Appendix A

Groundwater Technical Modelling Details – Golden Bar Mining Area

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Attachments

A-1 Introduction

This Appendix outlines the groundwater modelling undertaken for the Golden Bar Area for the Macraes Phase 4 Fast Track Approvals project. An overview of the site location and project description is provided in Sections 1 and 2 of the "Macraes Phase 4 FTA – Surface and Groundwater Assessment" report. Limitations and assumptions detailed in Section 1 of the "Surface and Groundwater Assessment" report are applicable to this Appendix.

A-2 Conceptual Groundwater Flow Model

The conceptual understanding of the groundwater system in the vicinity of the Golden Bar extension is as follows:

– Recharge of the groundwater system via rainfall infiltration through fractures within the bedrock.
– Groundwater flow is generally topographically driven, with discharge via seeps and/or springs in topographic lows (streams and depressions).
– Hydraulic conductivity of the schist is primarily influenced by the degree of weathering in the schist bedrock, with variability (anisotropy) in horizonal hydraulic conductivity due to rock mass fracturing by structural features such as foliation-parallel fractures, faults and shear zones.
– Rainfall recharge into the waste rock stacks is predominantly intercepted by drainage channels at base of stacks with limited infiltration into the underlying schist bedrock.

Based on the current hydrogeological understanding of the project area the conceptual groundwater flow model for the Golden Bar site is presented in Figure A-2.1, Figure A-2.2, and Figure A-2.3.

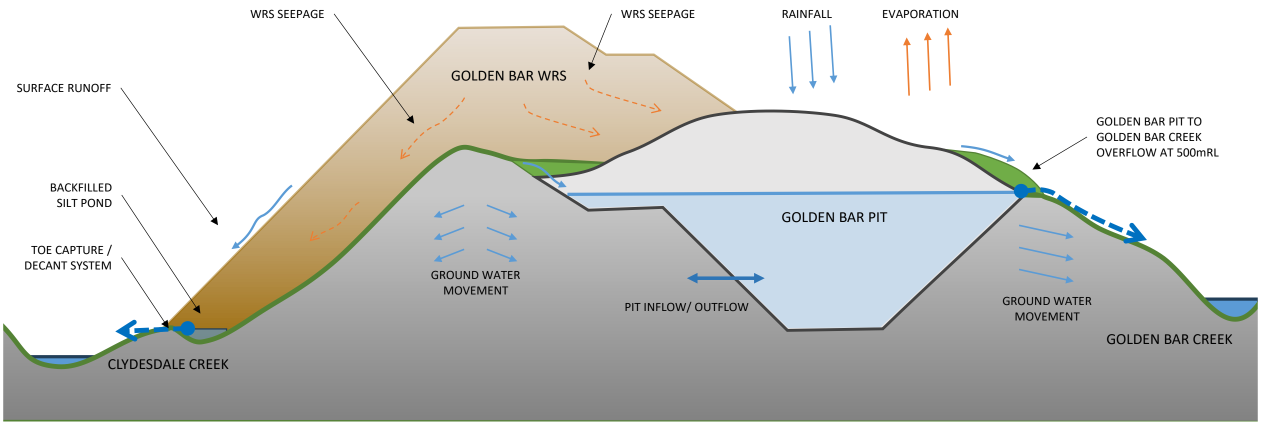


Figure A-2.1 Golden Bar conceptual site model

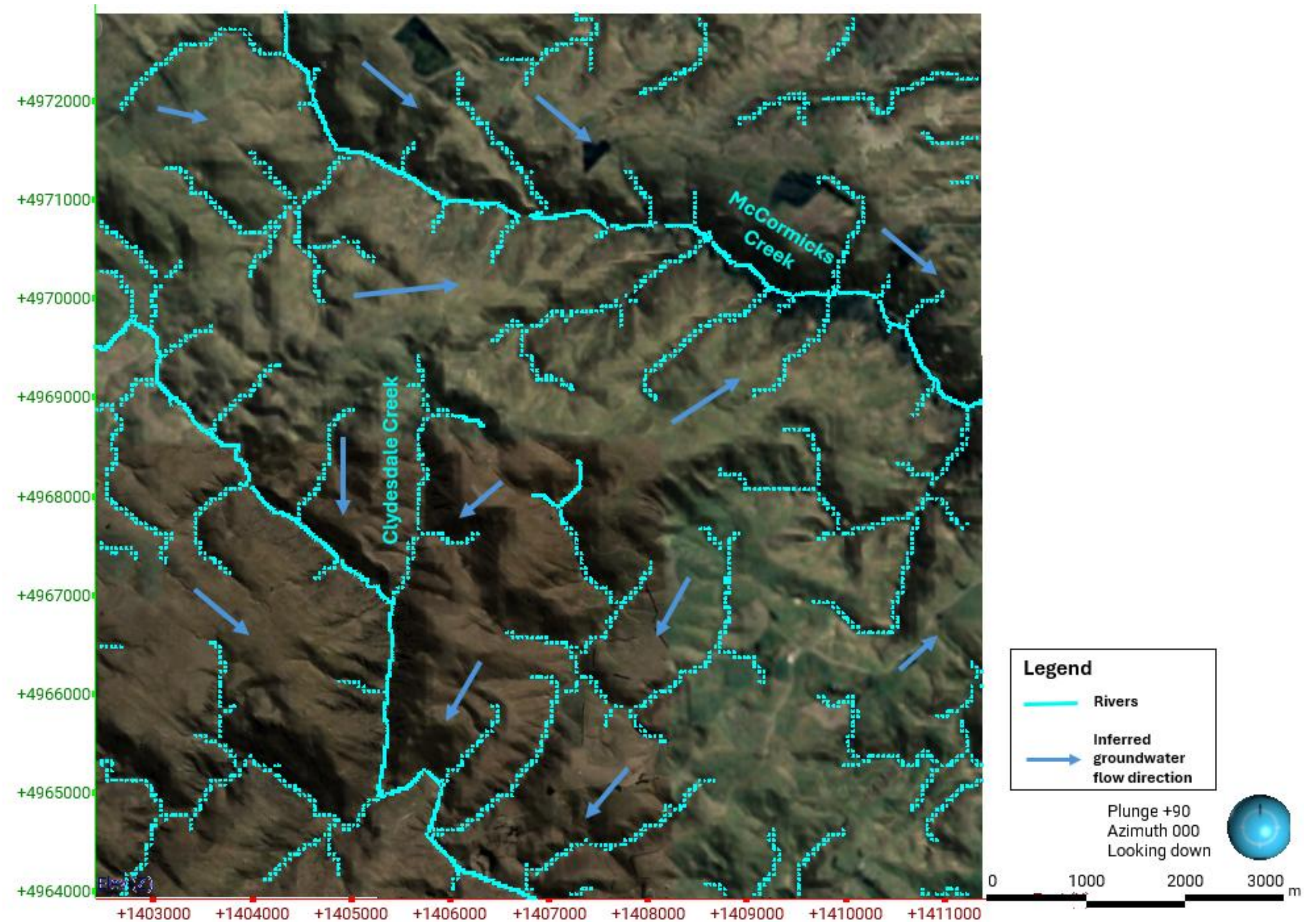


Figure A-2.2 Golden Bar conceptual groundwater model flow diagram (pre-mining)

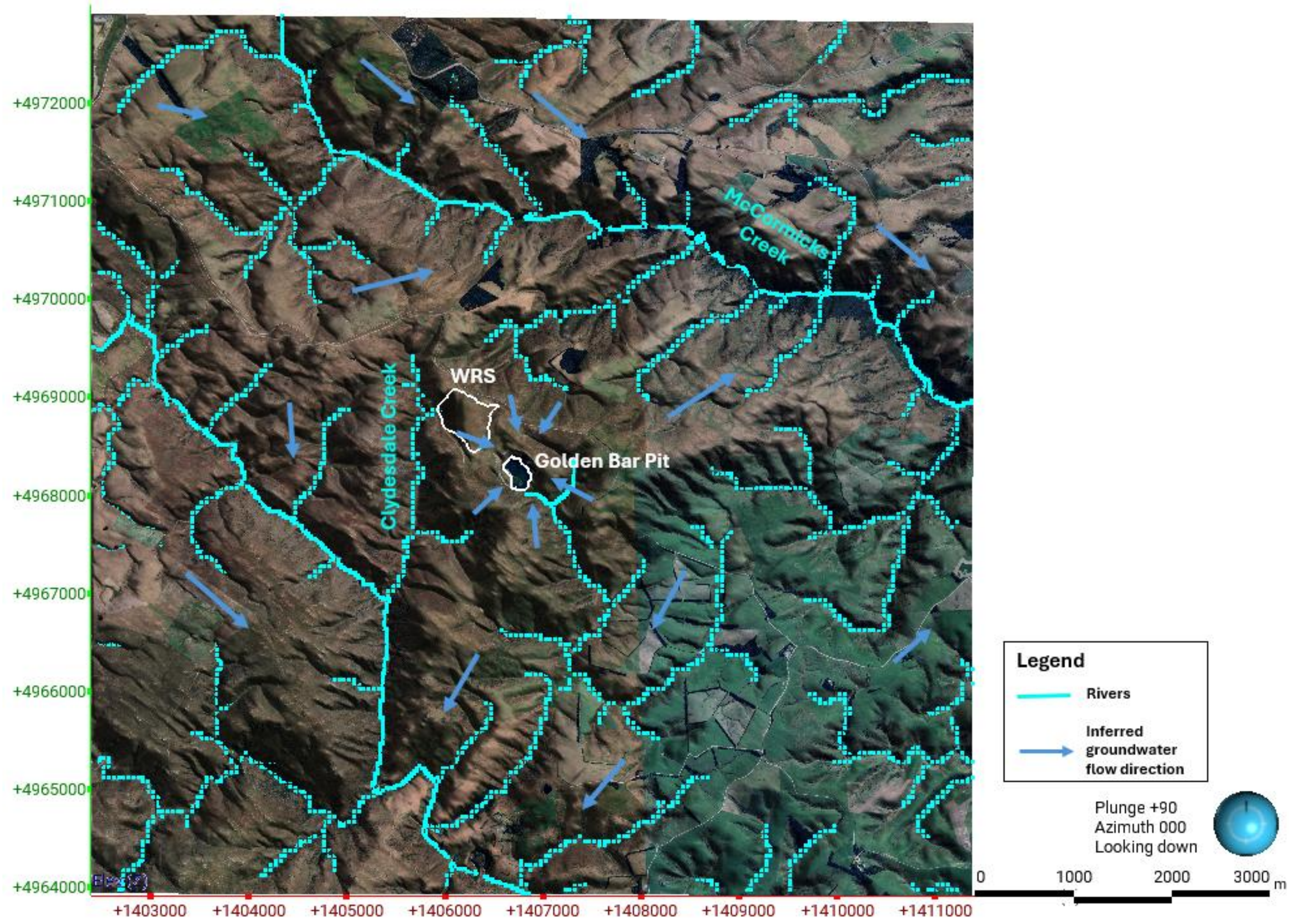


Figure A-2.3 Golden Bar conceptual groundwater model flow diagram (existing / proposed mining)

A-3 Groundwater Model Objectives and Setup

A 3D numerical groundwater flow model of the Golden Bar pit area has been set up using Groundwater Vistas and Leapfrog software, using MODFLOW-USG (numerical modelling code) developed by the USGS. The objectives of the modelling are to:

– Simulate pre-mining and existing conditions at Golden Bar (base case scenario)
– Predict pit inflow for the proposed expansion of Golden Bar open pit.
– Simulate groundwater recovery after the conclusion of the proposed expansion.
– Perform solute transport modelling

The model domain is 9 km by 9 km in east-west and north-south direction with the proposed pit extension at the centre of the model domain. The model has been setup in NZTM grid system.

Model grid size has been refined to 25 m within the proposed pit and around two creeks (McCormicks and Murphys Creek), outside of that, 50 m grid size has been adopted. Vertically, 8 model layers have been setup with the first layer 30 m thick followed by 50 m thick layers (layers 2 to 8, see Table A-4.2 of this Appendix), which resulted in a total of 298,152 model cells. This provides enough grid resolution for pit-dewatering, recovery, and contaminant transport modelling.

The extent of the model domain is presented in Figure A-3.1 and grid design is presented in Figure A-3.2.

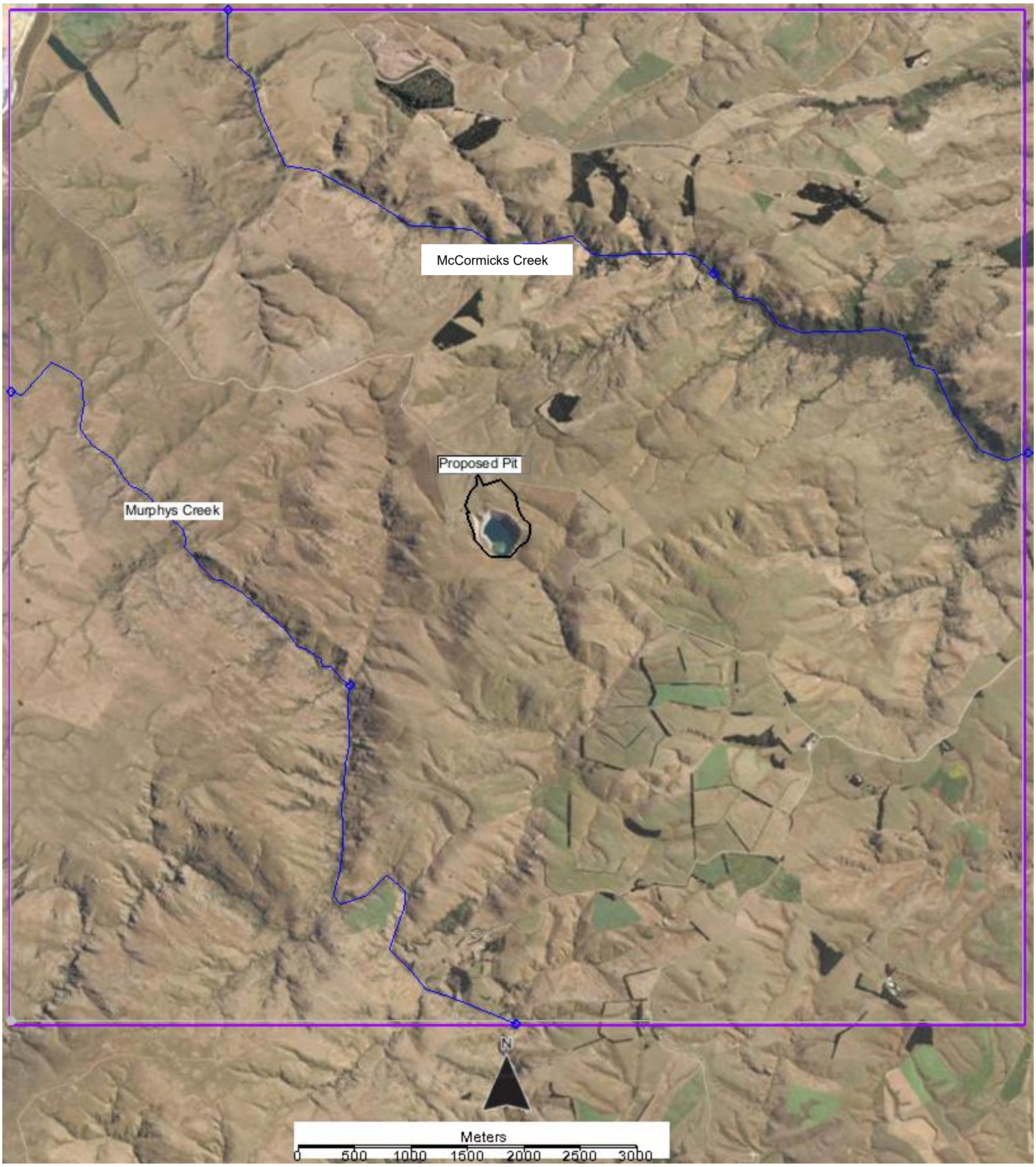


Figure A-3.1 ***Golden Bar groundwater model domain extent (purple outline)***

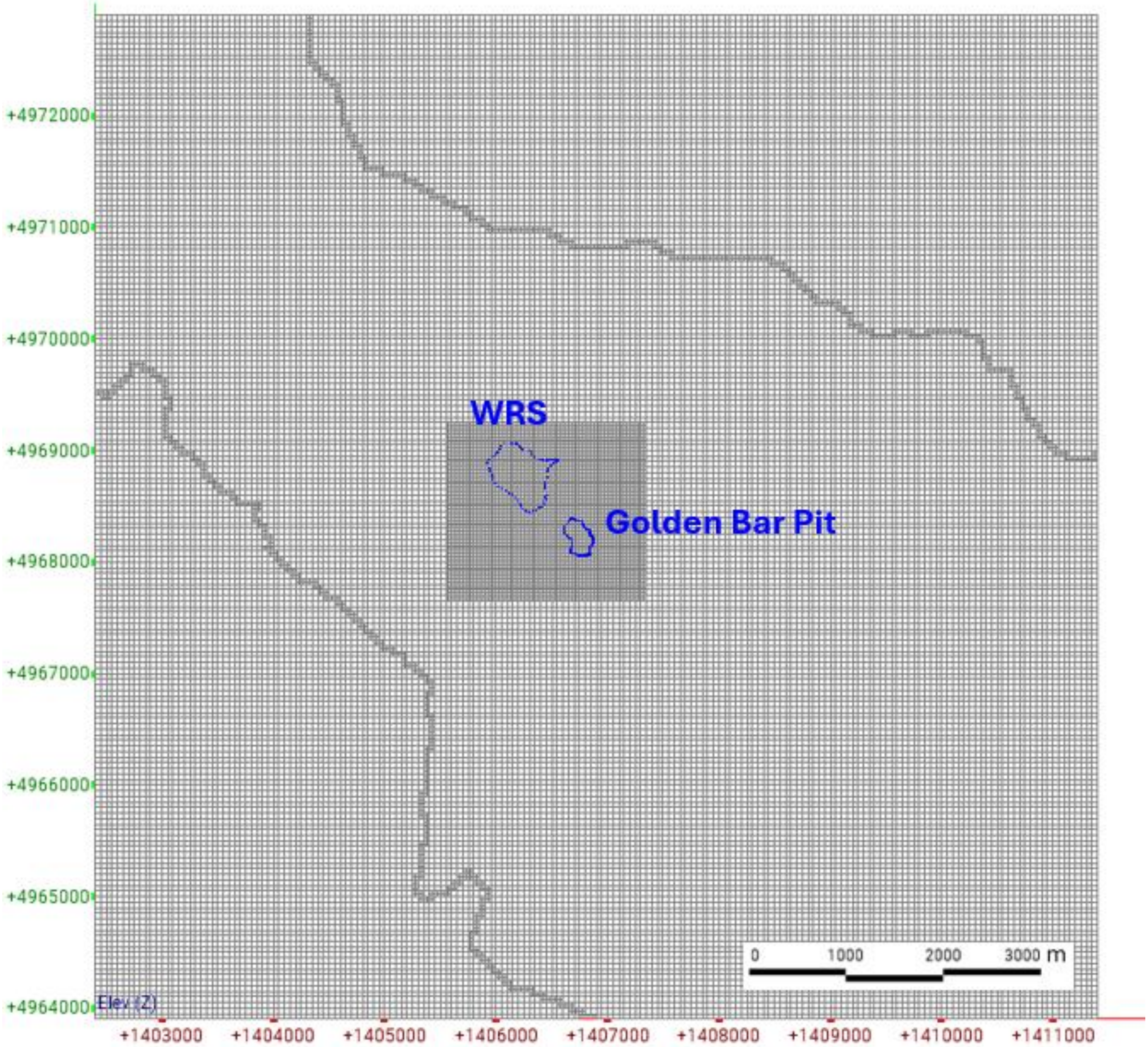


Figure A-3.2 Grid design Golden Bar model

A.3.1 Boundary Conditions

The following boundary conditions have been applied in the model:

– **River Boundary:** The McCormicks Creek and Murphys Creek have been modelled as river boundaries (Figure A-3.3). Riverbed conductance applied was 5 m^2/d/m with river stage applied at the topographic level, river bottom elevation was applied 1 m below the river stage level.

– **Drain Boundaries:** Dewatering of the pit has been simulated using the drain boundary conditions, with drain bottom elevation corresponding to the base of the mining. Small creeks and tributaries have been modelled as drain boundary conditions (Figure A-3.3). Drain conductance applied was 10 m^2/d/m with drain bottom elevation set at topographic level.

– **Recharge boundary**: Several reports (Kingett Mitchell, 2005a&b, Golder, 2011a, CDM Smith, 2016) have noted that the recharge rate of the wider area is approximately 32 mm/yr (equating to 5% of annual rainfall of 645 mm across the whole of the MGP site). In this assessment, the following recharge rates have been applied:

  - 143 mm/year within the waste rock stack (WRS) for the existing conditions and dewatering scenarios, based on site-specific seepage measurements provided by OceanaGold (as detailed in Appendix E).

- 32 mm/year was applied to the proposed rehabilitated waste rock stacks for the recovery model runs, in line with OceanaGold's proposed WRS rehabilitation efforts with respect to optimisation of WRS cap performance to minimise net percolation.
- 32 mm/year across the remainder of the model domain, consistent with previous studies.
- 128 mm/year applied to the WRS for the recovery model run as a sensitivity analysis to assess the effect on the recharge rate applied to the WRS (as detailed in Appendix E).

– **No flow boundary:** Along the model edge (due to relatively low hydraulic conductivity of the material and the distance from the area of impact and the presence of screeks and streams between the impacted area and the model boundaries.).

– **Constant Head Boundary:** Applied to the Golden Bar pit for the existing conditions simulation with a head value of 500 m (current water level in the pit which is equivalent to the pit overflow elevation) applied to the existing Golden Bar pit.

– **General Head Boundary**: The general head boundary is used to simulate head-dependent flux boundaries and was applied to model the recovery of water level post-mining within the pit. The location of general head boundary applied is presented in Figure A-3.4. The head values for the boundary condition are shown in Figure A-3.5 and were derived from the surface water modelling results (modelled pit lake filling curve) as detailed in Appendix G.

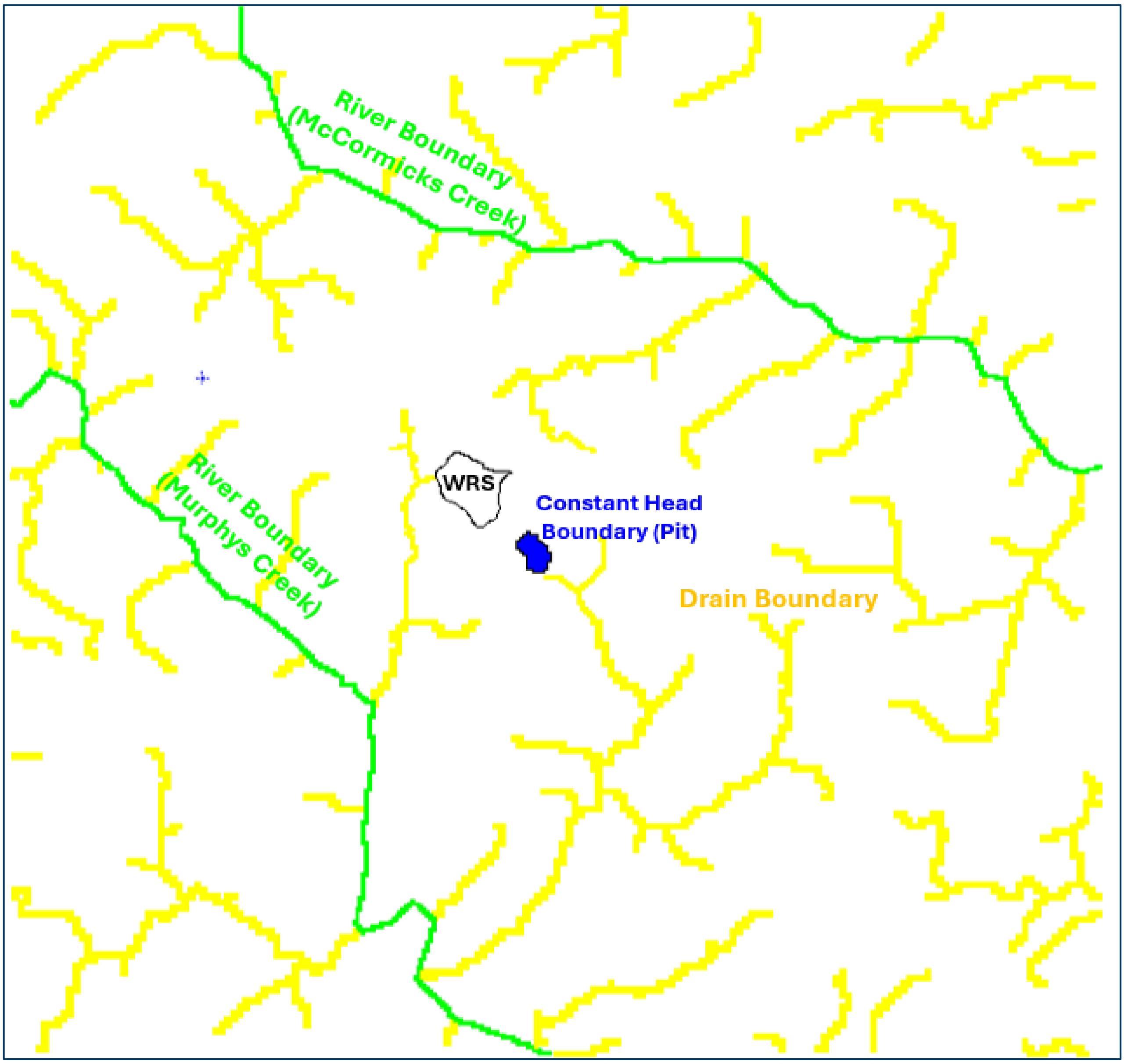


Figure A-3.3 Boundary conditions Golden Bar for the base case model (existing conditions).

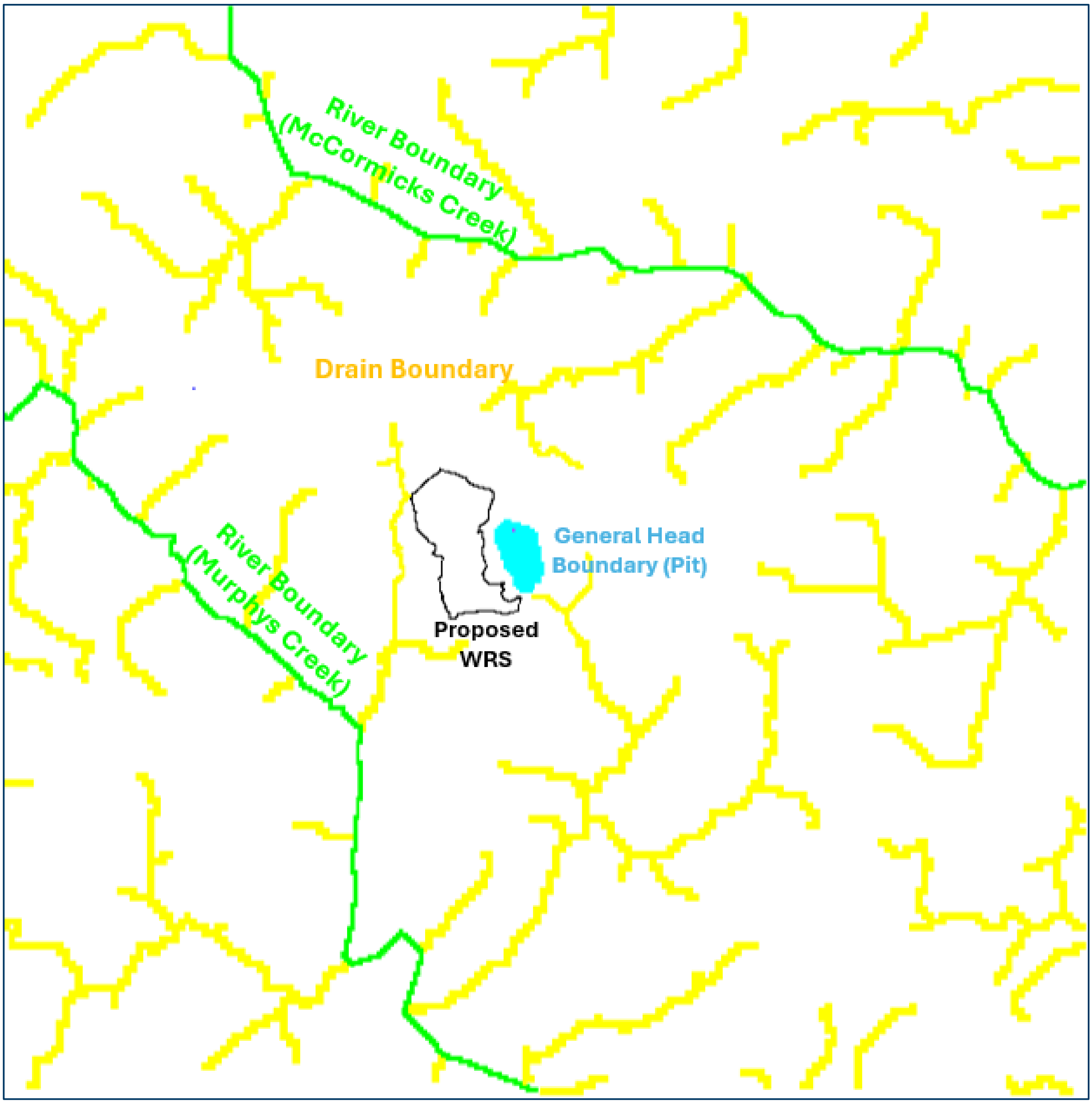


Figure A-3.4 Location of the general head boundary at the proposed pit lake (groundwater recovery model).

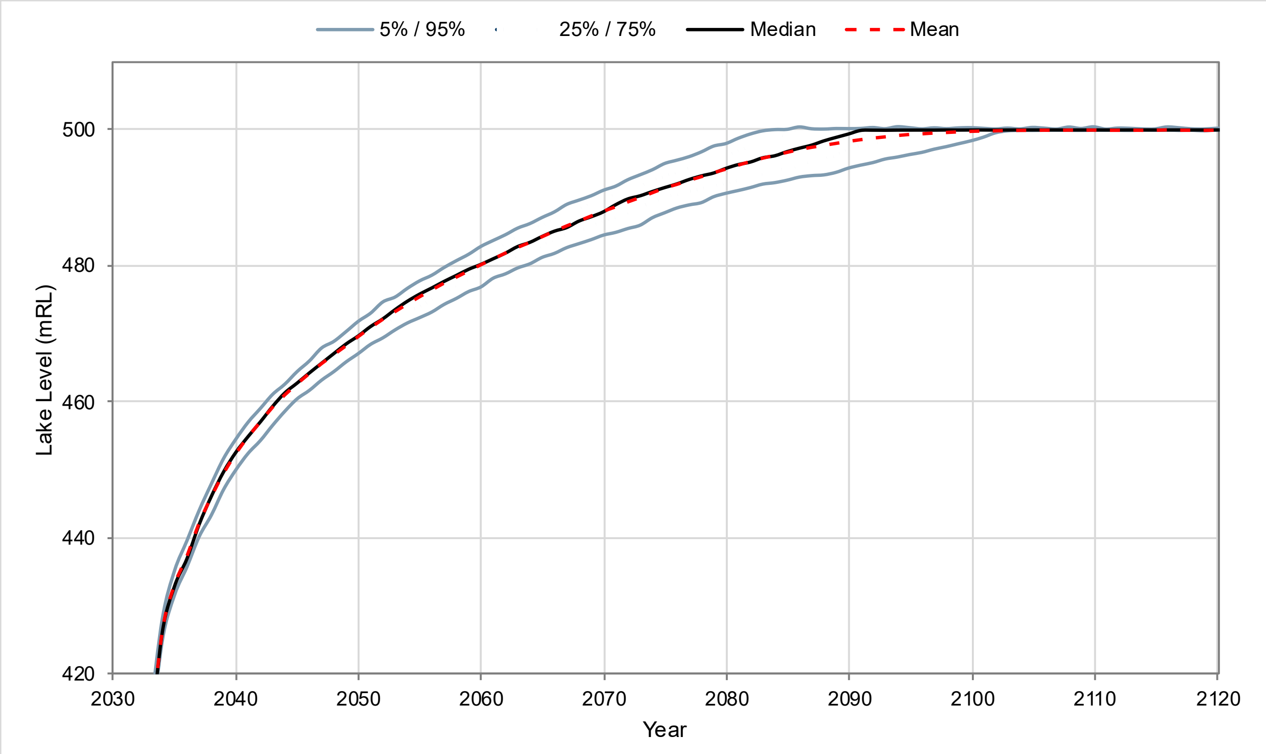


***Figure A-3.5 Golden Bar Pit Lake filling curve* - Mean values were used in General head boundary applied.**

Climate change has not been explicitly included in the groundwater recovery simulations, and the groundwater predictions should be regarded as baseline-condition estimates subject to climate-related uncertainty. The projected shift toward wetter winters, drier summers and more episodic heavy-rainfall events may alter the temporal distribution of recharge. This implies that groundwater recharge may become more seasonally concentrated and episodic, rather than changing uniformly through time (WDC, 2023). Applying eastern Otago climatic drivers using the national methodology of Mourot *et al.* (2022) indicates that the mean rainfall-recharge response for Otago is relatively small; however, the direction and magnitude of change are uncertain, with projected changes spanning approximately ±0.4 mm/day. Therefore, although there may be some potential implications for seasonal groundwater levels and groundwater contributions to streams these effects are expected to be most relevant to the timing and variability of groundwater discharge, rather than to the overall direction of groundwater flow or the broad spatial extent of modelled plumes. Considering the low-permeability nature of the Macraes schist groundwater system and the relatively small but uncertain mean recharge response indicated by regional climate-recharge assessments, the groundwater-related results remain suitable for assessing long-term groundwater recovery and plume behaviour, provided they are interpreted with recognition that future recharge may become more episodic and seasonally variable than represented in the model.

A-4 Steady-state Model Calibration

A.4.1 Pre-mining Conditions

The pre-mining conditions were modelled using Groundwater Modelling System (GMS) software using MODFLOW-USG (numerical modelling code) developed by the USGS and discussed in GHD, 2024. For completeness the input parameters and results are also presented in this Appendix A.

For the pre-mining model calibration, initial model parameters used were based on previous studies (Golder, 2011a, Golder, 2016, GHD, 2021, WSP- Golder, 2022 and GHD, 2024) and values were adjusted during the calibration process. The final hydraulic parameters from the model calibration are presented in Table A-4.1. A uniform recharge rate of 29.2 mm/year was applied in the pre-mining conditions model (GHD, 2021 and 2024).

Table A-4.1 Steady state pre-mining model parameters (Golden Bar model)

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*
Moderately Weathered Schist (Shallow)	1 (mostly 30 m thick)	1.0×10^{-7} (0.0086)	6.0×10^{-8} (0.0052)	2.5×10^{-7} (0.022)	0.02	1.0×10^{-5}
Slightly weathered shist	2 (50 m thick)	5×10^{-8} (0.0043)	5×10^{-9} (0.00043)	5×10^{-8} (0.0043)	0.01	1.0×10^{-5}
Slightly weathered - Unweathered Schist Bedrock	3 - 5 (50 m thick each layer)	1.5×10^{-8} (0.0013)	1.5×10^{-9} (0.00013)	1.5×10^{-8} (0.0013)	0.01	1.0×10^{-5}
Unweathered Schist	6 – 8 (50 m thick each layer)	5×10^{-9} (0.000432)	5×10^{-10} (0.000043)	5×10^{-9} (0.00043)	0.01	1.0×10^{-5}
Waste Rock	1 (0 to 160 m thick)	1.0×10^{-6} (0.086)	1.0×10^{-6} (0.086)	1.0×10^{-6} (0.086)	0.15	1.0×10^{-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 boreholes used as groundwater level calibration targets for the pre-mining and existing conditions models are shown in Figure A-4.1 and Figure A-4.4, respectively. These figures also present the difference between measured groundwater levels and the corresponding modelled groundwater heads at each borehole location. The available calibration boreholes are concentrated close to the Golden Bar pit area, with limited spatial coverage across the broader model domain. As a result, the calibration dataset provides useful local constraints on simulated groundwater levels in the vicinity of the pit, but provide comparatively less constraint on groundwater gradients and hydraulic conditions farther from the mining area.

A detailed summary of the borehole information, measured groundwater levels, modelled groundwater levels and calculated residuals is provided in Table A-4.2. The pre-mining calibration dataset is limited to groundwater level measurements collected in January 2016. Although the dataset is limited in both number and spatial distribution, these measurements were adopted as calibration targets to provide a quantitative basis for assessing the ability of the model to reproduce the interpreted pre-mining groundwater level distribution.

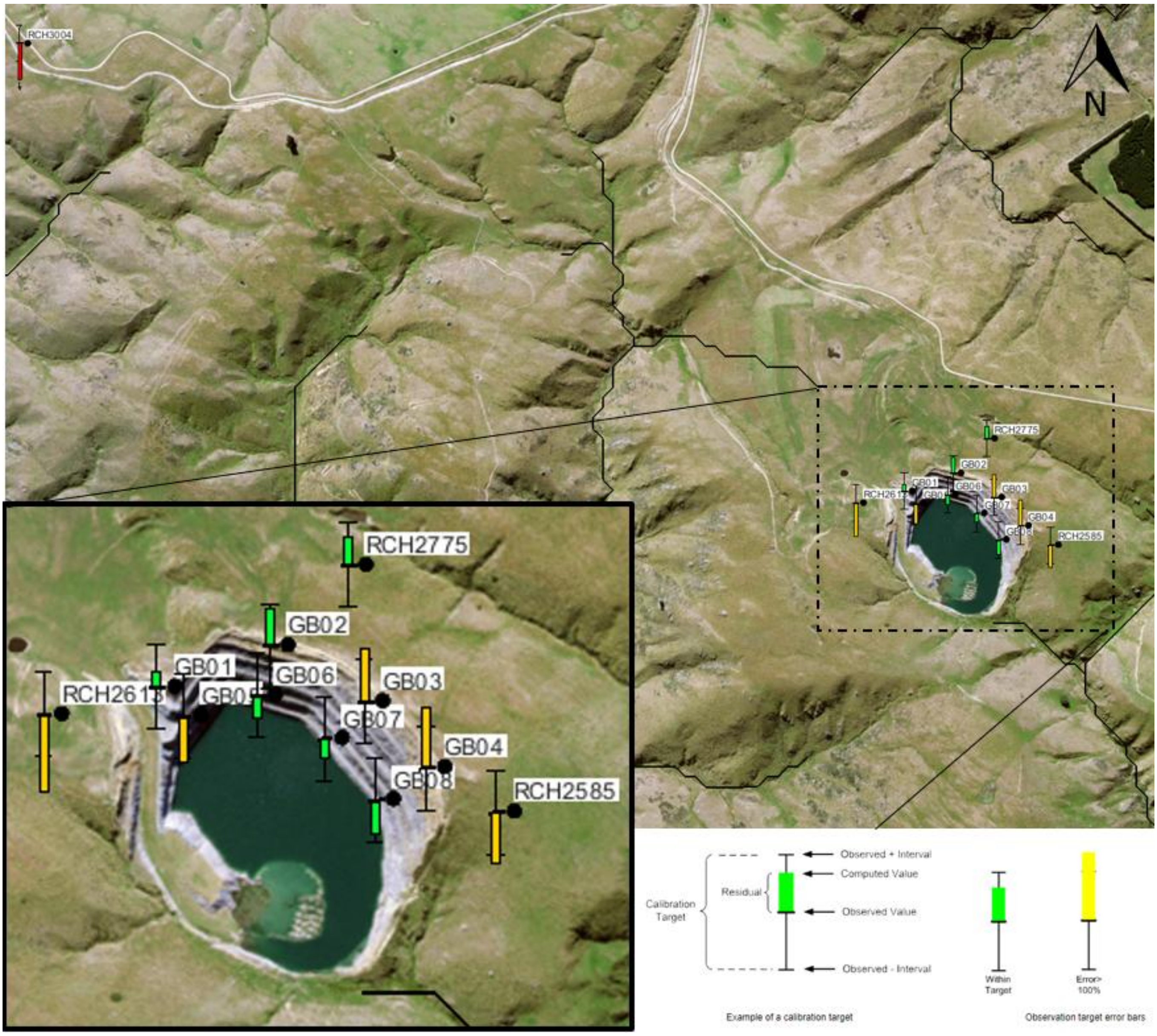


Figure A-4.1 Boreholes used in model calibration (pre mining), Red bars represent difference between modelled and observed head >10 m, Yellow bars represent difference between modelled and observed head <10 m but >5 m and Green bars represent difference between modelled and observed head <5 m

Table A-4.2 Measured and modelled groundwater level data measured January 2016 representing pre- mining conditions

Hole ID	Easting (NZTM2000)	Northing (NZTM200)	Ground Elevation (m RL)	Measured Groundwater level (m RL)	Modelled groundwater level (m RL)	Residual (m)
GB01	1406600	4968411	481.94	502.079	503.82	-1.7
GB02	1406743	4968463	492.02	503.914	508.38	-4.5
GB03	1406862	4968393	496.63	504.015	510.22	-6.2
GB04	1406940	4968309	502.64	501.984	509.14	-7.2
GB05	1406634	4968375	474.2	510.34	504.88	5.5
GB06	1406727	4968401	474.2	510.56	507.75	2.8
GB07	1406811	4968346	474.2	510.95	508.52	2.4
GB08	1406876	4968269	474.2	511.25	507.14	4.1
RCH2585	1407028	4968253	503.8	521.69	515.64	6.1
RCH2613	1406458	4968376	471.7	516.57	507.48	9.1
RCH2775	1406841	4968565	486	507.2	510.56	-3.4
RCH3004	1404013	4969721	470	472.44	456.55	15.9

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 squared (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 (Barnett et al, 2012).

The steady-state calibration for the pre-mining conditions resulted in a scaled root mean square error (SRMS) of 11.2%, following application of a 50% weighting to the more distant RCH3004 bore. This bore is located away from the main cluster of calibration boreholes near the Golden Bar pit and is therefore less directly representative of groundwater conditions in the immediate area of interest. In addition, the measured depth to water at RCH3004 was less than 2.5 m below ground level, and no bore depth or construction details are available. On this basis, the measured water level at this location may represent a perched or locally influenced groundwater condition rather than the regional groundwater system simulated by the model. The reduced weighting was therefore applied to limit the influence of this potentially less representative calibration point on the overall calibration statistics, while still retaining the bore as part of the broader calibration dataset. Model computed versus measured groundwater levels (scatter plot) are presented in Figure A-4.2.

For a high-confidence groundwater model, an SRMS value of less than approximately 5% to 10% is commonly adopted as a calibration target (Barnett et al., 2012). The SRMS achieved for the pre-mining model is marginally above this indicative range. However, the result is considered reasonable in the context of the available calibration dataset and the limitations associated with the groundwater level measurements. Data from Oceana Gold indicate that calibration boreholes are open holes (i.e. not screened or cased), meaning that the interval (or individual fractures) contributing most strongly to the measured in-hole water level is uncertain. As a result, the measured groundwater levels may reflect a composite response from multiple fractures or hydraulic zones intersected by each borehole, rather than a discrete model layer or hydrostratigraphic unit. Given these uncertainties, the limited number of calibration targets, and their concentration close to the pit area, the calibration is considered fit for purpose. It is suitable for representing the broad pre-mining groundwater level distribution and supporting the subsequent predictive modelling assessment.

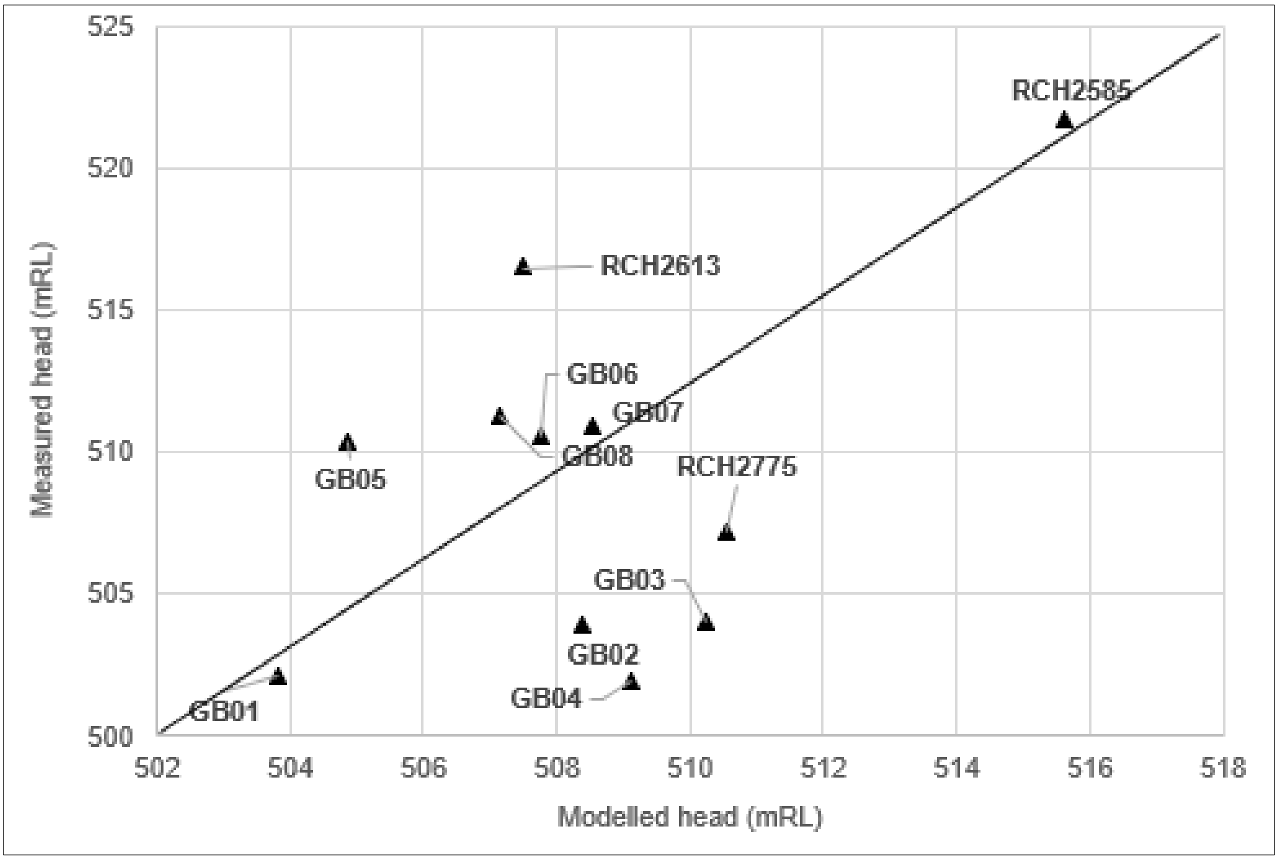


Figure A-4.2 Steady state pre- mining scatter plot (model computed vs measured head) - Golden Bar model (without the RCH3004)

The overall mass balance (outflows - inflows) for the steady state model (Figure A-4.3) is <0.01%, suggesting that the model is numerically stable.

```
 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 =          0.0000      CONSTANT HEAD =          0.0000
             DRAINS =          0.0000             DRAINS =          0.0000
      RIVER LEAKAGE =       3251.8774      RIVER LEAKAGE =       3251.8774
           RECHARGE =       6479.6997           RECHARGE =       6479.6997

           TOTAL IN =       9731.5771           TOTAL IN =       9731.5771

         OUT:                                 OUT:
         ----                                 ----
            STORAGE =          0.0000            STORAGE =          0.0000
      CONSTANT HEAD =          0.0000      CONSTANT HEAD =          0.0000
             DRAINS =       8420.7836             DRAINS =       8420.7836
      RIVER LEAKAGE =       1310.7957      RIVER LEAKAGE =       1310.7957
           RECHARGE =          0.0000           RECHARGE =          0.0000

          TOTAL OUT =       9731.5793          TOTAL OUT =       9731.5793

           IN - OUT =     -2.1339E-03           IN - OUT =     -2.1339E-03

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

Figure A-4.3 Steady state pre-mining Golden Bar model water balance summary (units of cubic metres per day)

A.4.2 Base Case Model (Existing conditions)

Mining at the current Golden Bar Stage 1 pit started in 2004 and ceased in 2005, and the water level in the pit reached the current spill level (approximately 500 m RL) in 2018. Existing conditions have been simulated with a steady-state flow model. Boundary conditions applied are detailed in section 3.1.

Some of the parameters derived from the pre-mining model were manually adjusted (Table A-4.3), together with the recharge rate (see Section 3.1), to assess the fit to recent groundwater monitoring data. The calibration check was undertaken against the conceptual understanding of the groundwater system and available monitoring data, recognising that groundwater levels in the vicinity of the pit are influenced by mining activities (i.e. the pit acting as a sink).

Application of the revised parameter set to the pre-mining model increased the SRMS from 11.2% to 13.7%. While this represents a slight reduction in the statistical fit to the pre-mining calibration dataset, there is no material change in the simulated groundwater flow regime or overall conceptualisation of the groundwater system. Given the limited number of calibration targets, their associated uncertainty, and their concentration around the pit (a relatively small part of the model domain), calibration performance was assessed using both quantitative measures and consistency with the conceptual site model. On this basis, the model is considered fit for purpose, providing a reasonable representation of the groundwater system and an appropriate basis for the predictive simulations undertaken in this assessment.

Table A-4.3 Steady-state existing conditions model parameters (Golden Bar model)

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*
Moderately Weathered Schist (Shallow)	1 (mostly 30 m thick)	8.7×10^{-8} (0.0075)	5.2×10^{-8} (0.0045)	2.2×10^{-7} (0.0188)	0.02	1.0×10^{-5}
Slightly weathered Schist	2 (50 m thick)	2.9×10^{-8} (0.0025)	2.9×10^{-9} (0.00025)	2.9×10^{-8} (0.0025)	0.01	1.0×10^{-5}
Slightly weathered - Unweathered Schist	3 - 5 (50 m thick each layer)	1.2×10^{-8} (0.001)	1.2×10^{-9} (0.0001)	1.2×10^{-8} (0.001)	0.005	1.0×10^{-5}
Unweathered Schist	6 – 8 (50 m thick each layer)	1×10^{-8} (0.0009)	1×10^{-9} (0.00009)	1×10^{-8} (0.0009)	0.005	1.0×10^{-5}
Waste Rock	1 (0 to 160 m thick)	1.0×10^{-6} (0.086)	1.0×10^{-6} (0.086)	1.0×10^{-6} (0.086)	0.18	1.0×10^{-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.					

Figure A-4.4 Boreholes used in base case model calibration and with residual statistics (difference between measured and modelled heads) displayed in parentheses.

Table A-4.4 Measured and modelled groundwater level data representing existing conditions at Golden Bar. Measured groundwater levels presented are average values measured January to September 2025

Hole ID	Easting (NZTM2000)	Northing (NZTM200)	Elevation (m RL)	Measured groundwater level (average values) (m RL)	Modelled groundwater level (m RL)	Residual (m)
RCH2585	1407028	4968253	503.8	521.21	518.64	2.57
RCH2613	1406458	4968376	472	518.30	519.61	1.14
RCH2775	1406841	4968565	486	518.46	517.31	-1.31
RCH3004	1404013	4969721	470	472.90	464.72	8.18

The steady-state calibration for the existing conditions resulted in a scaled root mean square error (SRMS) of 9.1% (improved slightly compared to the pre-mining calibration results) when a 50% weight was applied to the distant RCH3004 bore value; similar to the pre- mining calibration. The modelled computed vs observed head plot (scatter plot) from the existing conditions steady-state model calibration is presented in Figure A-4.5.

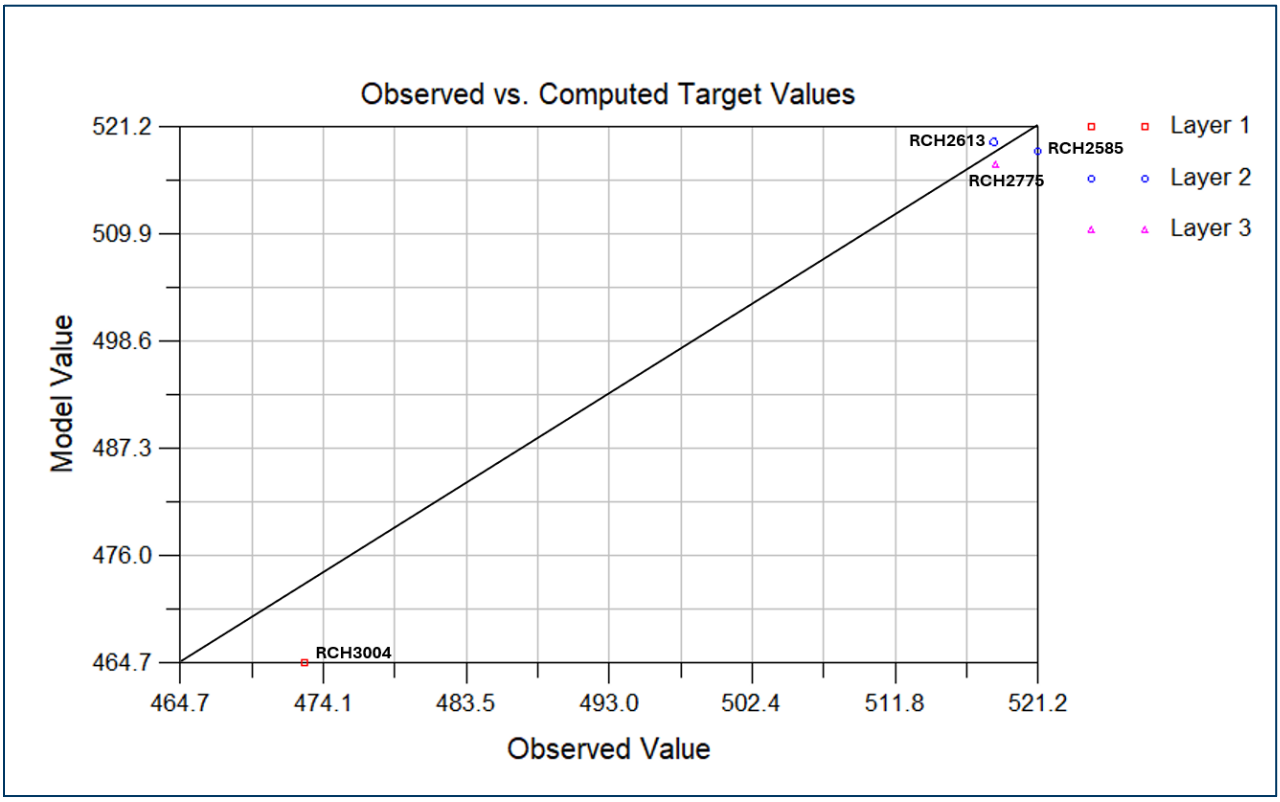


Figure A-4.5 ***Scatter plot (model computed vs measured head) - Golden Bar base case model***

Steady-state groundwater head contours for the base case model are presented in Figure A-4.6. These contours provide a spatial representation of the simulated water table under existing conditions and illustrate the modelled groundwater flow pattern across the Golden Bar model domain. The overall model mass balance (Figure A-4.7), expressed as the difference between total model outflows and inflows, is less than 0.01% for the steady-state base case simulation, suggesting that the model is numerically stable.

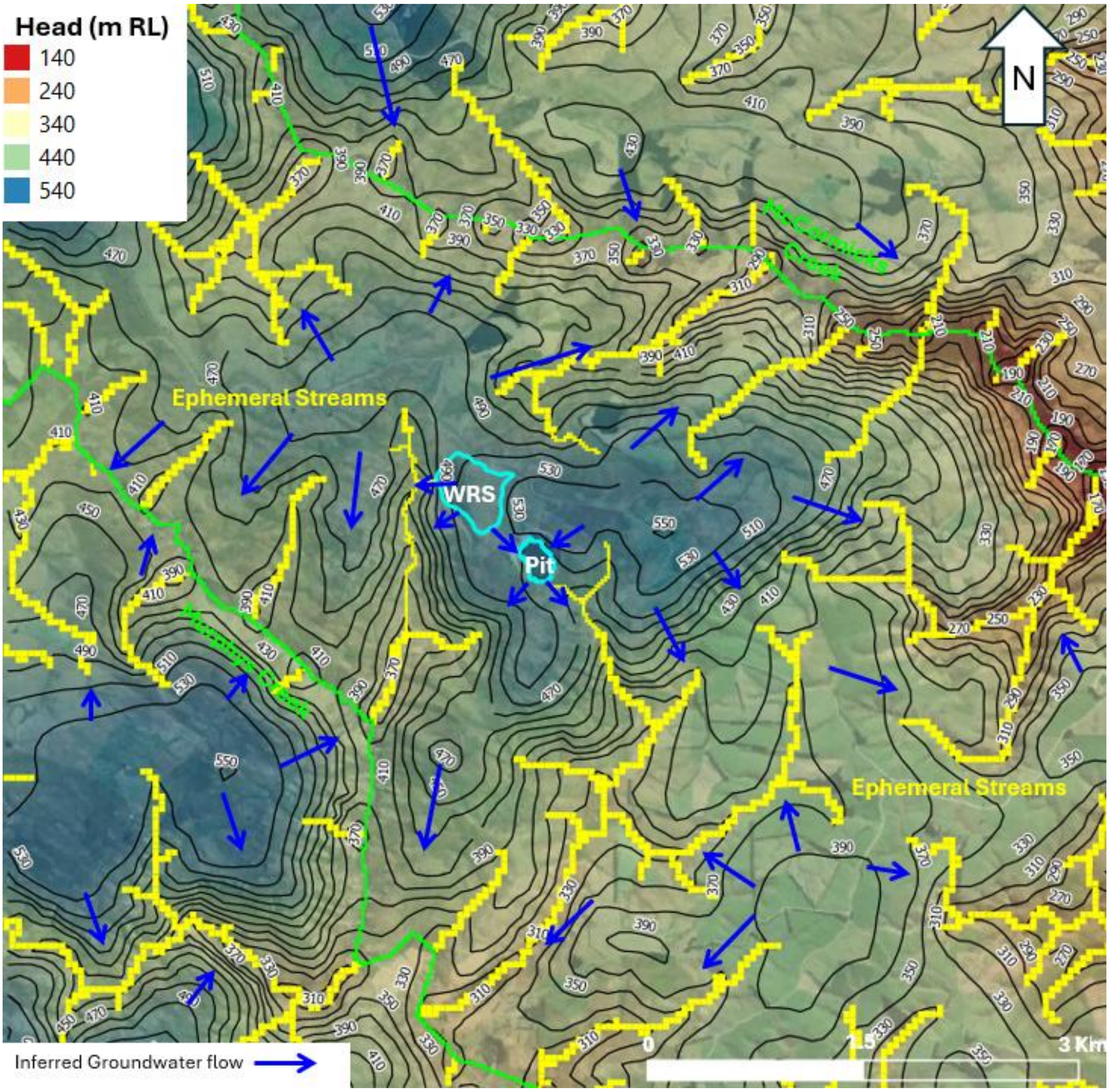


Figure A-4.6 Existing conditions steady-state modelled head contours (m RL) in model layer 1 (Golden Bar base case model).

```
  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 =           0.1439        CONSTANT HEAD =           0.1439
              DRAINS =           0.0000               DRAINS =           0.0000
       RIVER LEAKAGE =           0.1272        RIVER LEAKAGE =           0.1272
            RECHARGE =        7191.0103             RECHARGE =        7191.0103

            TOTAL IN =        7191.2813             TOTAL IN =        7191.2813

          OUT:                                    OUT:
          ----                                    ----
             STORAGE =           0.0000              STORAGE =           0.0000
       CONSTANT HEAD =          11.7739        CONSTANT HEAD =          11.7739
              DRAINS =        6871.2961               DRAINS =        6871.2961
       RIVER LEAKAGE =         308.2116        RIVER LEAKAGE =         308.2116
            RECHARGE =           0.0000             RECHARGE =           0.0000

           TOTAL OUT =        7191.2816            TOTAL OUT =        7191.2816

            IN - OUT =      -2.3309E-04             IN - OUT =      -2.3309E-04

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

Figure A-4.7 Steady state Golden Bar model water balance summary (units of cubic metres per day)

A-5 Predictive Analysis

A.5.1 Proposed Mining Activities - Dewatering

Proposed mining conditions for Golden Bar Stage 2 (GB2) and Stage 3 (GB3) have been simulated with a transient flow model assuming a total of 6 years of dewatering as per the indicative Macraes mining schedule (Figure 2.2 in Section 2.2 of the Surface and Groundwater Assessment report). Throughout the simulation the bigger and deeper extent of the proposed design for both stages has been adopted. This is a relative conservative assumption and is considered appropriate for assessing effects from pit dewatering.

```
 VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP      12 IN STRESS PERIOD       6
 ---------------------------------------------------------------------------------------

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

          IN:                                   IN:
          ---                                   ---
            STORAGE =      477494.9807            STORAGE =         38.6769
      CONSTANT HEAD =           0.0000      CONSTANT HEAD =          0.0000
              WELLS =           0.0000              WELLS =          0.0000
             DRAINS =           0.0000             DRAINS =          0.0000
      RIVER LEAKAGE =         205.8017      RIVER LEAKAGE =      9.3911E-02
           RECHARGE =    15971343.8525           RECHARGE =       7292.8511

           TOTAL IN =    16449044.6349           TOTAL IN =       7331.6219

         OUT:                                  OUT:
         ----                                  ----
            STORAGE =      716665.9398            STORAGE =         98.3490
      CONSTANT HEAD =           0.0000      CONSTANT HEAD =          0.0000
              WELLS =           0.0000              WELLS =          0.0000
             DRAINS =    15044443.9902             DRAINS =       6919.1246
      RIVER LEAKAGE =      688040.0923      RIVER LEAKAGE =        314.1492
           RECHARGE =           0.0000           RECHARGE =          0.0000

          TOTAL OUT =    16449150.0223          TOTAL OUT =       7331.6228

           IN - OUT =        -105.3874           IN - OUT =     -9.0152E-04

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

Figure A-5.1 Water balance summary at the end of the proposed Golden Bar pit dewatering.

The overall mass balance (outflows - inflows) at the end of dewatering model (Figure A-5.1) is <0.01%, suggesting that the model is numerically stable.

Modelled groundwater head contours (phreatic surface) at the end of the proposed 6-year dewatering period for both Stage 2 and Stage 3 are presented in Figure A-5.2. The initial dewatering (emptying the pit) is not included in the sense that several months of pumping will be required to empty the pit. The simulated dewatering period starts once the pit is empty of water and has been excavated to the proposed design. The hydraulic boundary conditions (Drain boundary) are applied to the proposed extend depth and area. A plan-view representation of the simulated drawdown is presented in Figure A-5.3. This figure shows the predicted spatial extent of drawdown greater than 1m associated with dewatering of the proposed Golden Bar pit expansion and provides an indication of the likely area over which the water table may be affected during mining.

Modelling results indicate that drawdown greater than 1 m is predicted to extend approximately 800 m to the north, 500 m to the west, 700 m to the east, and 500 m to the south of the proposed pit. The drawdown pattern is centred on the proposed pit and is interpreted to reflect the combined influence of pit depth, the relatively low hydraulic conductivity of the schist bedrock, and local variations in hydraulic gradients and groundwater flow pathways. There is a small increase in the groundwater table under the simulated Golden Bar WRS as a consequence of the increased recharge to the active WRS through this simulated period.

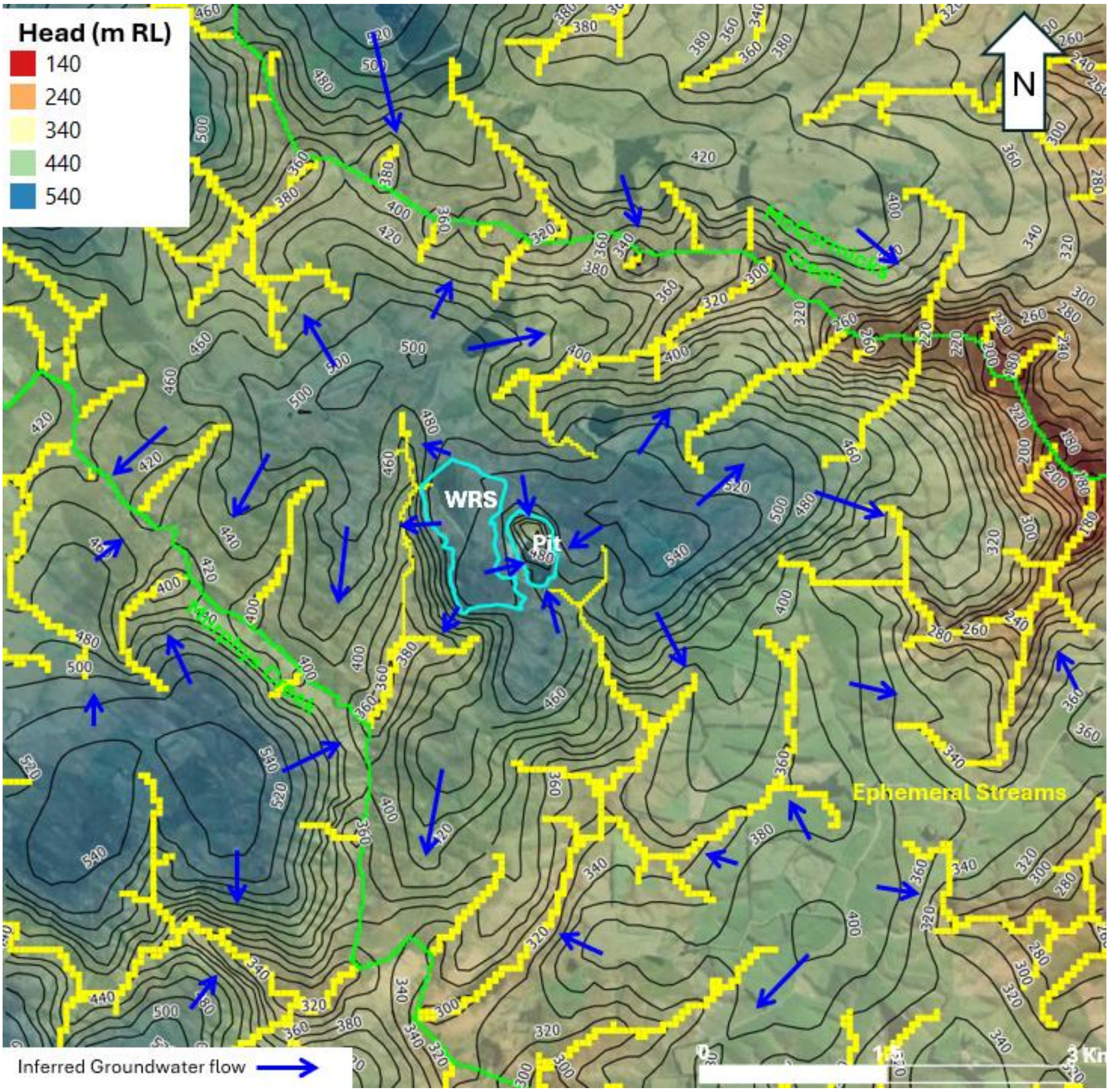


Figure A-5.2 Water table (m RL) at the end of dewatering for the pit expansion.

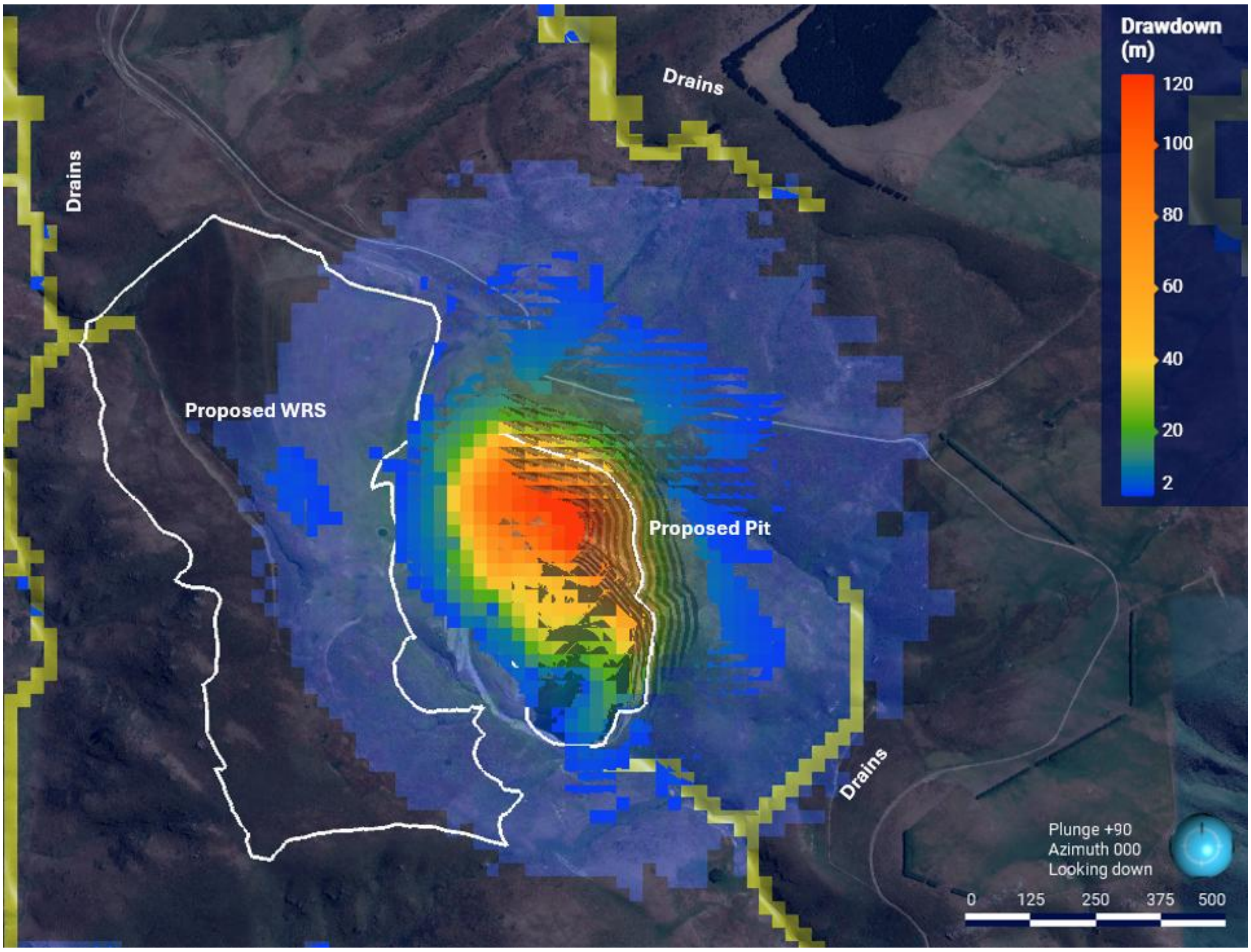


Figure A-5.3 Plan view of the extent of modelled drawdown greater than 1 m after 6 years of dewatering the proposed pit

Estimated dewatering rate (groundwater inflow) for the proposed expansion of the Golden Bar pit is presented in Figure A-5.4. As presented in this figure, the dewatering (groundwater inflow) rate is estimated to range from 1.4 L/s (at the beginning) to 0.7 L/s (towards the end of dewatering), excluding the volume of water stored in the pit itself.

Initial pit inflows are higher because dewatering first drains groundwater stored in the rock mass immediately surrounding the pit under a relatively steep hydraulic gradient. As groundwater levels decline and the local storage is depleted, the gradient toward the pit reduces and inflows into the pit decrease. The modelled pit groundwater inflows, were adopted as inputs to the surface water model for the pit lake filling assessment detailed in Appendix G.

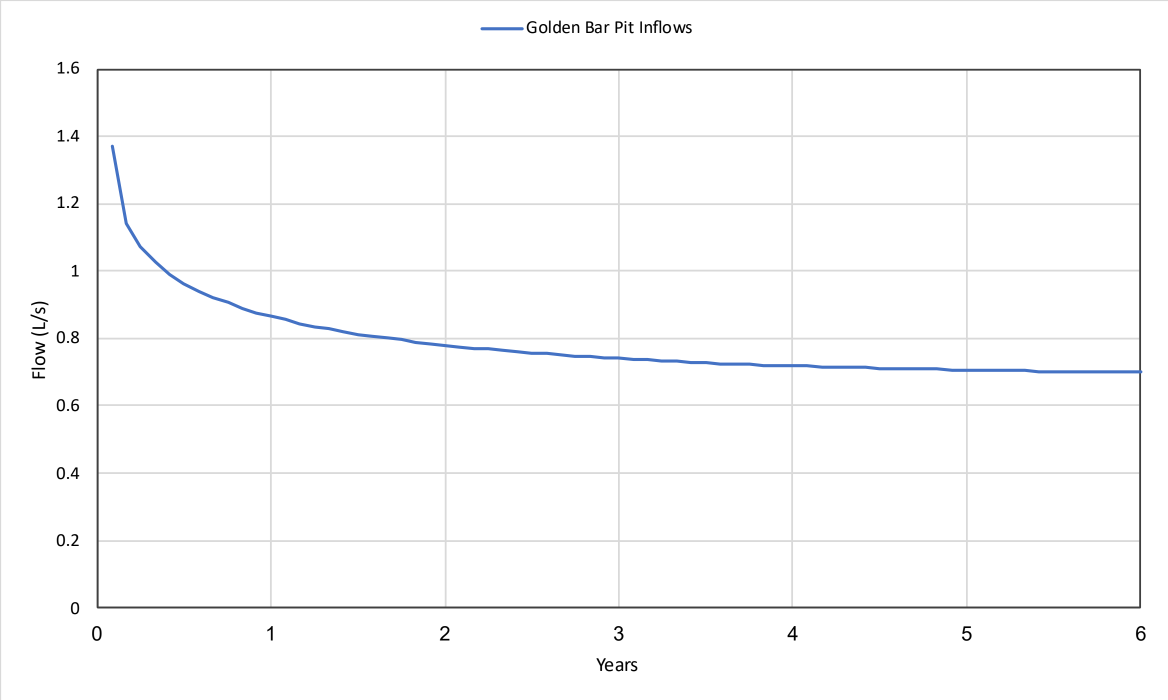


Figure A-5.4 Modelled dewatering rates (groundwater inflow only) for the proposed Golden Bar pit expansion

A.5.1.1 Drawdown effects to surrounding creeks/streams

Modelling results indicate that pit dewatering is predicted to have a very small effect on groundwater contributions to McCormicks Creek and tributary ephemeral streams. The reduction is calculated to be less than 0.15 L/s relative to the modelled groundwater contributions to the base case (existing) conditions. This reduction represents less than 0.5% of the modelled existing conditions groundwater contribution of 39 L/s to McCormicks Creek and ephemeral streams discharging to it within the model domain (Figure A-5.5).

Similarly, modelling results indicate a very small increase in groundwater discharge to the Murphys Creek and tributary ephemeral streams. The increase is estimated to be approximately 0.1 L/s relative to the modelled base case (existing) conditions representing approximately 0.2% of the modelled groundwater contribution of 44 L/s to Murphys Creek and ephemeral streams within the model domain (Figure A-5.5). The increase is primarily attributable to the expanded WRS footprint, which has a higher recharge rate, and exceeds the influence of pit dewatering on groundwater discharge to the catchment.

These modelled results represent changes to the groundwater component of flow only, rather than total streamflow, which is influenced by rainfall runoff, catchment storage, seasonal variability and other surface water processes. A discussion of implications on surface water flows is contained in Appendix H.

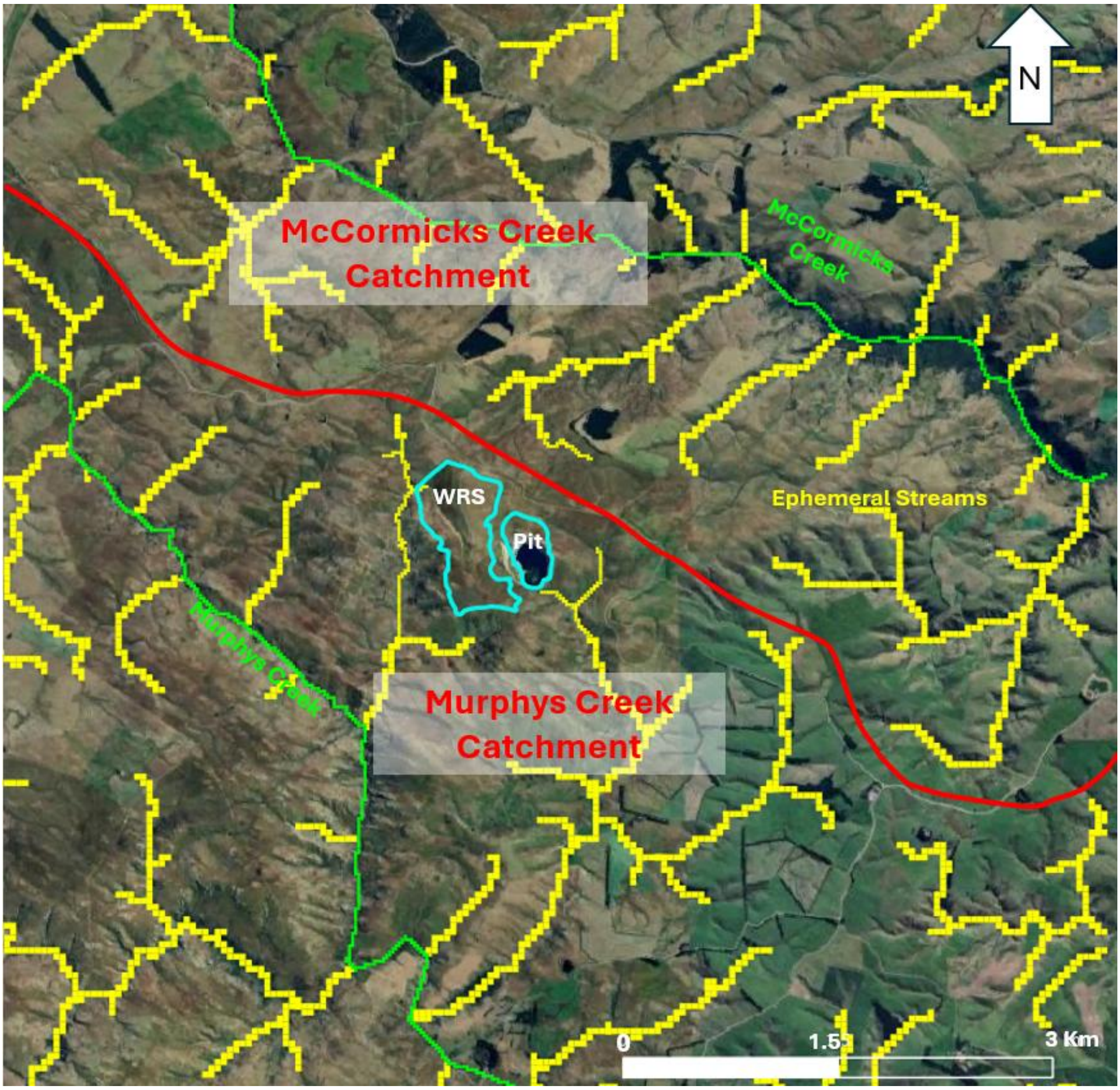


Figure A-5.5 McCormicks Creek and Murphys Creek "catchments" as defined in groundwater model.

A.5.2 Groundwater Recovery

Groundwater recovery was modelled for 400 years with the proposed Golden Bar pit-lake level modelled as a general head boundary condition. The head values for the boundary condition were derived from the surface water modelling results (refer to Appendix G). The head value applied with time were derived from the surface water modelling results (as detailed in Appendix G) and is also presented in Figure A-3.5 with the overflow elevation at 500 m RL.

Modelled pressure head contours at the end of the recovery run in model layer 1 (phreatic surface) are presented in Figure A-5.6. Modelling results indicate that after approximately 60 years groundwater levels around the pit stabilise and pit lake has recovered to the overflow level (500 mRL).

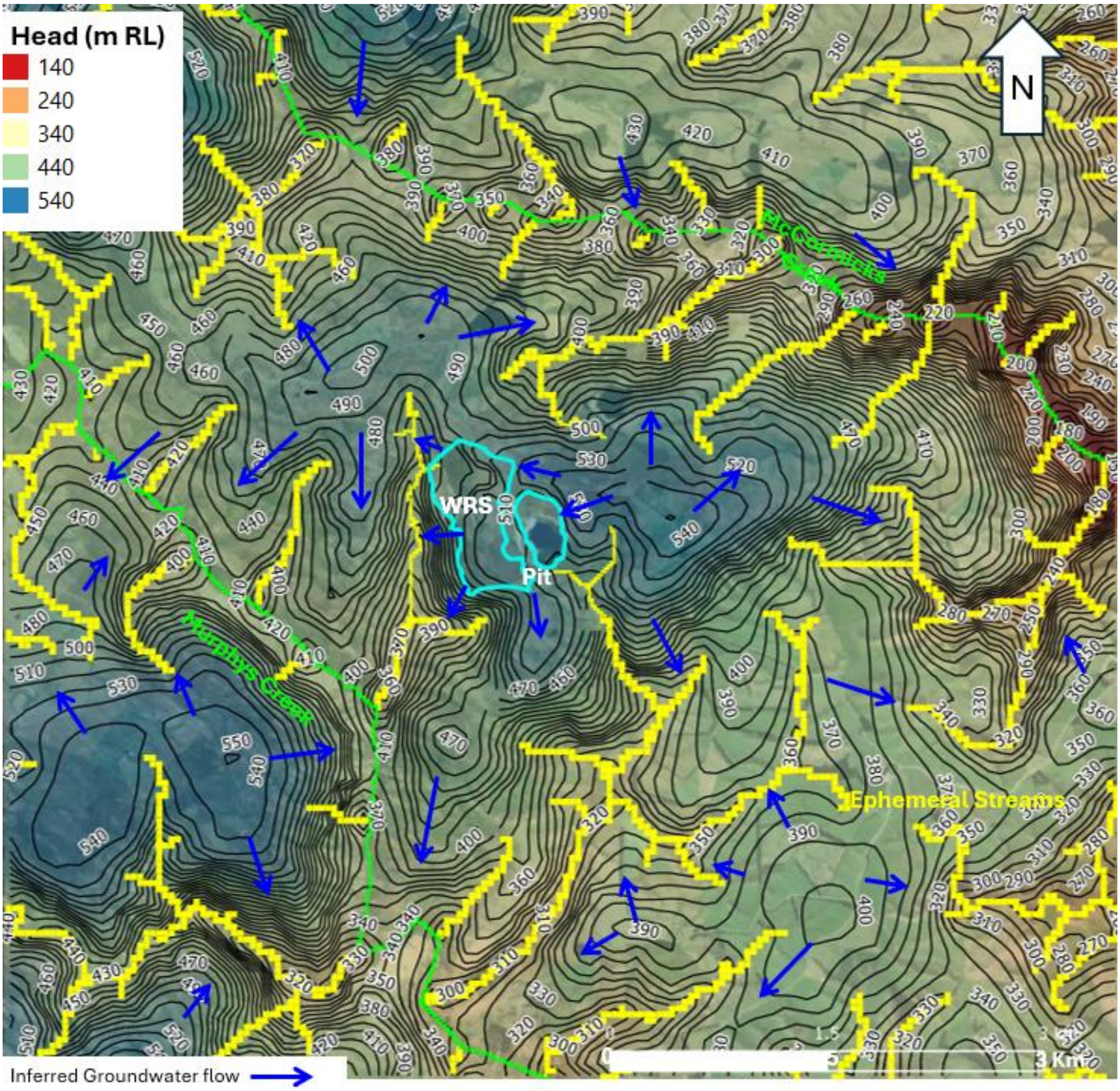


Figure A-5.6 Water table (mRL) and inferred groundwater flow at the end of 400 years of recovery.

The modelling results indicate that groundwater flow from the Golden Bar Pit is generally directed toward Golden Bar Creek. Seepage from the WRS is predicted to flow mainly toward Murphys Creek, with some flow paths also directed toward the Golden Bar pit lake.

A.5.3 Contaminant transport

Sulphate contaminant transport modelling was undertaken using the solute transport modelling code (MODFLOW USG-TRANSPORT) in the Existing Conditions, Dewatering and Recovery models. Sulphate is considered to be a conservative element with which to assess contaminant mobilisation and transport in groundwater at the site, as it is:

- Elevated (relative to other contaminants) in some of the receiving surface water bodies around the MGP site due to current site activities
- Likely to be elevated as a result of future site activities
- Undergoes limited attenuation within the groundwater system and can be used to assess the effects from backfilled waste, WRSs and subsequent pit lakes to receiving surface water bodies via the groundwater system.

The following inputs were used in the contaminant transport models:

- Effective porosity values equal to specific yield values (Table A-4.3).
- 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)
- The adopted sulphate concentrations are presented in Figure A-5.7 and were derived from MWM (2026b) as outlined in Appendix E. These concentrations were implemented in the groundwater contaminant transport model as time-varying Constant Concentration Boundary conditions, with concentration values updated at each stress period[1]. Annual stress periods were adopted during the existing conditions, dewatering, and early recovery phases to represent relatively rapid changes in sulphate concentrations while 10-year stress periods were used during the later recovery phase when concentration changes were less pronounced. The extent of the plume from the existing conditions model has been applied as initial concentrations for the dewatering model. Similarly for the recovery model, the predicted extent of the sulphate plume at the end of dewatering model are applied as initial concentrations.
- The background sulphate concentration in the groundwater models is set at 0 mg/L.
- The sulphate concentration applied to the Golden Bar Pit during the dewatering period was set at 0 mg/L. his reflects the assumption that the pit remains effectively dry during this phase, with groundwater flow directed toward the pit. Under these conditions, the pit acts as a hydraulic sink and is not represented as a source of sulphate loading. Initial sulphate concentrations outside the pit shell were based on the plume distribution predicted by the existing-conditions model.

[1] A stress period is a block of simulation time during which all external stresses (boundary conditions and inputs) applied to the model remain constant.

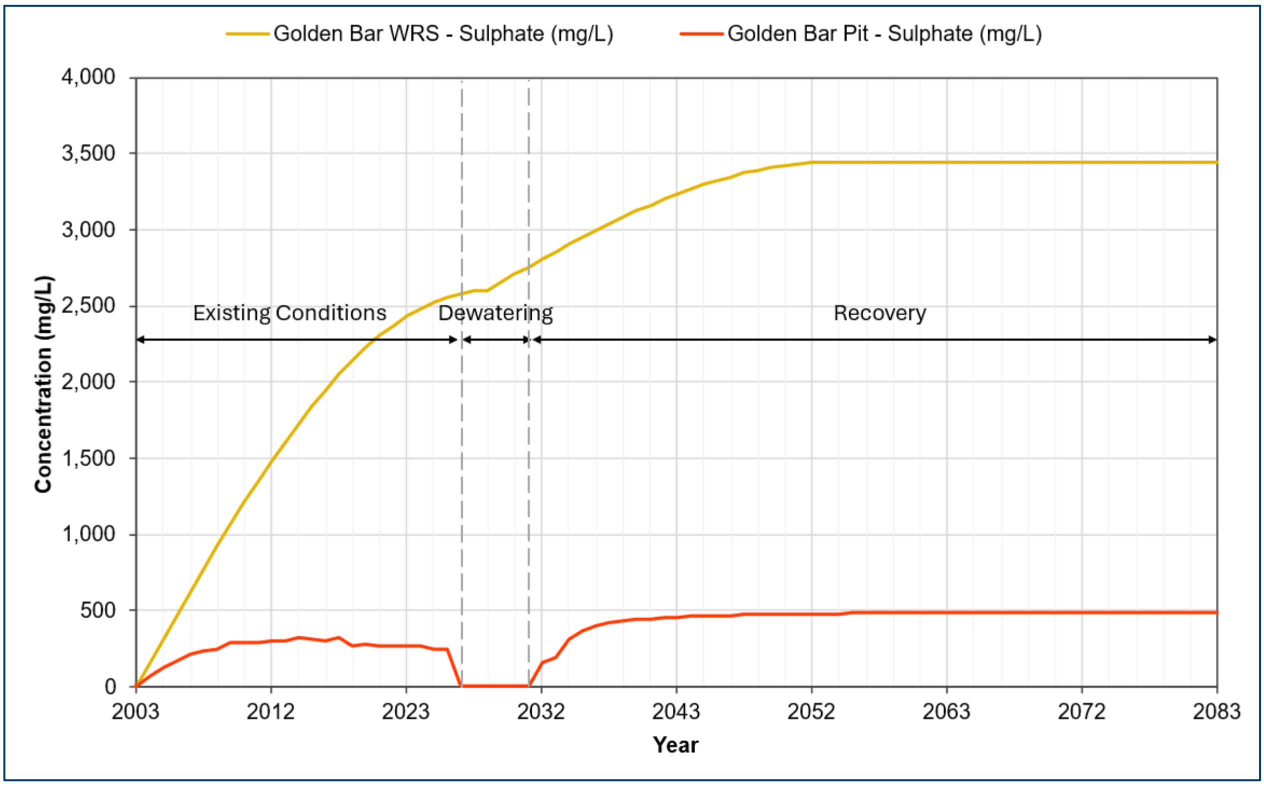


Figure A-5.7 Sulphate concentrations used as inputs for groundwater contaminant transport modelling.

Water balance error and solute transport mass balance error for all contaminant transport runs (existing conditions, dewatering and recovery models) were <0.01%, indicating all model runs completed were numerically stable.

The horizontal extent of the predicted sulphate plume in Layer 1 is shown in Figure A-5.8 to Figure A-5.11 with enlarged views provided in Attachment 1 of this Appendix. The figures also display the location of the closest surface water compliance monitoring point for Murphy's Creek to the plume, GB02. These figures provide a spatial summary of the modelled sulphate distribution in Layer 1 for the key stages of the assessment under existing conditions, at the end of the 6-year dewatering phase, and at the end of the 400-year recovery simulation.

For consistency across the model outputs, the plume extent has been interpreted using the 10 mg/L sulphate concentration contour as the outer plume boundary. This concentration value was adopted as a practical indicator of plume extent because it is considered to be broadly compatible with background sulphate concentrations in Otago schist.

Modelling results indicate that:

- The predicted sulphate plume develops primarily from the Golden Bar WRS and Pit source areas and migrates along the interpreted groundwater flow paths (Figure A-5.8 to Figure A-5.11).
- Plume migration around the pit is constrained during dewatering by groundwater flow toward the pit, which acts as a hydraulic sink and locally captures groundwater and dissolved sulphate (Figure A-5.9).
- The reduction in the modelled Layer 1 plume extent after 400 years (Figure A-5.10), relative to the dewatering model (Figure A-5.9), is attributed to the lower recharge rate applied to the rehabilitated WRS, which was reduced from 148 mm/year to 32 mm/year. The results indicate that seepage flow from the WRS toward McCormicks Creek in layer 1 is diminished. Figure A-5.11 shows the sensitivity scenario where recharge of 128 mm/year is applied during the recovery period.

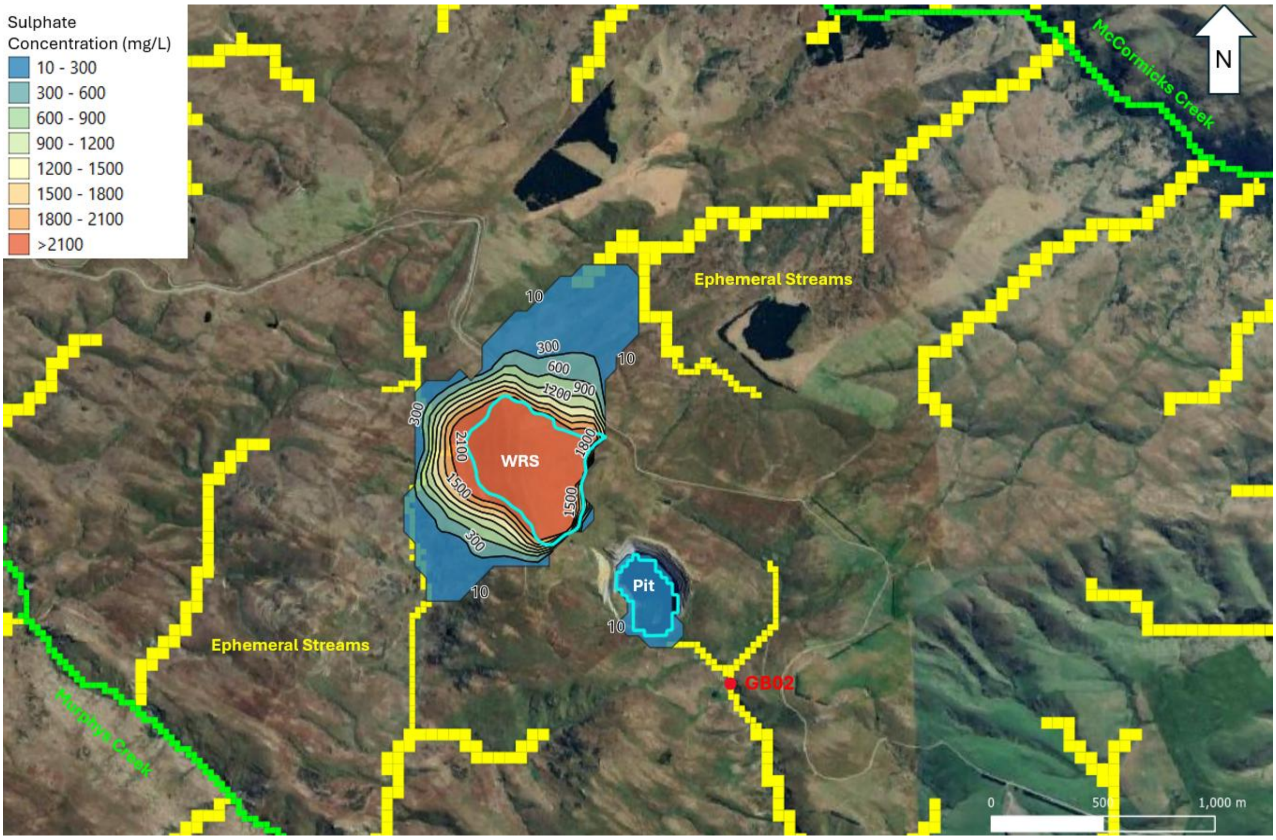


Figure A-5.8 Contour plot showing sulphate plume extent and the end of the existing conditions model in model layer 1

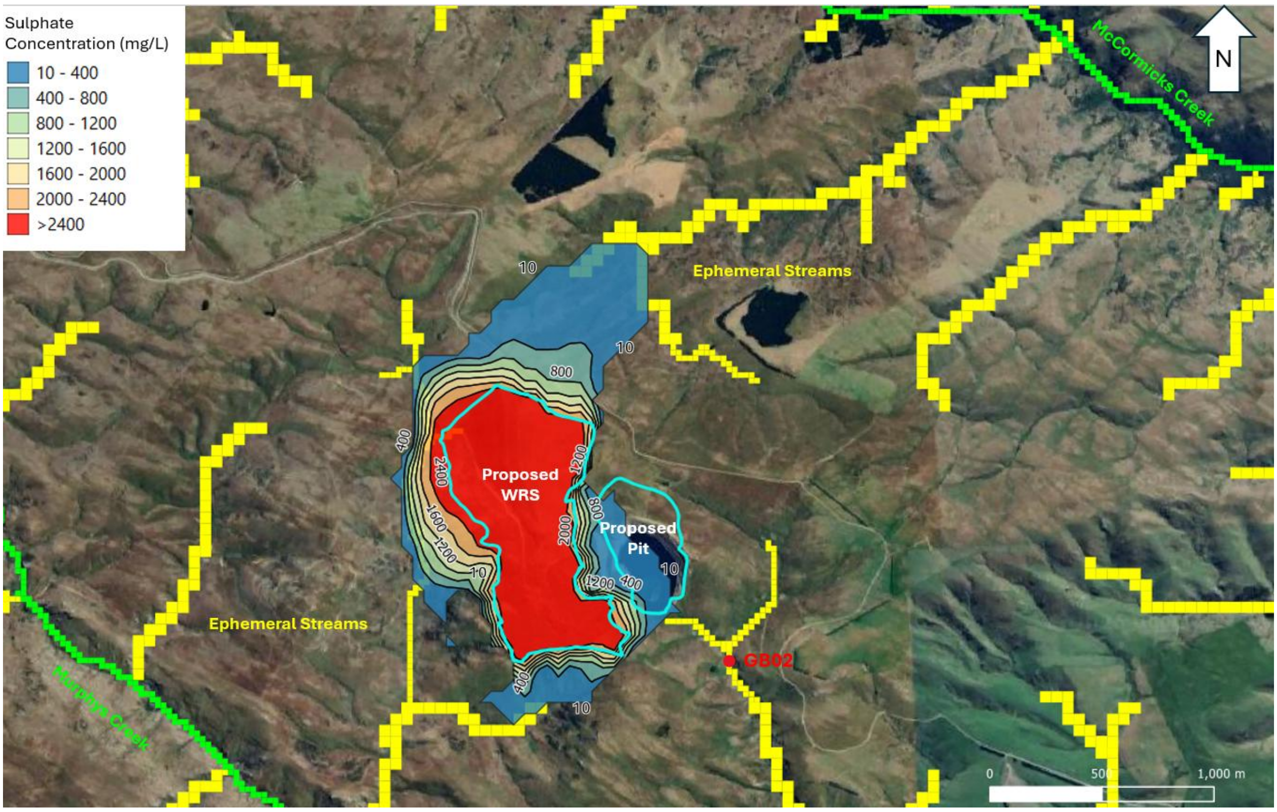


Figure A-5.9 Contour plot showing sulphate plume extent and the end of the dewatering model (6 years of dewatering) in model layer 1.

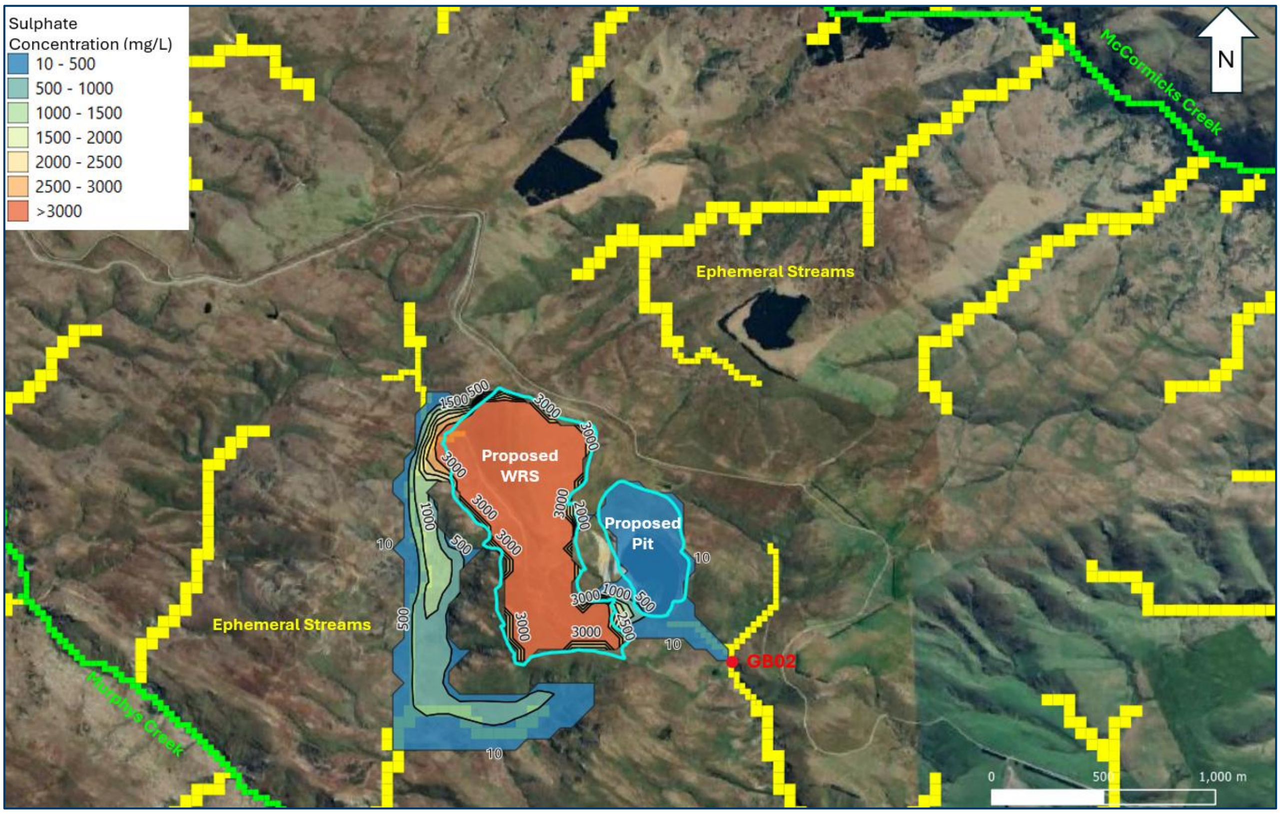


Figure A-5.10 Contour plot showing sulphate plume extent and the end of the recovery model (400 years of recovery) in model layer 1.

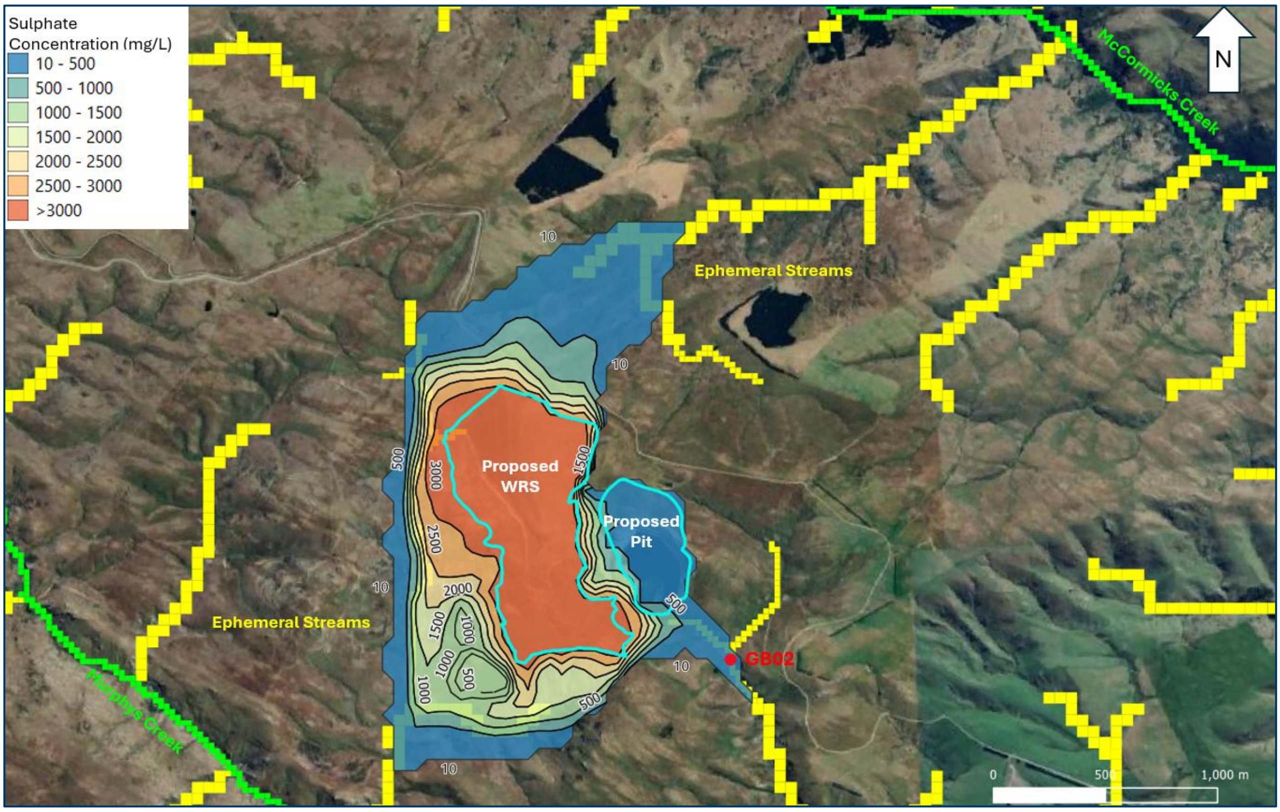


Figure A-5.11 Contour plot illustrating the extent of the sulphate plume at the end of the recovery simulation (400 years) in model layer 1, assuming recharge within the waste rock stack of 128 mm/year (sensitivity scenario).

The maximum horizontal extent of the plume is predicted to be approximately 1,200 m to the northeast of the source areas and approximately 900 m to the south of the source area.

The total modelled sulphate mass discharging to the Murphys Creek and McCormicks Creek and tributary ephemeral streams (Figure A-5.5) was estimated using results from the contaminant transport model in combination with simulated flows across surface water boundaries (river boundaries representing the creeks and drain boundaries representing the ephemeral streams). At 400 years post-closure, the sulphate flux is estimated to be approximately 0.26 kg/day for the McCormicks Creek catchment (combined ephemeral streams and river boundaries) and approximately 149 kg/day for the Murphys Creek and Waikouaiti River North Branch catchment. These values represent an increase in sulphate loading from groundwater discharge relative to pre-mining conditions.

A-6 Groundwater Assessment Summary

A three-dimensional numerical groundwater flow and solute transport model has been developed for the Golden Bar pit area using MODFLOW-USG and MODFLOW-USG-TRANSPORT. The model was developed to represent the current conceptual understanding of the groundwater system and to assess the potential groundwater effects associated with the proposed Golden Bar pit expansion. The assessment considered pre-mining and existing groundwater conditions, groundwater inflows during the proposed 6-year dewatering period, the spatial extent of drawdown, post-mining groundwater recovery over a 400-year period, and contaminant (sulphate) transport from the Golden Bar pit and WRS source areas.

Modelling results indicate that after approximately 60 years groundwater levels around the pit stabilise as pit lake has recovered to the overflow level (500 mRL). A summary of the modelled groundwater effects during dewatering are summarised in Table A-6.1.

Table A-6.1 Summary of modelled groundwater effects associated with Golden Bar pit dewatering

Groundwater Inflows	Extent of modelled drawdown (<1m) from the extension of pit	Change in groundwater discharge to McCormicks Creek catchment*	Change in groundwater discharge to Murphys Creek & Waikouaiti River North Branch*
1.4 L/s at the start of dewatering to 0.7 L/s toward the end of the 6-year dewatering period	800 m north, 500 m west, 700 m east and 500 m south	0.15 L/s decrease of less than 0.5%	0.07 L/s, increase of approximately 0.2%
Notes	**Representing changes to the groundwater component of flow only*		

Sulphate transport modelling was undertaken for the existing-conditions, dewatering and recovery model stages. Sulphate was selected as a conservative indicator of contaminant transport due to its expected elevated concentrations relative to other key contaminants, its existing elevated nature in some receiving surface water bodies around the Macraes Gold Project area, and its limited attenuation within the groundwater system. Sulphate transport modelling results are summarised in Table A-6.2.

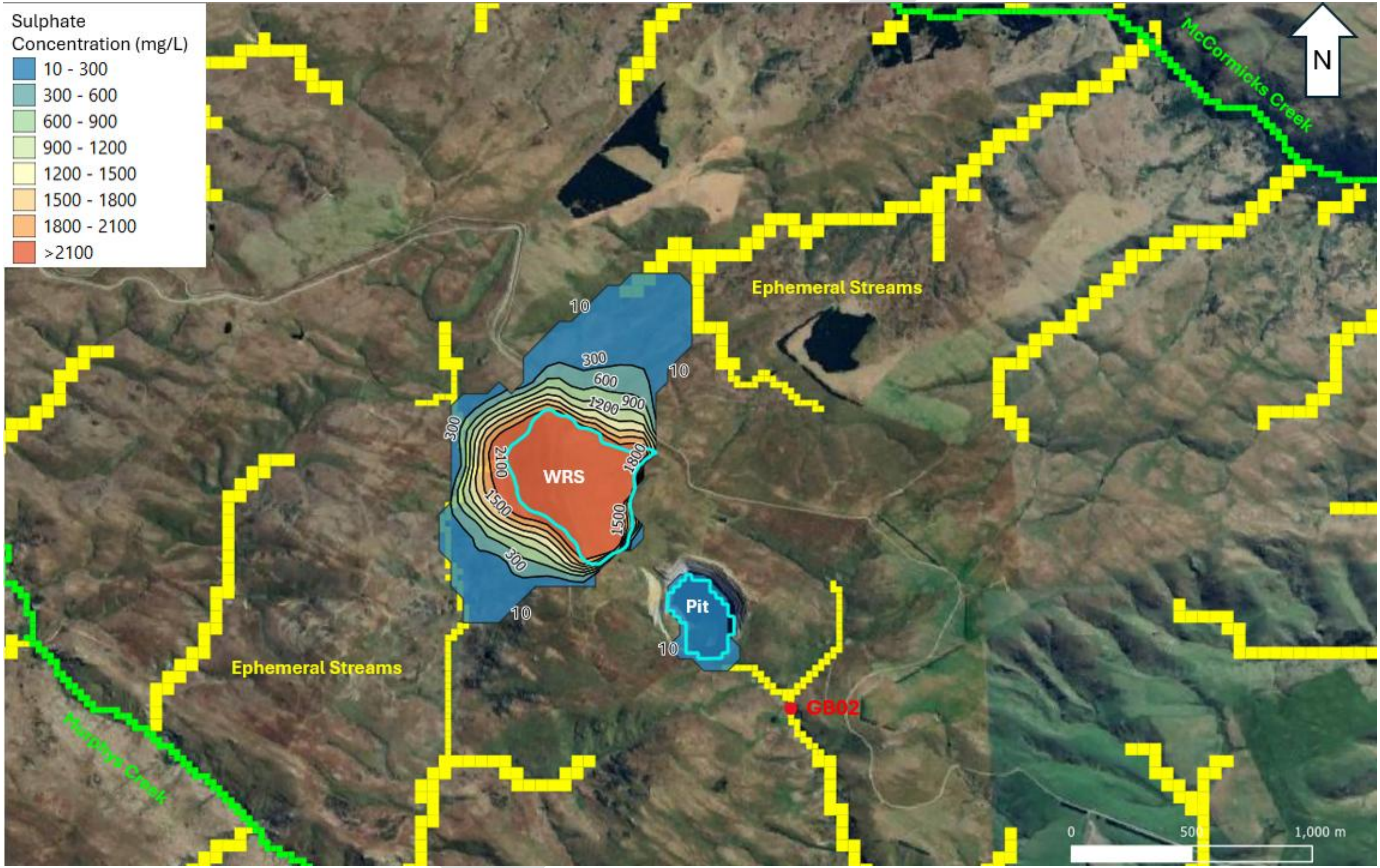
Table A-6.2 Summary of contaminant transport results in the Golden Bar mining area

Maximum extent of modelled sulphate plume*	Groundwater sulphate flux to McCormicks Creek catchment	Groundwater sulphate flux to Murphys Creek & Waikouaiti River North Branch catchment
1,200 m to the northeast and 900 m to the south	0.26 kg/day	149 kg/day
Notes	**10 mg/L sulphate contour used to define the outer plume extent*	

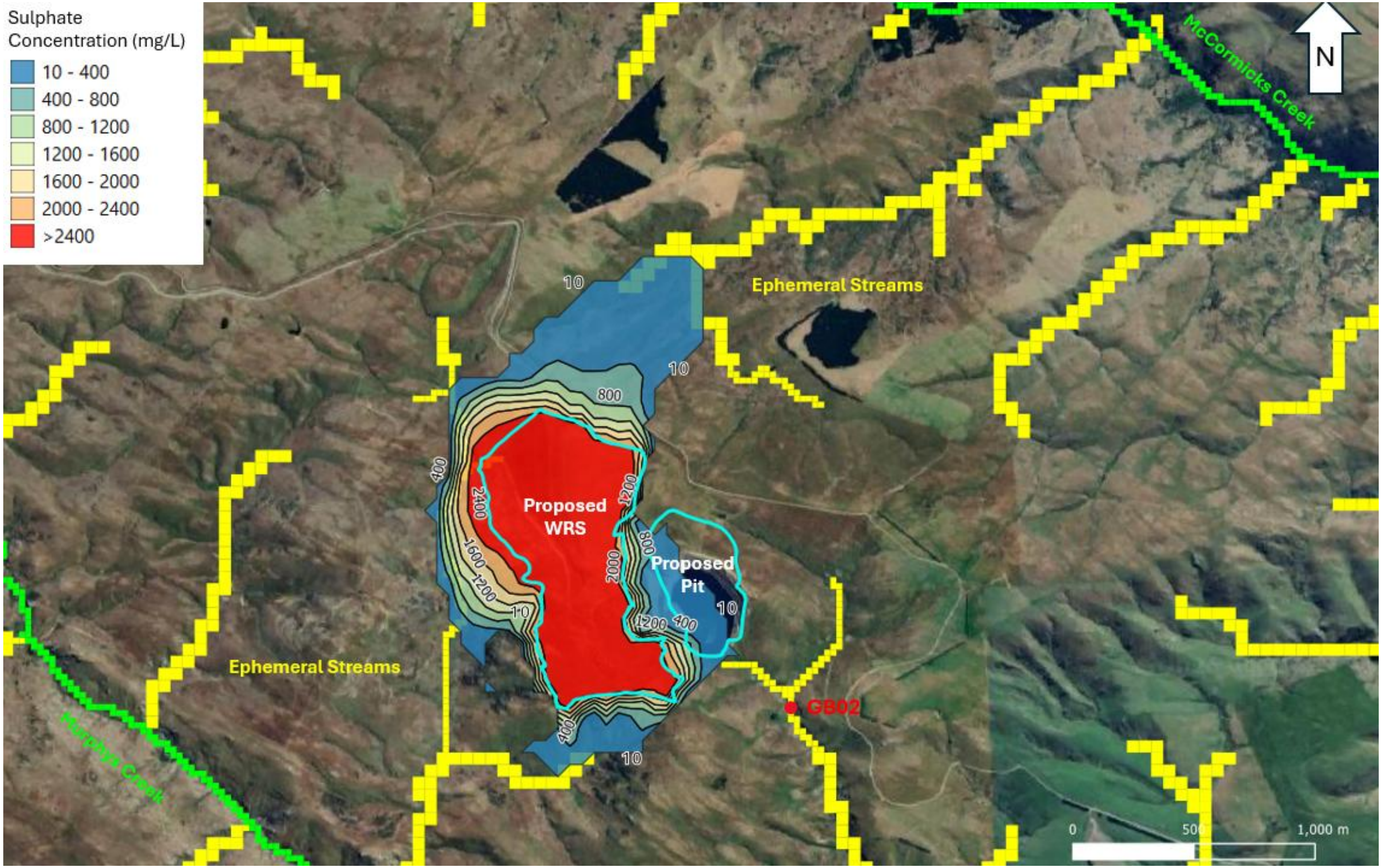
Attachment 1

Sulphate Plume Contours

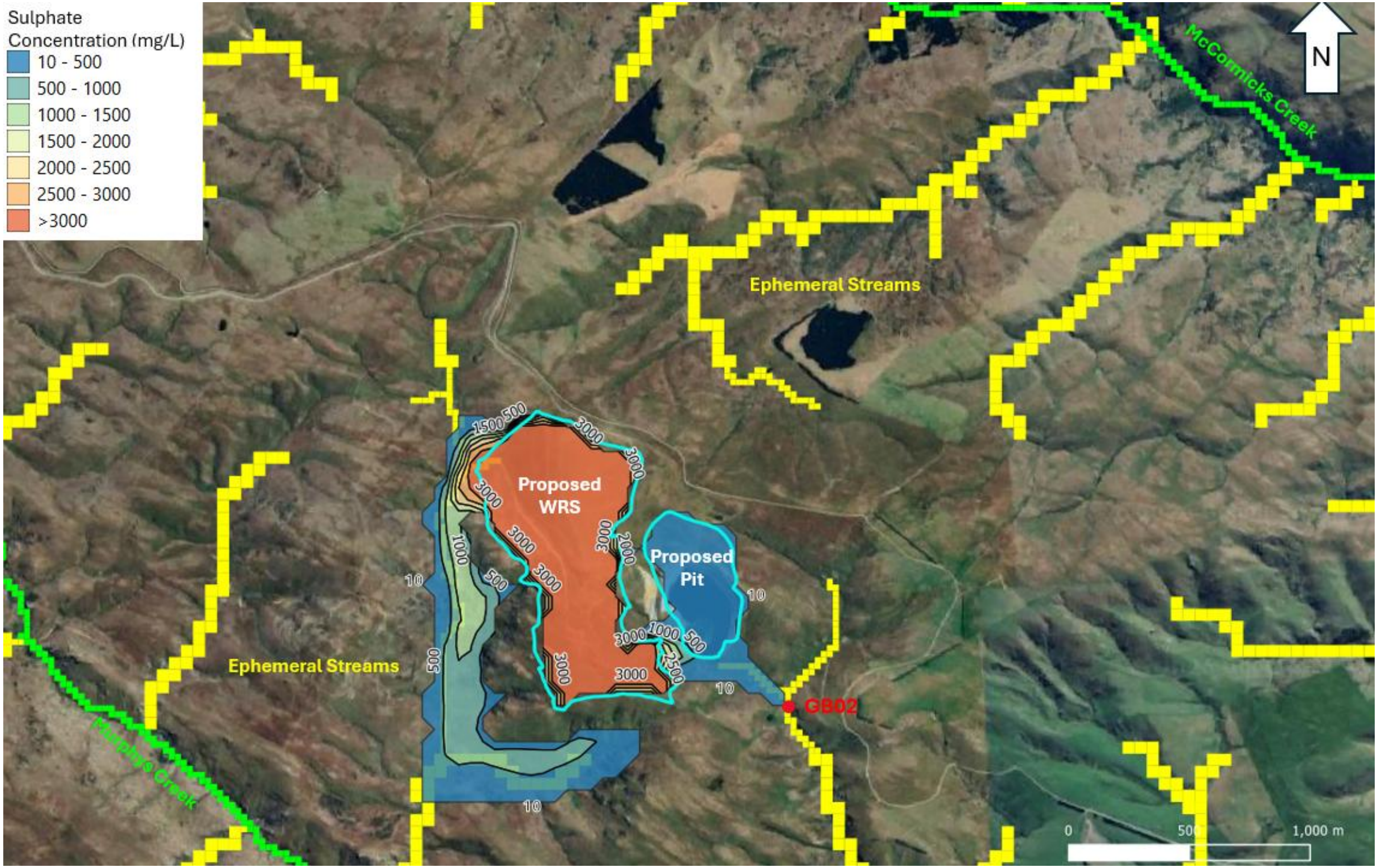
Contour plot showing sulphate plume extent and the end of the existing conditions model in model layer 1



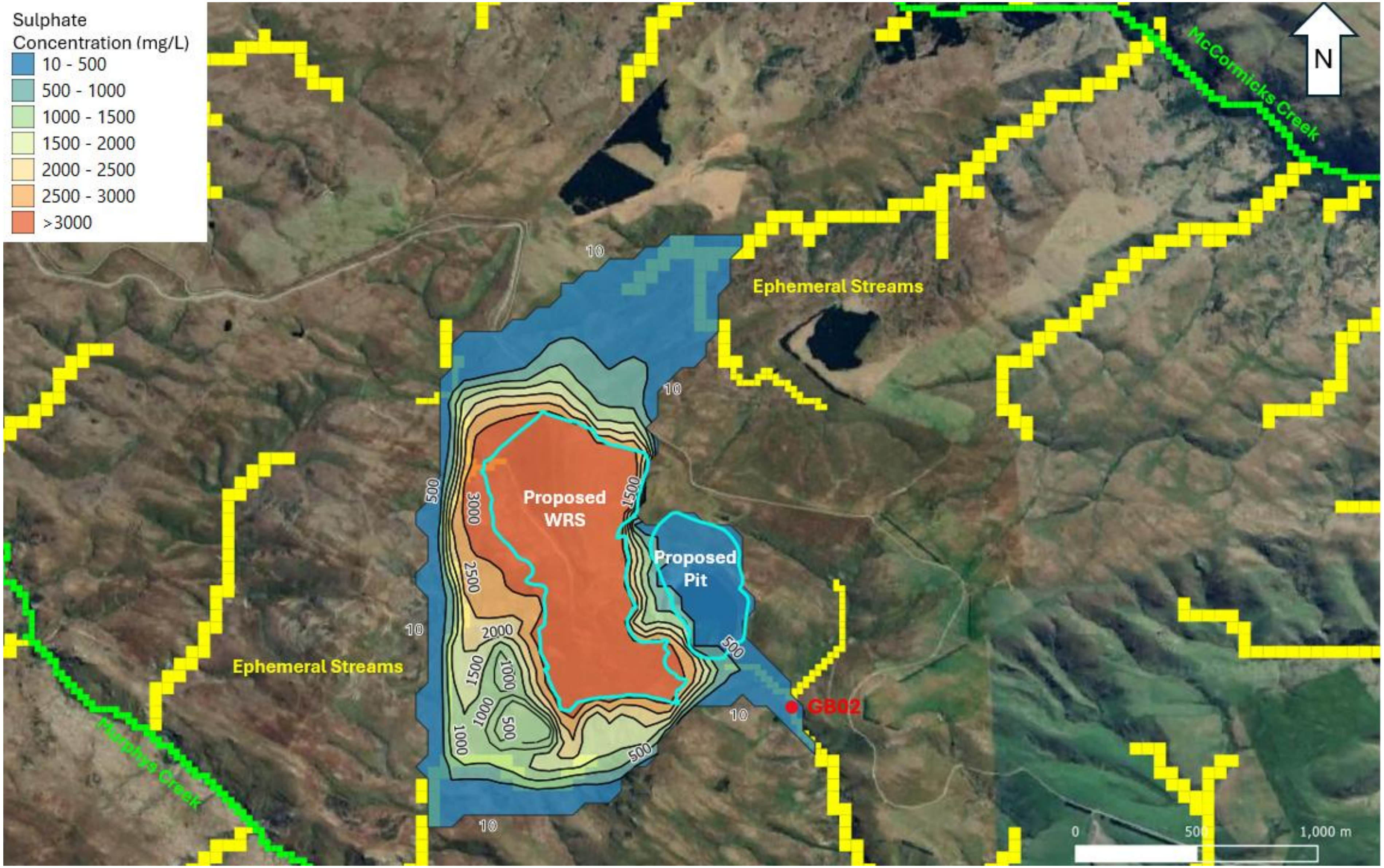
Contour plot showing sulphate plume extent and the end of the dewatering model (6 years of dewatering) in model layer 1



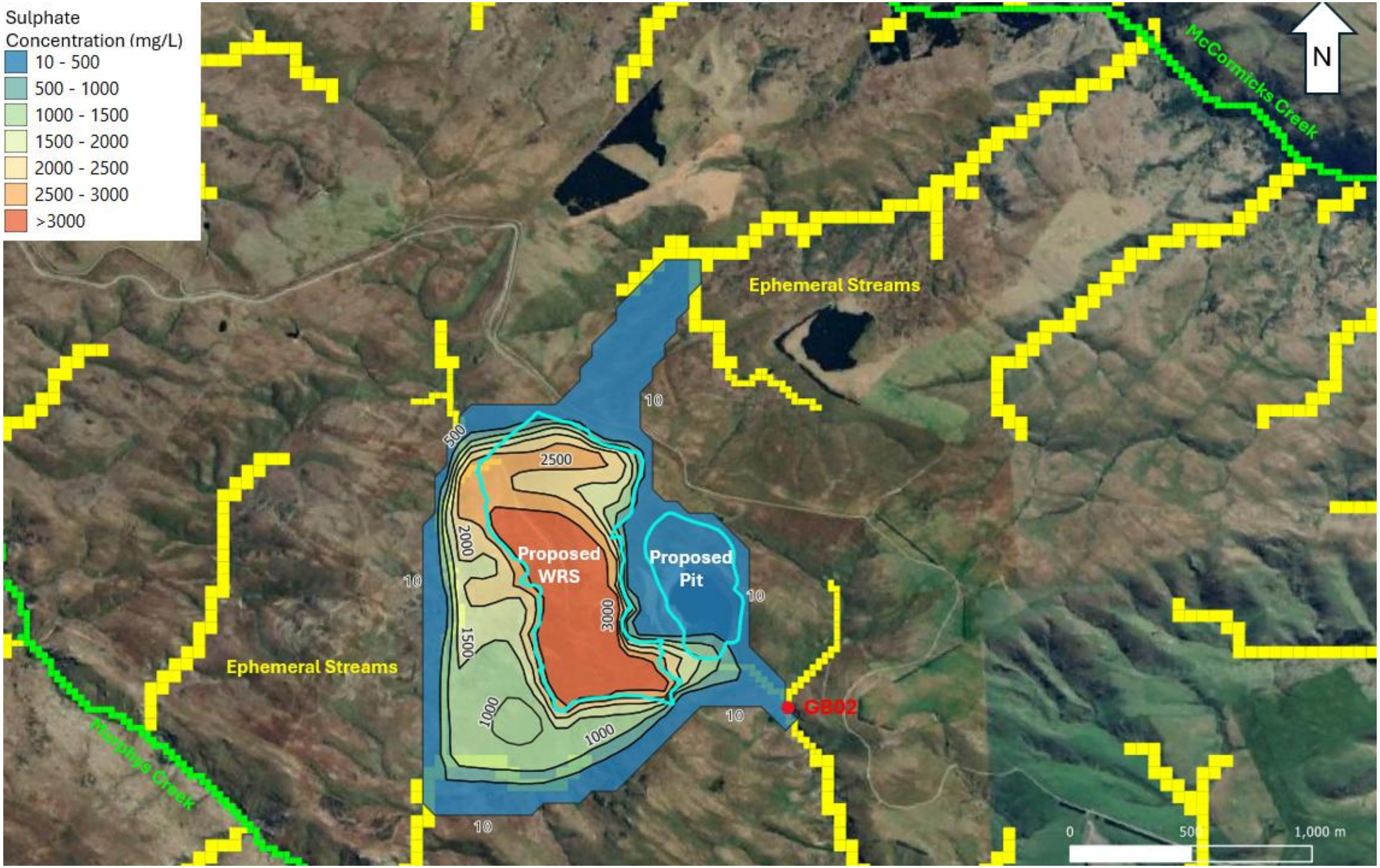
Contour plot showing sulphate plume extent and the end of the recovery model (400 years of recovery) in model layer 1.



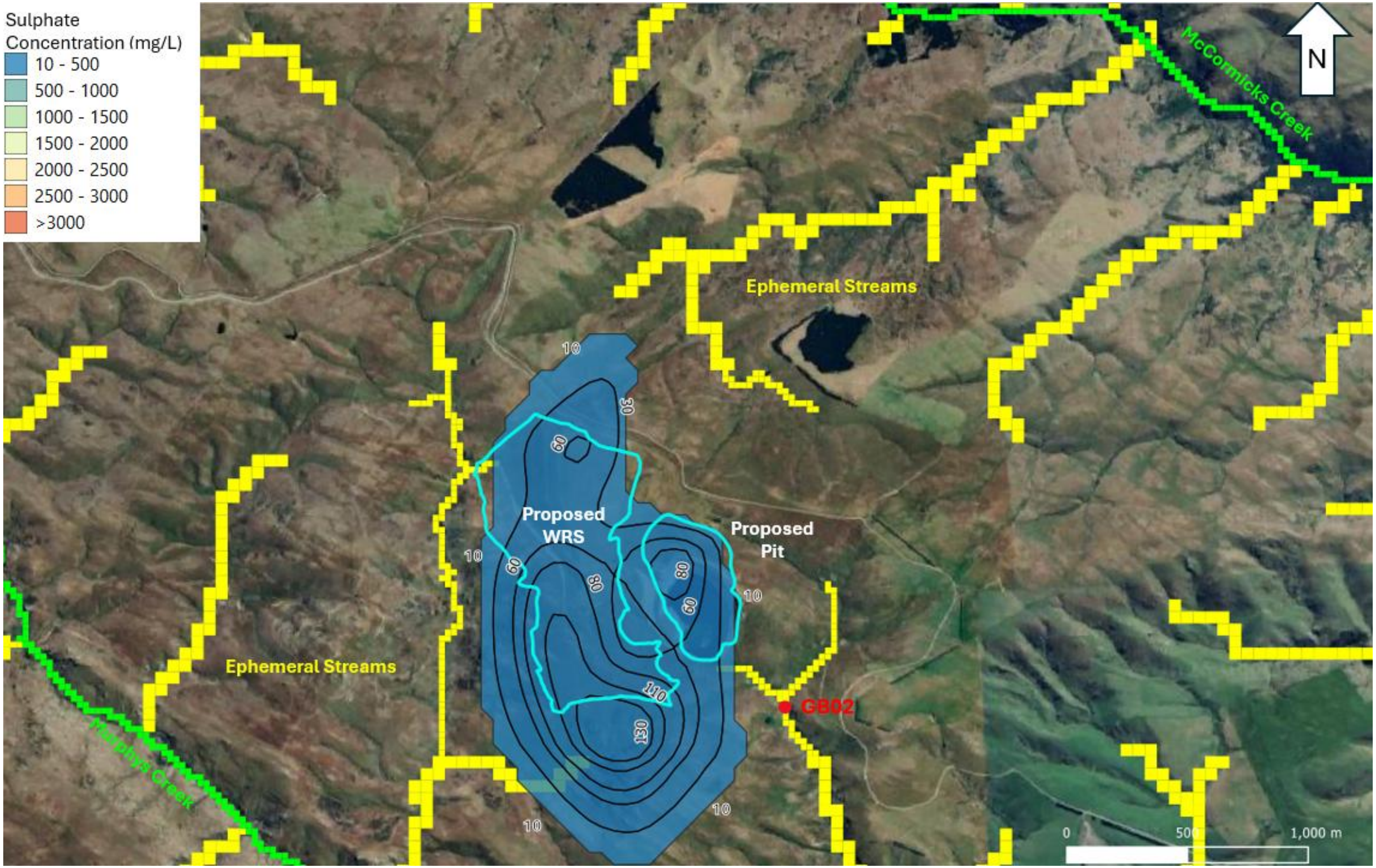
Contour plot illustrating the extent of the sulphate plume at the end of the recovery simulation (400 years) in model layer 1, assuming recharge within the waste rock stack of 128 mm/year (sensitivity scenario).



Contour plot showing sulphate plume extent and the end of the recovery model (400 years of recovery) in model layer 2.



Contour plot showing sulphate plume extent and the end of the recovery model (400 years of recovery) in model layer 8.



Attachment 2

Contaminant Mass Balance Summary Reports

Mass balance summary at the end of the existing conditions model

```
  MASS BUDGET FOR ENTIRE MODEL AT END OF TIME STEP      12 IN STRESS PERIOD      24
  -------------------------------------------------------------------------------------

     CUMULATIVE MASS         M/L^3 * L^3       RATES FOR THIS TIME STEP      M/L^3 * L^3/T
     ------------------                  ------------------------

           IN:                                     IN:
           ---                                     ---
        MASS STORAGE =        475.8625          MASS STORAGE =      6.3177E-03
       ADSORBED MASS =          0.0000         ADSORBED MASS =          0.0000
    PRESCRIBED CONCS =    3834950.1271      PRESCRIBED CONCS =        244.3794
    CNST H MASS FLUX =          0.0000      CNST H MASS FLUX =          0.0000
      WELL MASS FLUX =          0.0000        WELL MASS FLUX =          0.0000
       DRN MASS FLUX =      6.2706E-82         DRN MASS FLUX =          0.0000
       RIV MASS FLUX =      3.2467-101         RIV MASS FLUX =          0.0000
       RCH MASS FLUX =          0.0000         RCH MASS FLUX =          0.0000

            TOTAL IN =    3835425.9896              TOTAL IN =        244.3857

          OUT:                                    OUT:
          ----                                    ----
        MASS STORAGE =    3050159.3587          MASS STORAGE =         76.6192
       ADSORBED MASS =          0.0000         ADSORBED MASS =          0.0000
    PRESCRIBED CONCS =        861.1982      PRESCRIBED CONCS =          0.1599
    CNST H MASS FLUX =          0.0000      CNST H MASS FLUX =          0.0000
      WELL MASS FLUX =          0.0000        WELL MASS FLUX =          0.0000
       DRN MASS FLUX =     784405.4327         DRN MASS FLUX =        167.6065
       RIV MASS FLUX =      1.7765E-19         RIV MASS FLUX =      5.2746E-22
       RCH MASS FLUX =          0.0000         RCH MASS FLUX =          0.0000

           TOTAL OUT =    3835425.9896             TOTAL OUT =        244.3857

            IN - OUT =     -4.0801E-06              IN - OUT =     -1.3439E-06

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

Mass balance summary at the end of the dewatering of Golden Bar Pit

```
   MASS BUDGET FOR ENTIRE MODEL AT END OF TIME STEP      12 IN STRESS PERIOD       6
   -------------------------------------------------------------------------------------

      CUMULATIVE MASS         M/L^3 * L^3       RATES FOR THIS TIME STEP      M/L^3 * L^3/T
      ------------------                  ------------------------

            IN:                                       IN:
            ---                                       ---
         MASS STORAGE =      155648.9245          MASS STORAGE =         15.4493
        ADSORBED MASS =           0.0000         ADSORBED MASS =          0.0000
     PRESCRIBED CONCS =     2474981.8445      PRESCRIBED CONCS =        598.3560
     CNST H MASS FLUX =           0.0000      CNST H MASS FLUX =          0.0000
       WELL MASS FLUX =           0.0000        WELL MASS FLUX =          0.0000
        DRN MASS FLUX =       6.8085-207         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 =     2630630.7690              TOTAL IN =        613.8053

           OUT:                                      OUT:
           ----                                      ----
         MASS STORAGE =     2307440.7062          MASS STORAGE =        407.8548
        ADSORBED MASS =           0.0000         ADSORBED MASS =          0.0000
     PRESCRIBED CONCS =           0.0000      PRESCRIBED CONCS =          0.0000
     CNST H MASS FLUX =           0.0000      CNST H MASS FLUX =          0.0000
       WELL MASS FLUX =           0.0000        WELL MASS FLUX =          0.0000
        DRN MASS FLUX =      323190.0625         DRN MASS FLUX =        205.9505
        RIV MASS FLUX =       4.6768E-17         RIV MASS FLUX =      1.0498E-19
        RCH MASS FLUX =           0.0000         RCH MASS FLUX =          0.0000

            TOTAL OUT =     2630630.7687             TOTAL OUT =        613.8053

             IN - OUT =       2.9944E-04              IN - OUT =      5.7220E-06

  PERCENT DISCREPANCY =           0.00     PERCENT DISCREPANCY =          0.00
```

Mass balance at the end of the recovery model

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

      CUMULATIVE MASS         M/L^3 * L^3       RATES FOR THIS TIME STEP      M/L^3 * L^3/T
      ------------------                   ------------------------

            IN:                                       IN:
            ---                                       ---
         MASS STORAGE =    4599385.7731           MASS STORAGE =          0.1715
        ADSORBED MASS =          0.0000          ADSORBED MASS =          0.0000
     PRESCRIBED CONCS =   27542155.7027       PRESCRIBED CONCS =        181.4033
     CNST H MASS FLUX =          0.0000       CNST H MASS FLUX =          0.0000
       WELL MASS FLUX =          0.0000         WELL MASS FLUX =          0.0000
        GHB MASS FLUX =          0.0000          GHB MASS FLUX =          0.0000
        DRN MASS FLUX =      3.2620E-56          DRN MASS FLUX =          0.0000
        RIV MASS FLUX =      7.3449E-65          RIV MASS FLUX =          0.0000
        RCH MASS FLUX =          0.0000          RCH MASS FLUX =          0.0000

             TOTAL IN =   32141541.4758               TOTAL IN =        181.5748

           OUT:                                      OUT:
           ----                                      ----
         MASS STORAGE =    6584798.3675           MASS STORAGE =         14.7855
        ADSORBED MASS =          0.0000          ADSORBED MASS =          0.0000
     PRESCRIBED CONCS =     456618.9920       PRESCRIBED CONCS =          2.1980
     CNST H MASS FLUX =          0.0000       CNST H MASS FLUX =          0.0000
       WELL MASS FLUX =          0.0000         WELL MASS FLUX =          0.0000
        GHB MASS FLUX =          0.0000          GHB MASS FLUX =          0.0000
        DRN MASS FLUX =   25100123.8141          DRN MASS FLUX =        164.5913
        RIV MASS FLUX =          0.3021          RIV MASS FLUX =      2.0488E-05
        RCH MASS FLUX =          0.0000          RCH MASS FLUX =          0.0000

            TOTAL OUT =   32141541.4757              TOTAL OUT =        181.5748

             IN - OUT =      1.1759E-04               IN - OUT =     -8.4480E-06

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