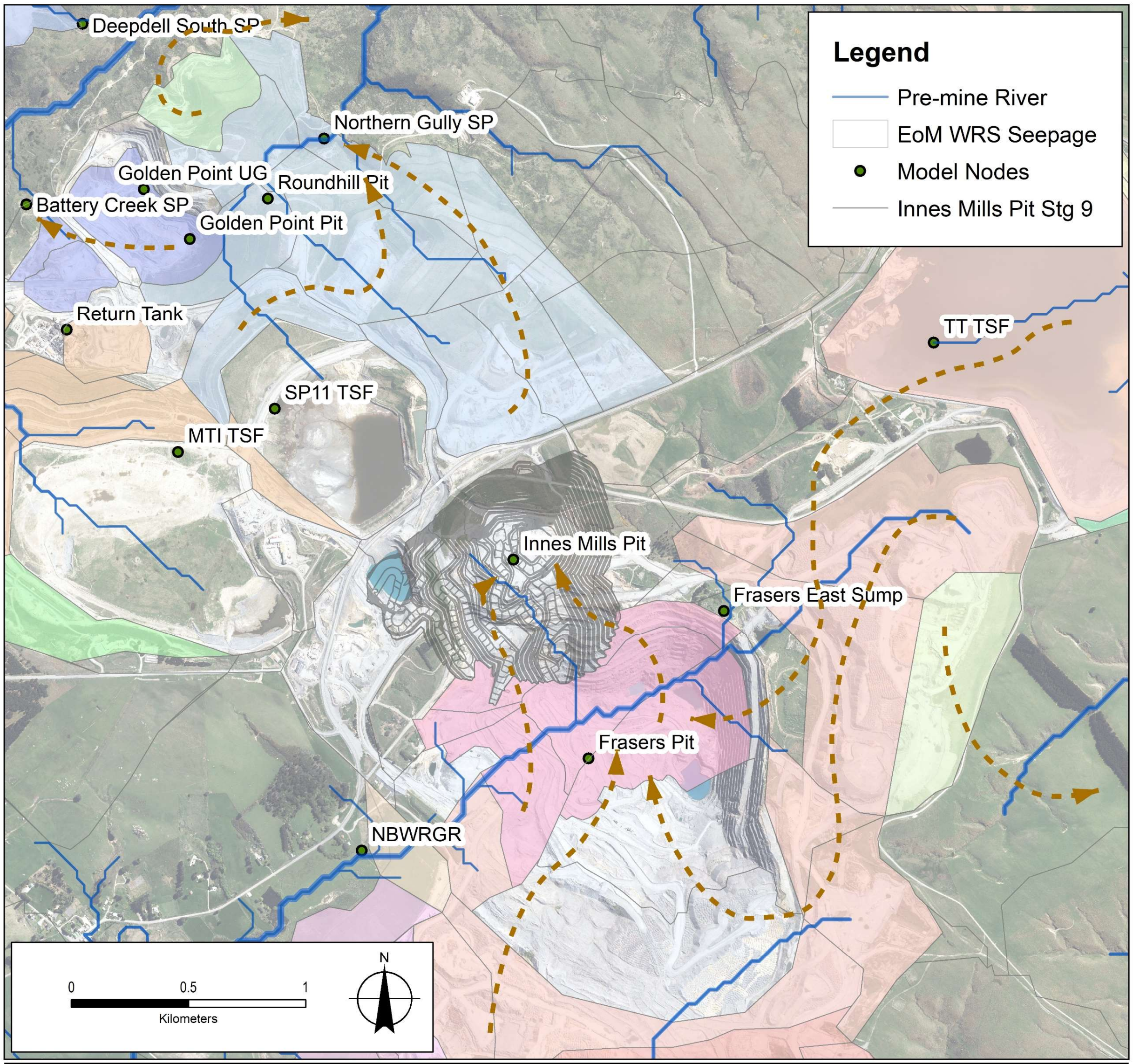
Figure A-6 Future Mine Surface Runoff Figure



G:\51\12576793\GIS\Maps\Working\GIS figures\RHIMSPIM Figures\A4 figs\Current_WRS_Seepage_A4.mxd
Print date: 26 Jun 2023 - 11:55

Data source: . Created by: eosborn

Figure A-7 Current Mine WRS Seepage



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Data source: Created by:eosborn

Figure A-8 Future Mine WRS Seepage

Appendix B

Summary of Hydraulic Properties

Appendix B Table B-1 Summary of Hydrogeological properties applied in previous groundwater models

Report	Property zone	Hydraulic conductivity (m/s)			Specific yield	Specific storage	Porosity (n)	
		Kx	Ky	Kz	Sy	Ss	Effective ne	Total pt
Kingett Mitchell Ltd 2002 Kingett Mitchell Ltd 2005a	Highly weathered schist	1.0E-06	1.0E-05	1.0E-06	-	-	0.02	-
	Moderately weathered schist	5.0E-08	1.0E-06	1.0E-07	-	-	0.02	-
	Slightly weathered schist	1.0E-08	5.0E-08	5.0E-08	-	-	0.004	-
	Unweathered schist	1.0E-09	1.0E-08	1.0E-8	-	-	0.004	-
	Footwall Fault	1.0E-08	1.0E-07	1.0E-09	-	-	-	-
	Hanging Wall Shear	1.0E-08	1.0E-07	1.0E-09	-	-	-	-
	Intra-shear schist	1.0E-09	1.0E-08	1.0E-08	-	-	-	-
	Embankment material	1.0E-07	5.0E-06	1.0E-07	-	-	-	-
	Waste rock	1.0E-06	1.0E-06	1.0E-06	0.25	-	-	-
	Flotation tailings	1.0E-07	1.0E-06	5.0E-08	-	-	-	-
	Mixed tailings	1.0E-07	1.0E-06	5.0E-08	-	-	-	-
	Concentrate tailings	1.0E-06	1.0E-06	1.0E-06	-	-	-	-
	HMSZ movement area	5.0E-06	5.0E-06	5.0E-06	-	-	-	-
Kingett Mitchell Ltd 2005b	Highly weathered schist	3.5E-07	1.0E-06	2.5E-07	0.01	0.00001	0.01	0.01
	Moderately weathered schist	1.0E-07	2.5E-07	6.0E-08	0.01	0.00001	0.01	0.01
	Slightly weathered schist	9.0E-09	9.0E-09	1.0E-09	0.004	0.00001	0.004	0.005
	Unweathered schist	1.0E-09	5.0E-09	5.0E-10	0.004	0.00001	0.004	0.005
	Shear zones of the HMSZ	8.0E-08	8.0E-08	1.0E-08	-	-	-	-
	Embankment material	1.0E-06	1.0E-06	1.0E-06	-	-	-	-
	Waste rock	1.0E-06	1.0E-06	1.0E-06	0.2	0.00001	0.15	0.2
	Fine tailings	1.0E-07	5.0E-07	1.0E-07	0.01	0.00001	0.01	0.02
	Coarse tailings	5.0E-06	5.0E-06	5.0E-06	0.01	0.00001	0.01	0.02
	Schist movement area	5.0E-06	5.0E-06	5.0E-06	-	-	-	-
	Highly weathered schist	3.5E-07	1.0E-06	2.5E-07	0.02	0.00001	0.02	0.03

Golder Associates 2011a	Moderately weathered schist	1.0E-07	2.5E-07	6.0E-08	0.02	0.00001	0.02	0.03
	Slightly weathered schist	5.0E-09	9.0E-09	1.0E-09	0.005	0.00001	0.005	0.006
	Unweathered schist	1.0E-09	5.0E-09	5.0E-10	0.005	0.00001	0.005	0.006
	Embankment Zone A	1.0E-07	1.0E-07	1.0E-07	-	-	-	-
	Embankment Zone B	5.0E-06	5.0E-06	5.0E-06	-	-	-	-
	Embankment Zone C and WRS	1.0E-06	1.0E-06	1.0E-06	0.2	0.00001	0.2	0.25
	Fine tailings	2.0E-07	2.0E-07	2.0E-07	0.38	0.00001	0.38	0.4
	Coarse tailings	5.0E-06	5.0E-06	5.0E-06	0.38	0.00001	0.38	0.4
Golder Associates 2011b	Highly weathered schist	3.5E-07	1.0E-06	2.5E-07	0.02	0.00001	0.01	0.02
	Moderately weathered schist	1.0E-07	2.5E-07	6.0E-08	0.02	0.00001	0.01	0.02
	Slightly weathered schist	9.0E-09	9.0E-09	1.0E-09	0.005	0.00001	0.004	0.005
	Unweathered schist	1.0E-09	5.0E-09	5.0E-10	0.005	0.00001	0.004	0.005
	Embankment material	1.0E-06	1.0E-06	1.0E-08	-	-	-	-
	Waste rock	1.0E-06	1.0E-06	1.0E-06	0.2	0.00001	0.15	0.2
	Fine tailings	1.0E-07	5.0E-07	1.0E-06	0.38	0.00001	0.35	0.4
	Coarse tailings	5.0E-06	5.0E-08	1.0E-07	0.38	0.00001	0.35	0.4
Golder Associates 2011d	Schist	1.0E-07	-	-	-	-	-	-
	Hanging Wall Shear	5.0E-08	-	-	-	-	-	-
	Backfill	3.0E-05	-	-	-	-	-	-
	Pit Liner	1.0E-07	-	-	-	-	-	-
CDM Smith 2016	Schist	5.8E-08	5.8E-08	5.8E-09	-	0.00001	-	0.01
	Waste rock	5.8E-07	5.8E-07	5.8E-07	-	0.00001	-	0.1
	Tailings	1.2E-08	1.2E-08	1.2E-09	-	0.00001	-	0.1
GHD, 2021	Schist	5.8E-08	1E-07	6.9E-09	-	0.00001	0.01	
	Schist (Frasers pit surfaces)	5.8E-07	5.8E-07	5.8E-08	-	0.00001	0.01	
	Waste rock	1E-06	1E-06	1E-06	-	0.00001	0.15	
	Tailings	2E-07	2E-07	2E-07	-	0.00001	0.35	
	FRUG	1E-05	1E-05	1E-05	-	0.00001	0.1	

Appendix C

Boundary Conditions

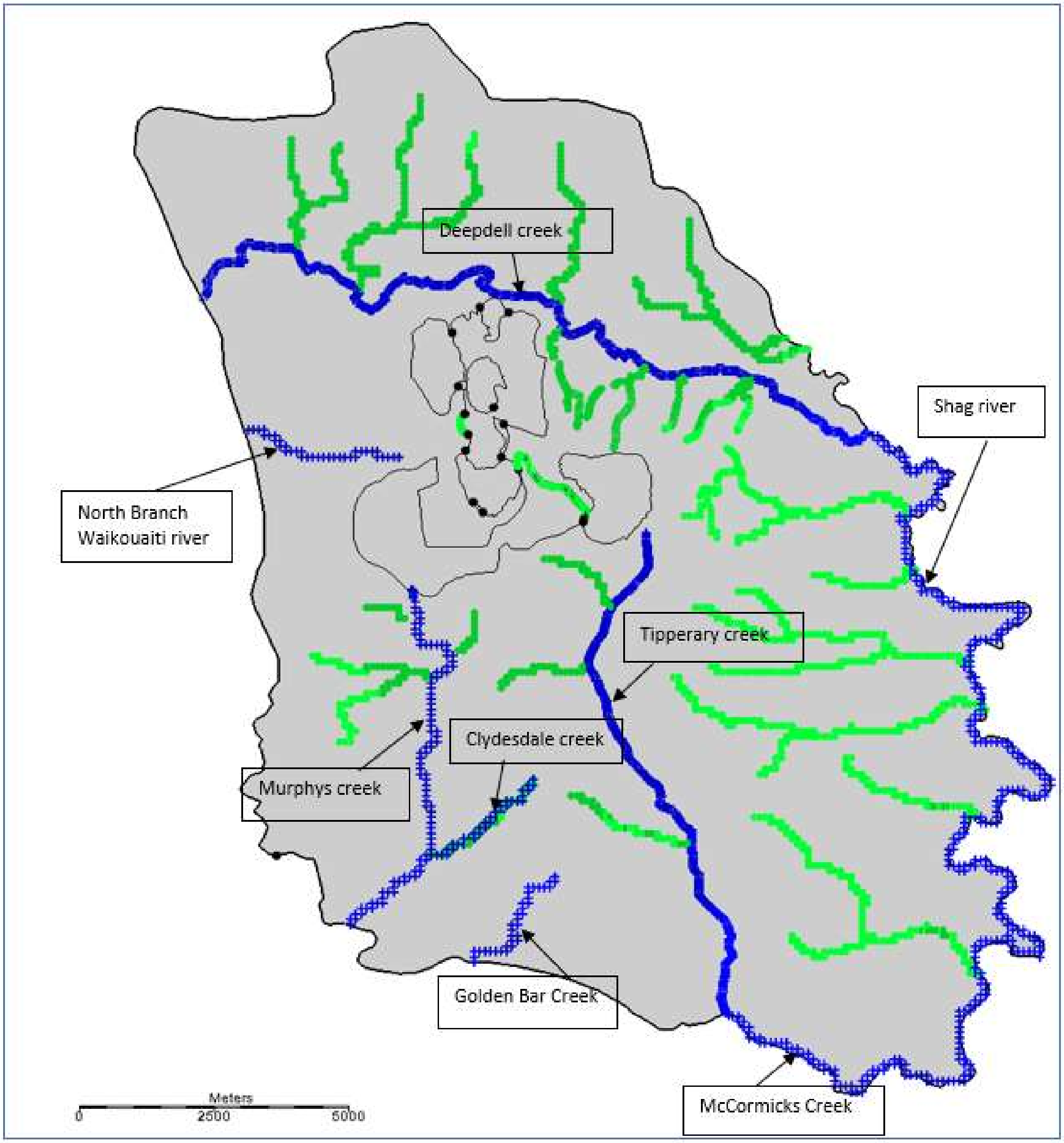

Figure C.1 ***Surface Drain and River boundary conditions applied in the model***

Note that these boundary conditions were largely unchanged in all model runs.

Blue lines represent river boundaries.

Green lines represent drain boundaries.

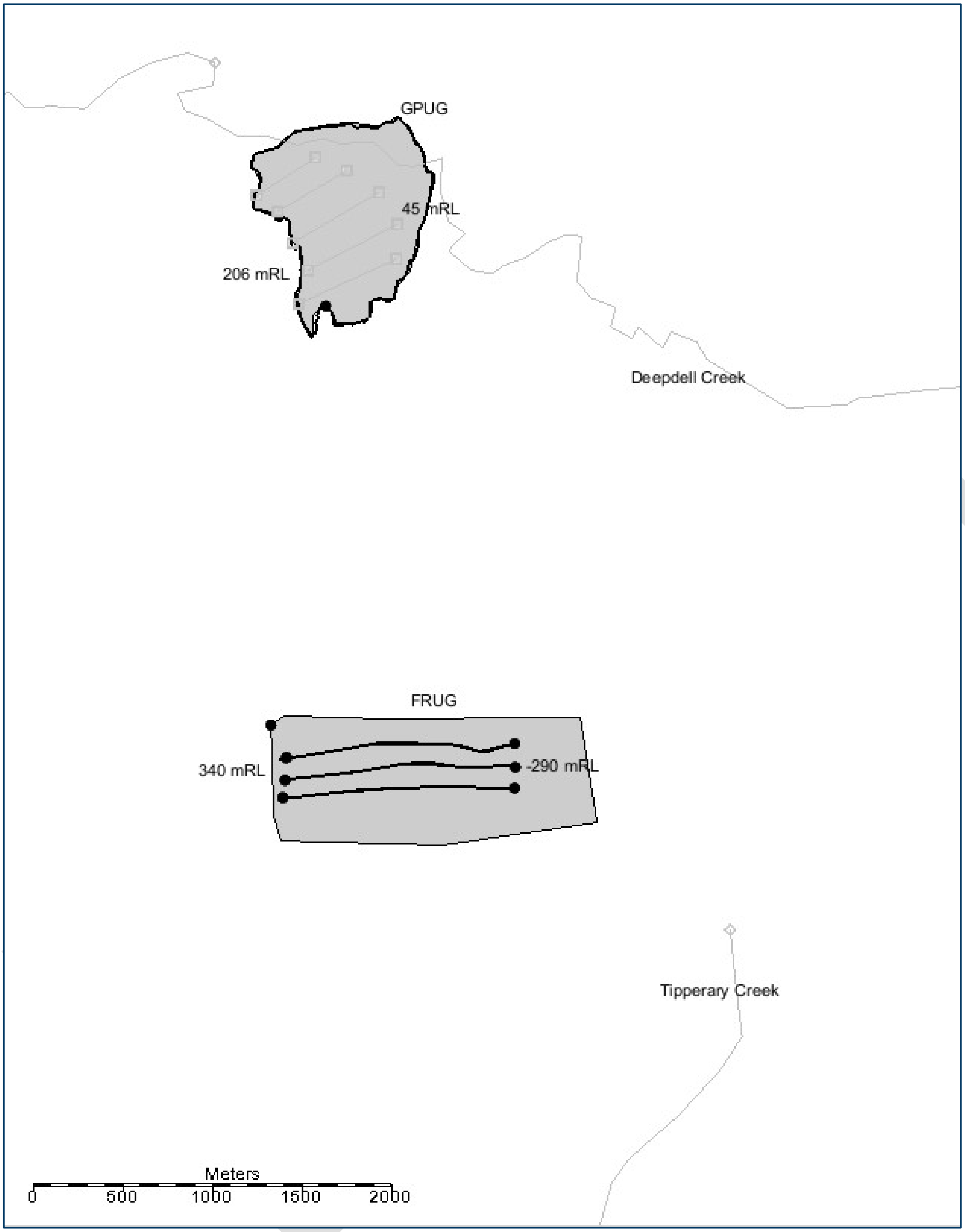

Figure C.2 ***Drain boundary conditions applied during FRUG and GPUG mining.***

Drain boundary conditions were applied using three lining with base elevation at the start and end of 340 mRL and -290 mRL respectively for FRUG. For GPUG, starting and end elevation was different for each line. Start and end elevation for GPUG at deepest point is 206 mRL and 45 mRL respectively..Drain elevation was linearly interpolated in between the two end points.

Area covered in gray represents FRUG and GPUG zone. The hydraulic properties were altered (increased to 0.086 m/d) within the gray polygon to represent mine voids (tunnels) as well as the zone impacted by the FRUG.
These boundary condition was turned off during the recovery runs.

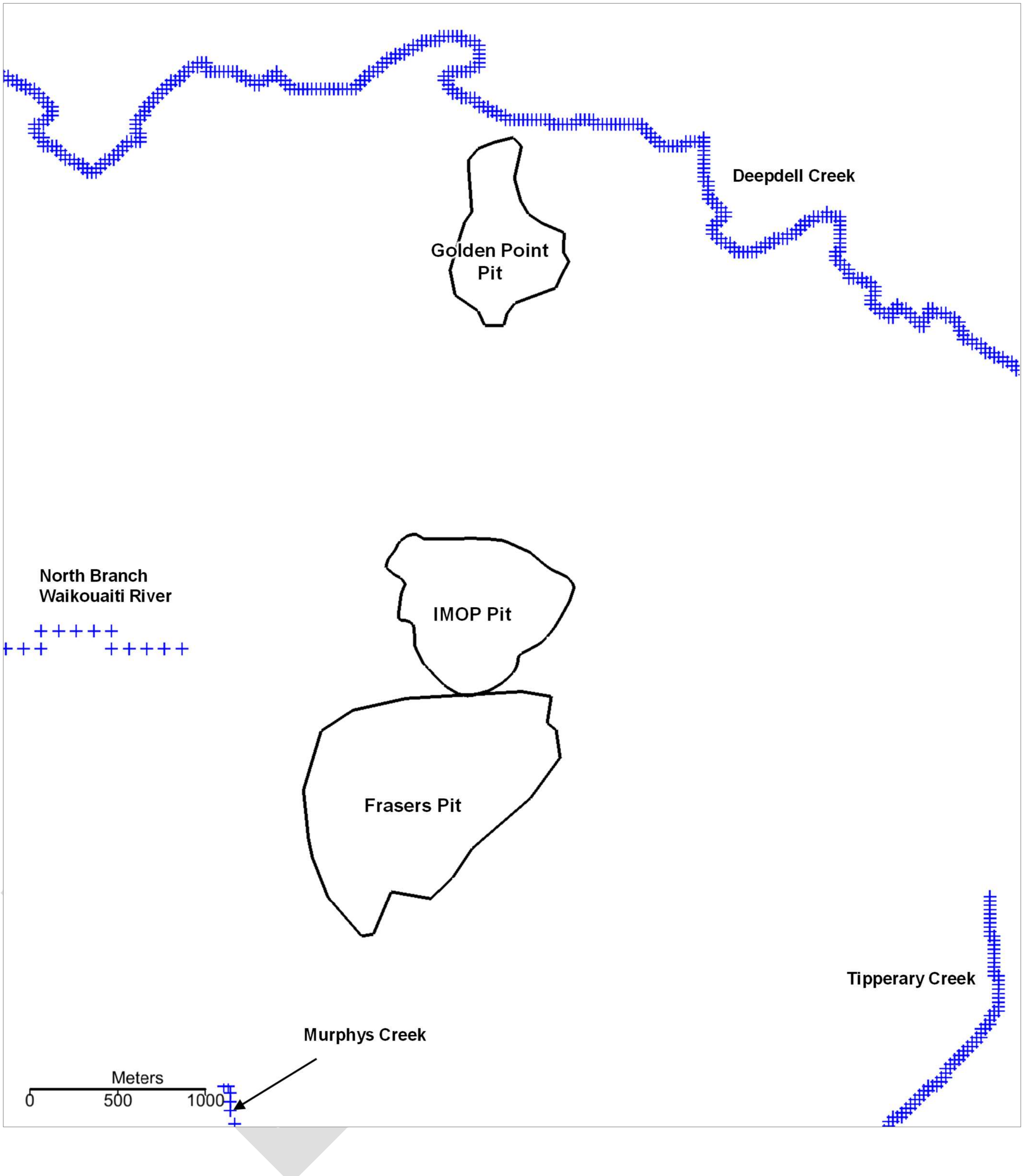

Figure C.3 ***Drain boundary conditions applied during dewatering of for Frasers Pit, IMOP Pit and Golden Point Pit.***

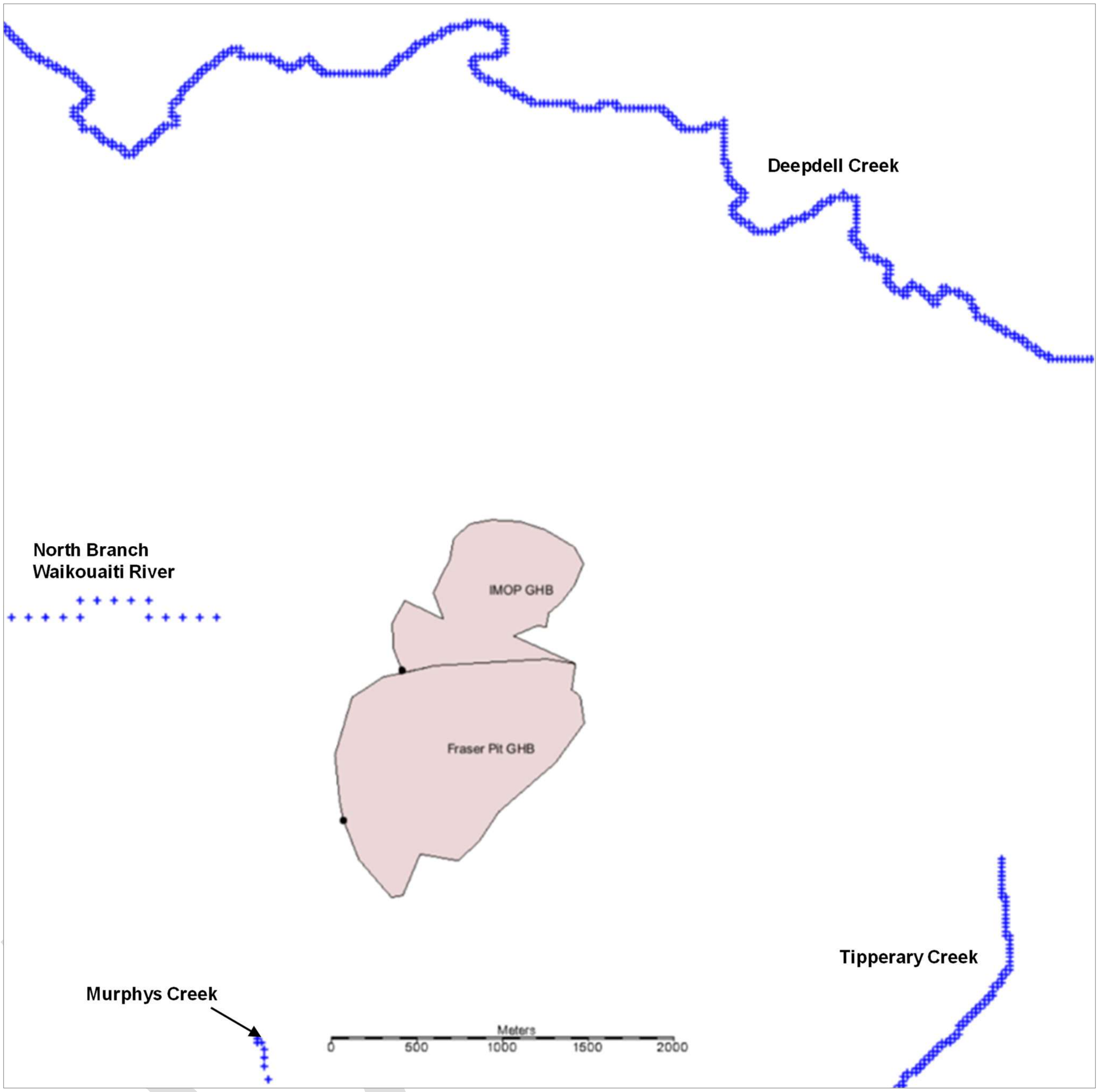

Figure C.4 *General head boundaries applied during recovery for Fraser and IMOP pits.*

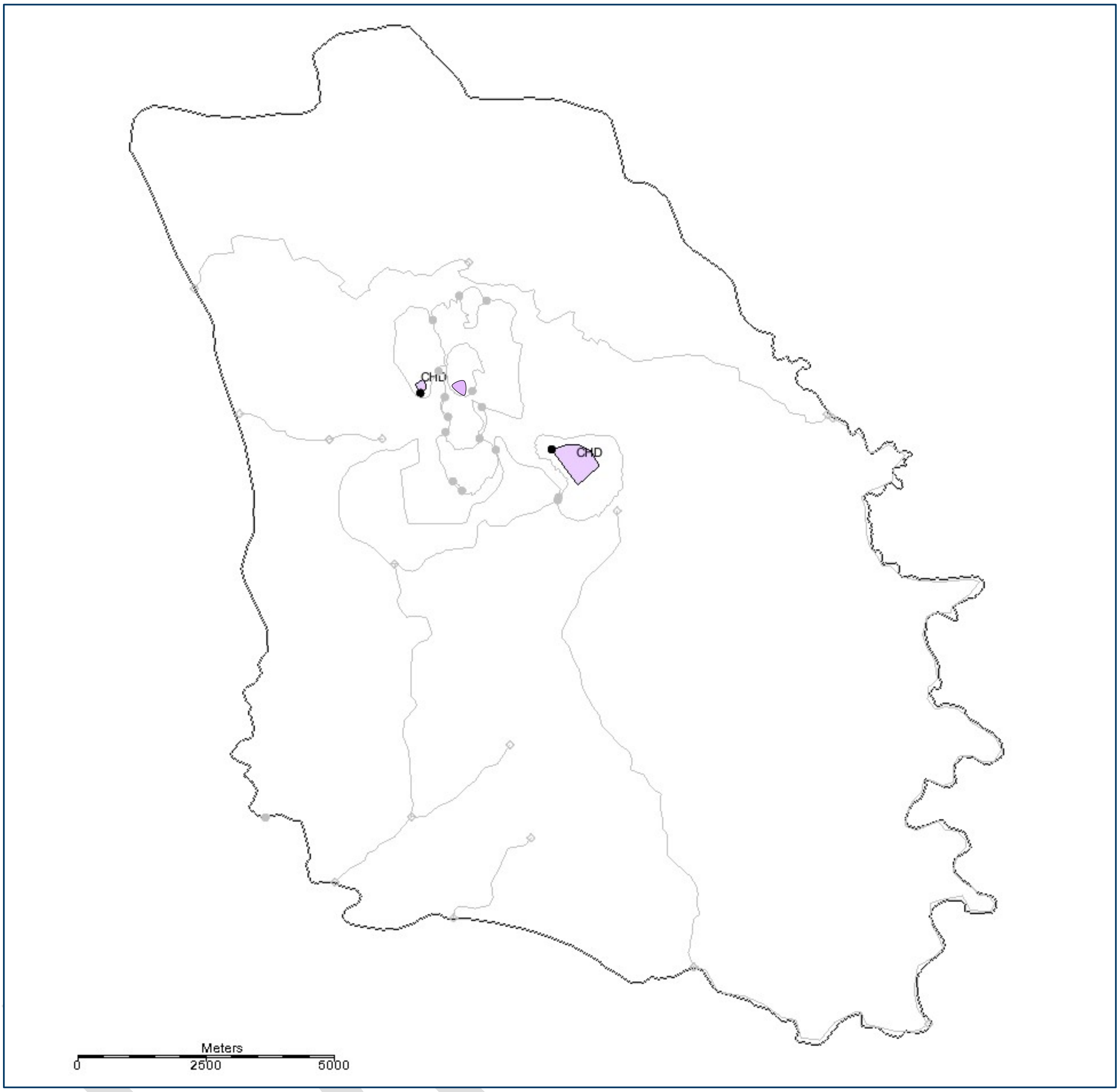

Figure C.5 CHD (Constant head boundary) applied at the TTTSF and MTI /SP11 tailings.

Appendix D

Groundwater Levels

(modelled and measured)

Hole ID	Easting (mine grid)	Northing (mine grid)	Measured groundwater elevation (mRL)	Modelled groundwater elevation (mRL)	Residual - modelled minus measured (m)
DDS 01 A	70345.48	16750.5	413.1133	424.899	11.7857
DDS 02 A	**70502.08**	**16696.41**	**426.375**	426.644	0.269
DDS 03 A	70504.01	16537.11	422.64	416.168	-6.472
FR 02 A	69353.31	12898.28	484.3016	461.109	-23.1926
FR 08	69372.45	12752.43	470.7914	447.497	-23.2944
FR 15	69472.66	12739.81	449.6562	423.625	-26.0312
FR 52 A	69382.23	12210.85	433.9707	421.691	-12.2797
FR 53 A	69326.32	12275.7	433.3069	429.932	-3.3749
FR 54 A	69253.86	12391.73	428.2459	441.32	13.0741
FR 55 A	69313.11	12507.43	432.5826	426.006	-6.5766
FRA 01 A	68360.17	14861.26	501.9556	496.137	-5.8186
FRA 02 A	68383.94	14634.28	512.2542	506.766	-5.4882
FRA 03 A	69564.5	14853.84	438.4511	446.126	7.6749
GB 01	70821.76	5819.16	488.6512	491.608	2.9568
GB 02	70957.5	5751.19	495.7819	495.08	-0.7019
GB 03	70988.24	5615.98	498.0646	499.341	1.2764
GB 04	70980.84	5501.94	505.824	500.437	-5.387
GB 05	70818	5770	494.5081	491.806	-2.7021
GB 06	70901	5720	501.3874	493.434	-7.9534
GB 07	70919	5621	489.7396	495.074	5.3344
GB 08	70907	5521	491.5115	496.934	5.4225
GP 01 A	69681.44	15865.02	370.517	386.271	15.754
GP 02 A	69765.21	15716.04	373.1818	390.937	17.7552
GP 03 A	69758.77	15511.48	372.7273	396.086	23.3587
GP 04 A	69735.27	15421.31	387.5167	400.266	12.7493
GP 05 A	69636.9	15735.25	376.6597	398.136	21.4763
GP 07 A	69620.1	15084.43	403.1169	423.296	20.1791
GP 08 A	69721.19	14869.25	405.944	425.369	19.425
GP 09 A	69865.46	15614.32	373.6682	384.461	10.7928
IM IV 01 A	70220.05	13505.64	483.0432	461.352	-21.6912
IM IV 02 A	70161.88	13451.06	481.6373	459.122	-22.5153
IM IV 03 A	70180.71	13309.46	476.2788	455.986	-20.2928
IM IV 07 A	70032.86	13491.12	447.3536	459.339	11.9854
IM IV 08	70117.1	13424.89	450.9789	457.347	6.3681
IM IV 09	70140.4	13320.35	451.4038	454.631	3.2272
IM IV 10	70082.6	13239.94	452.9586	448.614	-4.3446
IM IV 11	70056.01	13118.44	452.5883	436.633	-15.9553

Hole ID	Easting (mine grid)	Northing (mine grid)	Measured groundwater elevation (mRL)	Modelled groundwater elevation (mRL)	Residual - modelled minus measured (m)
IM IV 12	70048.09	13067.33	452.8471	429.164	-23.6831
IM IV 15	70162.59	13070.04	457.82	448.859	-8.961
IM IV 16	70025.77	13051.44	439.148	423.744	-15.404
IM IV 17	70036.19	13102.73	438.9875	432.435	-6.5525
IM IV 18	70028.34	13174.81	421.5076	440.191	18.6834
IM IV 19	70026.63	13152.44	423.8252	437.436	13.6108
IM IV 20	70024.26	13129.71	428.258	434.474	6.216
IM IV 21	70022.35	13107.58	427.6687	431.693	4.0243
IM IV 22	70017.37	13085.95	428.099	429.468	1.369
IM IV 23	70013.96	13066.96	423.6756	426.911	3.2354
IM IV 24	70010.29	13048.45	427.1501	423.175	-3.9751
IM IV 25	69999.86	13025.28	415.762	416.972	1.21
IM IV 26	69985.06	13002.69	408.459	412.362	3.903
MTD DH.01 A	68801.61	14082.51	529.3889	528.032	-1.3569
MTD DH.02 A	68980.73	13821.83	530.9975	533.319	2.3215
Piezo 02	69563.2	14988.8	445.1733	434.634	-10.5393
Piezo 70 A	69547.94	15101.53	426.4042	431.442	5.0378
PS.03	69377.29	15463.06	433.8707	433.016	-0.8547
PS.05	69425.42	15296.22	428.2217	436.988	8.7663
PS.06	69420.38	15366.67	439.1122	434.103	-5.0092
PS.07	69390.17	15386.28	431.1427	435.28	4.1373
PWC 004 A	69405.58	15368.82	421.4892	434.938	13.4488
PWC 007 A	69594.21	14964.91	410.8827	432.732	21.8493
PWC 009	69369.05	15165.45	447.3605	448.319	0.9585
PWC 101	69564.14	14811.95	448.1573	452.458	4.3007
PWC 102	69558.49	14909.69	439.241	440.547	1.306
PWC 111 A	69559.44	15063.3	417.5288	430.473	12.9442
PWC 112 A	69553.94	15166.77	421.9271	427.851	5.9239
PWC 112 B	69553.18	15169.34	422.1953	428.042	5.8467
SP 02	69716.99	14125.35	493.06	484.492	-8.568
SP 04	69992.42	14250.53	496.054	479.846	-16.208
SP 05	69978.78	14080.54	506.952	482.437	-24.515
SP 06	69847.29	14385.27	494.702	474.348	-20.354
SP 08	69943.9	14130.11	496.454	481.847	-14.607
SP 09	69837.07	14108.32	493.69	482.493	-11.197
SP 10	69829.97	14365.93	485.904	475.622	-10.282
SP 13	69839.53	14126.43	476.57	482.348	5.778
SP 14	69739.42	14161.41	480.84	482.697	1.857

Hole ID	Easting (mine grid)	Northing (mine grid)	Measured groundwater elevation (mRL)	Modelled groundwater elevation (mRL)	Residual - modelled minus measured (m)
SP 15	69698.22	14290.06	485.526	480.808	-4.718
SP 16	69806.2	14336.8	463.82	477.102	13.282
SP 17	69916.33	14230.3	462.356	479.974	17.618
SP 18	69914.93	14163.92	464.5025	481.251	16.7485
SP 21	69720.6	14274.1	465.99	480.821	14.831
SP 27 A	70059.87	14182.43	484.0791	482.155	-1.9241
SP 28 A	70006.17	14030.53	467.7978	482.918	15.1202
SPD 03	69985.89	14792.66	435.0914	417.09	-18.0014

Appendix E

Contaminant Plume Extent

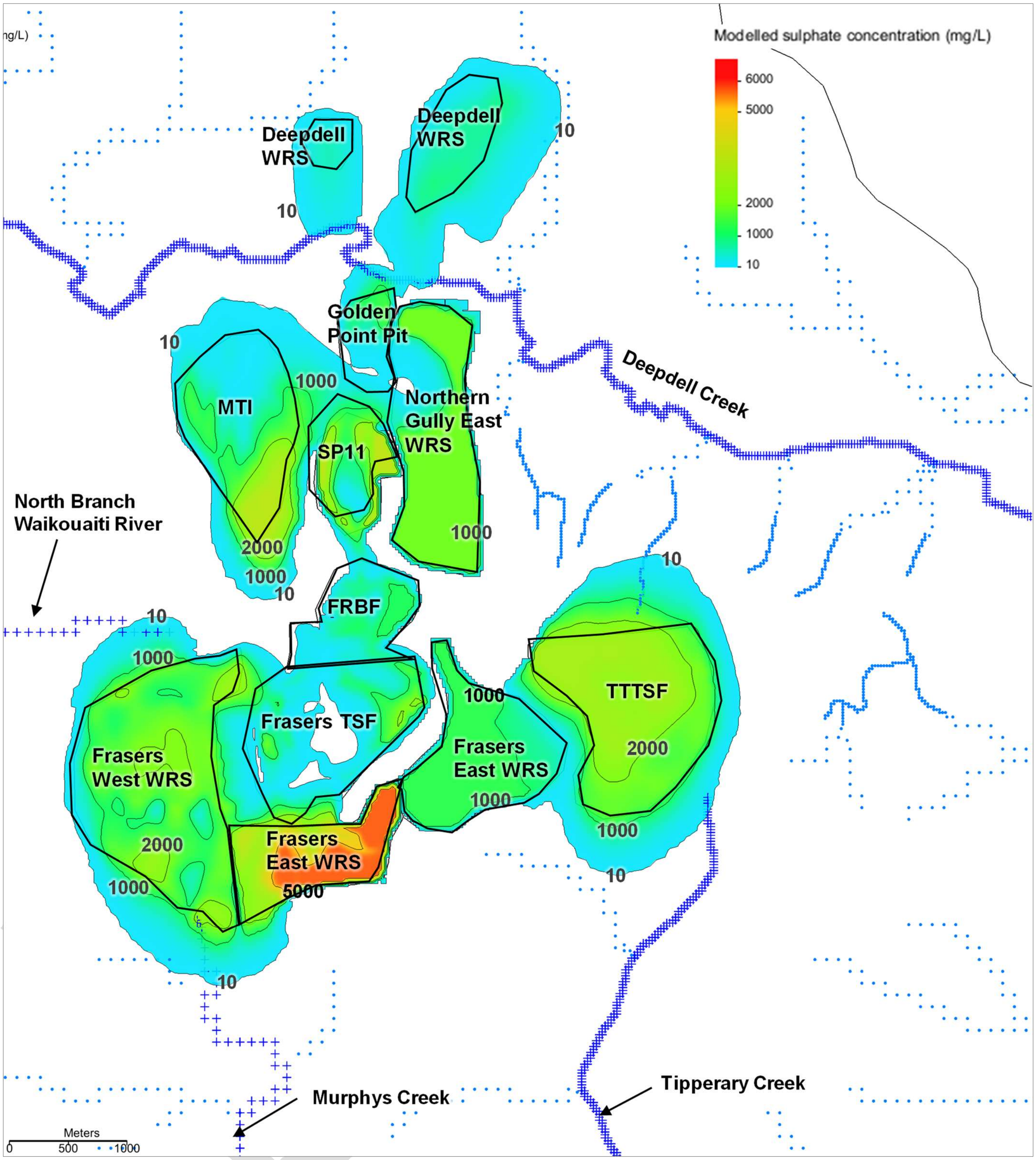

Figure E.1 *Sulphate plume extent in model layer 6, 20-years post closure*

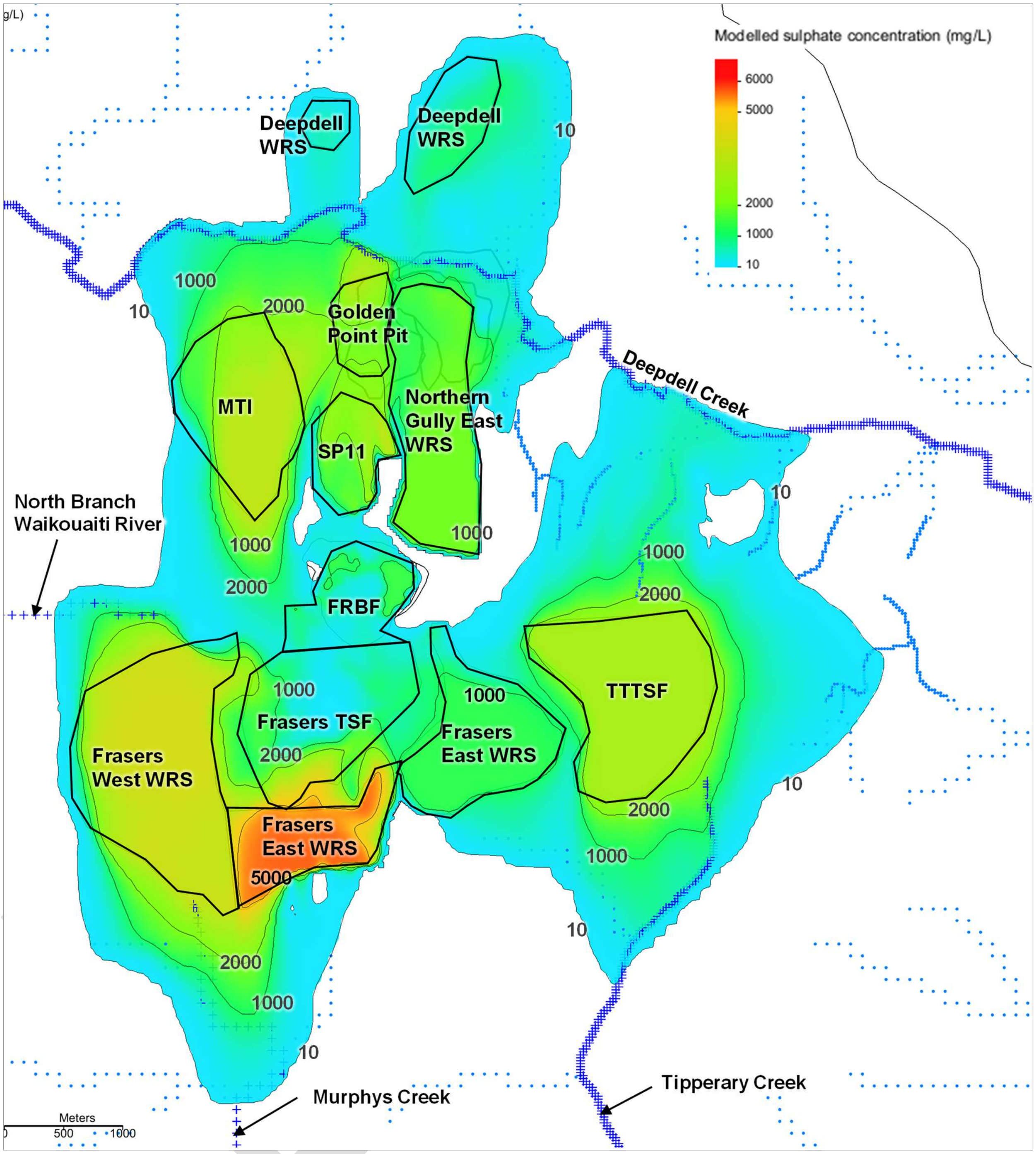

Figure E.2 Sulphate plume extent in model layer 6, 200-years post closure

Appendix F

WBM Water Quality Results

F-1 Deepdell Creek

Table F-1 summarises key water quality metrics for modelled results and the established DC07 compliance point.

Table F-1 Predicted Water Quality Statistics for DC07

Constituent	Statistic	Phase (g/m³)					
		Camp Creek Dilution Dam			No Camp Creek Dilution Dam		
		Mining	Closure	Long Term	Mining	Closure	Long Term
Sulphate	Median	110	100	110	110	100	110
	95th %	390	330	360	510	550	560
	Maximum	1090	930	920	1090	1080	1150
Nitrate-N	Median	0.73	0.63	0.67	0.74	0.63	0.68
	95th %	2.5	1.5	1.6	3.4	3.3	3.3
	Maximum	7.6	3.6	3.8	7.6	8.1	8.7
Ammoniacal-N	Median	0.014	0.013	0.013	0.014	0.013	0.013
	95th %	0.028	0.02	0.02	0.031	0.022	0.023
	Maximum	0.21	0.044	0.044	0.21	0.044	0.044
Arsenic	Median	0.003	0.0032	0.0036	0.0032	0.0034	0.0042
	95th %	0.012	0.0083	0.011	0.015	0.0093	0.012
	Maximum	0.25	0.023	0.024	0.25	0.022	0.024
Copper	Median	0.001	0.001	0.001	0.001	0.001	0.001
	95th %	0.0012	0.0011	0.0012	0.0012	0.0012	0.0012
	Maximum	0.0013	0.0012	0.0013	0.0014	0.0014	0.0014
Iron	Median	0.19	0.19	0.19	0.19	0.18	0.18
	95th %	0.23	0.22	0.22	0.23	0.22	0.22
	Maximum	0.82	0.24	0.24	0.82	0.24	0.24
Lead	Median	0.00016	0.00016	0.00016	0.00016	0.00016	0.00016
	95th %	0.00019	0.00018	0.00018	0.0002	0.0002	0.0002
	Maximum	0.00026	0.00022	0.00022	0.00026	0.00027	0.00027
Zinc	Median	0.0023	0.0021	0.0022	0.0023	0.0021	0.0022
	95th %	0.0045	0.0034	0.0035	0.0057	0.0055	0.0055
	Maximum	0.011	0.0059	0.0062	0.011	0.011	0.012

Note: Highlighted values indicate where the existing compliance criteria is exceeded by the statistic.

Table F-2 summarises key water quality metrics for modelled results and the established DC08 compliance point.

Table F-2 Predicted Water Quality Statistics for DC08

Constituent	Statistic	Phase (g/m^3)					
		Camp Creek Dilution Dam			No Camp Creek Dilution Dam		
		Mining	Closure	Long Term	Mining	Closure	Long Term
Sulphate	Median	99	94	100	100	95	100
	95th %	360	310	330	460	510	520
	Maximum	1040	900	920	1040	990	1070
Nitrate-N	Median	0.68	0.59	0.63	0.69	0.59	0.63
	95th %	2.3	1.5	1.6	3.1	3	3
	Maximum	7.3	3.4	3.6	7.3	7.5	7.9
Ammoniacal-N	Median	0.014	0.012	0.013	0.014	0.012	0.013
	95th %	0.026	0.019	0.02	0.029	0.021	0.022
	Maximum	0.18	0.044	0.044	0.18	0.044	0.044
Arsenic	Median	0.003	0.0032	0.0036	0.0031	0.0034	0.0041
	95th %	0.011	0.0079	0.011	0.015	0.0089	0.011
	Maximum	0.22	0.023	0.024	0.22	0.022	0.024
Copper	Median	0.001	0.001	0.001	0.001	0.001	0.001
	95th %	0.0012	0.0011	0.0011	0.0012	0.0012	0.0012
	Maximum	0.0013	0.0012	0.0012	0.0013	0.0014	0.0014
Iron	Median	0.19	0.19	0.19	0.19	0.18	0.18
	95th %	0.23	0.22	0.22	0.23	0.22	0.22
	Maximum	0.74	0.24	0.24	0.74	0.24	0.24
Lead	Median	0.00016	0.00016	0.00016	0.00016	0.00016	0.00016
	95th %	0.00019	0.00018	0.00018	0.0002	0.0002	0.0002
	Maximum	0.00025	0.00022	0.00022	0.00026	0.00026	0.00027
Zinc	Median	0.0022	0.0021	0.0022	0.0022	0.0021	0.0022
	95th %	0.0043	0.0033	0.0035	0.0053	0.0051	0.0052
	Maximum	0.011	0.0056	0.006	0.011	0.01	0.011

Note: Highlighted values indicate where the existing compliance criteria is exceeded by the statistic.

F-2 Shag River

Table F-3 summarises key water quality metrics for modelled results and the established Shag River at Loop Road compliance point.

Table F-3 Predicted Water Quality Statistics for Shag River at Loop Road

Constituent	Statistic	Phase (g/m³)					
		Camp Creek Dilution Dam			No Camp Creek Dilution Dam		
		Mining	Closure	Long Term	Mining	Closure	Long Term
Sulphate	Median	21	21	22	20	20	21
	95th %	56	69	74	56	70	74
	Maximum	450	610	750	440	610	750
Nitrate-N	Median	0.21	0.21	0.21	0.21	0.21	0.21
	95th %	0.44	0.45	0.48	0.45	0.46	0.48
	Maximum	1.6	1.5	1.6	1.6	1.5	1.6
Ammoniacal-N	Median	0.011	0.011	0.01	0.011	0.01	0.01
	95th %	0.013	0.013	0.013	0.013	0.013	0.013
	Maximum	0.055	0.039	0.037	0.055	0.039	0.037
Arsenic	Median	0.0027	0.0027	0.0028	0.0027	0.0027	0.0028
	95th %	0.0039	0.0036	0.0039	0.004	0.0036	0.004
	Maximum	0.053	0.019	0.02	0.053	0.019	0.02
Copper	Median	0.001	0.001	0.001	0.001	0.001	0.001
	95th %	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012
	Maximum	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013
Iron	Median	0.2	0.2	0.2	0.2	0.2	0.2
	95th %	0.24	0.24	0.24	0.24	0.24	0.24
	Maximum	0.31	0.26	0.26	0.31	0.26	0.26
Lead	Median	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015
	95th %	0.00018	0.00018	0.00018	0.00019	0.00018	0.00018
	Maximum	0.00021	0.00019	0.00021	0.00021	0.0002	0.00021
Zinc	Median	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016
	95th %	0.002	0.002	0.002	0.002	0.002	0.002
	Maximum	0.0037	0.0032	0.0034	0.0037	0.0034	0.0034

Note: Highlighted values indicate where the existing compliance criteria is exceeded by the statistic.

Table F-4 summarises key water quality metrics for modelled results and the established Shag River at McCormicks Creek compliance point.

Table F-4 Predicted Water Quality Statistics for Shag River at McCormicks Creek

Constituent	Statistic	Phase (g/m^3)					
		Camp Creek Dilution Dam			No Camp Creek Dilution Dam		
		Mining	Closure	Long Term	Mining	Closure	Long Term
Sulphate	Median	26	23	27	25	23	27
	95th %	67	65	73	68	66	73
	Maximum	280	560	600	280	550	600
Nitrate-N	Median	0.21	0.21	0.21	0.21	0.21	0.21
	95th %	0.42	0.41	0.44	0.42	0.42	0.44
	Maximum	1.4	1.3	1.5	1.4	1.4	1.5
Ammoniacal-N	Median	0.021	0.01	0.01	0.021	0.01	0.01
	95th %	0.052	0.012	0.012	0.053	0.012	0.012
	Maximum	0.17	0.036	0.031	0.17	0.036	0.031
Arsenic	Median	0.0064	0.0029	0.003	0.0064	0.0029	0.003
	95th %	0.017	0.0037	0.0039	0.017	0.0037	0.0039
	Maximum	0.057	0.018	0.016	0.057	0.017	0.016
Copper	Median	0.0016	0.001	0.00099	0.0016	0.001	0.00099
	95th %	0.0035	0.0012	0.0012	0.0036	0.0012	0.0012
	Maximum	0.011	0.0013	0.0013	0.011	0.0013	0.0013
Iron	Median	0.24	0.2	0.2	0.24	0.2	0.2
	95th %	0.33	0.23	0.23	0.34	0.23	0.23
	Maximum	0.72	0.25	0.25	0.72	0.25	0.25
Lead	Median	0.00016	0.00015	0.00015	0.00016	0.00015	0.00015
	95th %	0.00019	0.00018	0.00018	0.00019	0.00018	0.00018
	Maximum	0.00027	0.00019	0.0002	0.00027	0.00019	0.0002
Zinc	Median	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016
	95th %	0.002	0.002	0.002	0.002	0.002	0.002
	Maximum	0.0034	0.003	0.0032	0.0034	0.0031	0.0032

Note: Highlighted values indicate where the existing compliance criteria is exceeded by the statistic.

F-3 Waikouaiti River North Branch

Table F-5 to Table F-7 summarise key water quality metrics for modelled results at the established NBWRRF, MC02 and NB03 compliance points.

Table F-5 Predicted Water Quality Statistics for NBWRRF (Selected Mitigation)

Constituent	Statistic	Phase (g/m³)		
		Mining	**Closure**	**Long Term**
Sulphate	Median	38	130	130
	95th %	170	280	280
	Maximum	760	550	640
Nitrate-N	Median	0.21	0.43	0.44
	95th %	0.44	0.82	0.82
	Maximum	1.6	1.5	1.5
Ammoniacal-N	Median	0.011	0.013	0.013
	95th %	0.014	0.017	0.017
	Maximum	0.037	0.024	0.024
Arsenic	Median	0.0026	0.0027	0.0026
	95th %	0.0032	0.0032	0.0033
	Maximum	0.0054	0.0056	0.0058
Copper	Median	0.0011	0.0012	0.0012
	95th %	0.0013	0.0015	0.0015
	Maximum	0.002	0.002	0.002
Iron	Median	0.2	0.19	0.19
	95th %	0.24	0.24	0.23
	Maximum	0.26	0.25	0.26
Lead	Median	0.00015	0.00016	0.00016
	95th %	0.00019	0.0002	0.0002
	Maximum	0.00022	0.00023	0.00024
Zinc	Median	0.0017	0.0022	0.0022
	95th %	0.0022	0.0032	0.0032
	Maximum	0.0052	0.005	0.005

Note: Highlighted values indicate where the existing compliance criteria is exceeded by the statistic.

Table F-6 Predicted Water Quality Statistics for MC02 (Selected Mitigation)

Constituent	Statistic	Phase (g/m^3)		
		Mining	Closure	Long Term
Sulphate	Median	12	290	300
	95th %	23	450	440
	Maximum	140	580	570
Nitrate-N	Median	0.15	0.85	0.88
	95th %	0.19	1.3	1.3
	Maximum	0.33	1.6	1.6
Ammoniacal-N	Median	0.01	0.01	0.01
	95th %	0.012	0.012	0.012
	Maximum	0.016	0.013	0.013
Arsenic	Median	0.0026	0.0026	0.0026
	95th %	0.0032	0.0032	0.0032
	Maximum	0.0053	0.0062	0.0061
Copper	Median	0.001	0.003	0.0033
	95th %	0.0013	0.0096#	0.0098#
	Maximum	0.0054	0.014#	0.014#
Iron	Median	0.2	0.18	0.18
	95th %	0.24	0.22	0.22
	Maximum	0.25	0.24	0.24
Lead	Median	0.00015	0.00019	0.00019
	95th %	0.00018	0.00023	0.00023
	Maximum	0.00019	0.00026	0.00027
Zinc	Median	0.0015	0.0035	0.0036
	95th %	0.0018	0.0052	0.0052
	Maximum	0.0028	0.0067	0.0068

Note: Highlighted values indicate where the existing compliance criteria is exceeded by the statistic.
#The elevated copper concentrations are all modelled with an associated elevated hardness (in excess of 400 mg/L). Based on the hardness related compliance criteria, the hardness related copper compliance limit would be 0.035 mg/L, therefore the water quality at MC02 is expected to be within the consented limits.

Table F-7 Predicted Water Quality Statistics for NB03 (Selected Mitigation)

Constituent	Statistic	Phase (g/m³)		
		Mining	Closure	Long Term
Sulphate	Median	19	120	120
	95th %	68	190	190
	Maximum	260	320	340
Nitrate-N	Median	0.17	0.42	0.42
	95th %	0.27	0.61	0.61
	Maximum	0.7	0.95	0.97
Ammoniacal-N	Median	0.011	0.011	0.011
	95th %	0.015	0.012	0.012
	Maximum	0.032	0.015	0.016
Arsenic	Median	0.0029	0.0026	0.0039
	95th %	0.0097	0.0029	0.0083
	Maximum	0.03	0.0045	0.017
Copper	Median	0.001	0.0016	0.0017
	95th %	0.0012	0.0034	0.0035
	Maximum	0.0024	0.0048	0.0048
Iron	Median	0.19	0.19	0.19
	95th %	0.21	0.22	0.22
	Maximum	0.23	0.24	0.24
Lead	Median	0.00015	0.00016	0.00016
	95th %	0.00017	0.00018	0.00018
	Maximum	0.00019	0.00021	0.00021
Zinc	Median	0.0016	0.0022	0.0023
	95th %	0.0018	0.0029	0.003
	Maximum	0.0027	0.004	0.0042

Note: Highlighted values indicate where the existing compliance criteria is exceeded by the statistic.