REPORT

Fosterville Gold Mine - Southern Mine Extension

Groundwater assessment

Submitted to:

Kirkland Lake Gold

McCormick Road Fosterville, Victoria

Submitted by:

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Distribution List

Fosterville Gold Mine

Table of Contents

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

1.1 Background

The Fosterville Gold Mine (FGM) is a high-grade, underground gold mine operated by Kirkland Lake Gold (KLG). The mine is located on mining lease MIN5404, about 20 km from the city of Bendigo in the State of Victoria, Australia.

FGM plan to extend their existing underground mining operation to the south and north of current development and into a new mining licence to the west in the Sugarloaf Reserve. This report presents the results of a hydrogeological impact assessment of the proposed southern extension only (Figure 1).

Golder Associates Pty Ltd was engaged by FGM to update the existing conceptual hydrogeological model and numerical groundwater model to assess the potential impacts of the proposed southern extension on groundwater and surface water systems. Mining of the southern extension will occur at depths of between 600 m to 1,600 m bgl (metres below ground level) over a period of 5 years. The proposed underground mine will pass beneath the Axe Creek at a depth of about 970 m bgl (Figure 1). Potential impacts on the Axe Creek and adjacent Campaspe River from mine dewatering were therefore key considerations of this groundwater assessment.

This report provides details on the conceptual hydrogeological model, numerical model development, calibration process and results of future mining on the groundwater and surface water systems. The modelling work undertaken for this assessment builds upon previous groundwater modelling and results of previous hydrogeological and drilling investigations, long-term groundwater monitoring undertaken at and in the vicinity of the site, site geological models and publicly available information (from databases such as the Visualising Victoria Groundwater database).

1.2 Project objective

The overall objective of this report is to provide sufficient information on the state of the groundwater environment around the mine areas and immediate surrounds, and to assess the potential impacts on groundwater and surface water from development of the southern extension. This has been done to address concerns regarding potential impacts on groundwater and surface water resources and existing groundwater users.

1.3 Scope of work

The following activities were undertaken to achieve the above objective:

- A review was undertaken of available geological and hydrogeological information from investigations undertaken onsite since the 1990's and from publicly available information. This was used to update the existing site conceptual hydrogeological model for the southern extension area.
- An existing numerical groundwater model was updated by extending the model domain further to the south to accommodate the southern mine extension area. This included updates to topography, surface water features and incorporation of key hydrogeological features such as faults and the alluvial aquifers along the terraces of the Campaspe River and Axe Creek (informed by the updated conceptual model).
- Predictive simulations were undertaken of groundwater impacts associated with past, current and future mine areas (including post mining), each operating in accordance with their respective mine plans. This was used to assess potential risk of the proposed southern extension on groundwater and surface water resources and other groundwater users.

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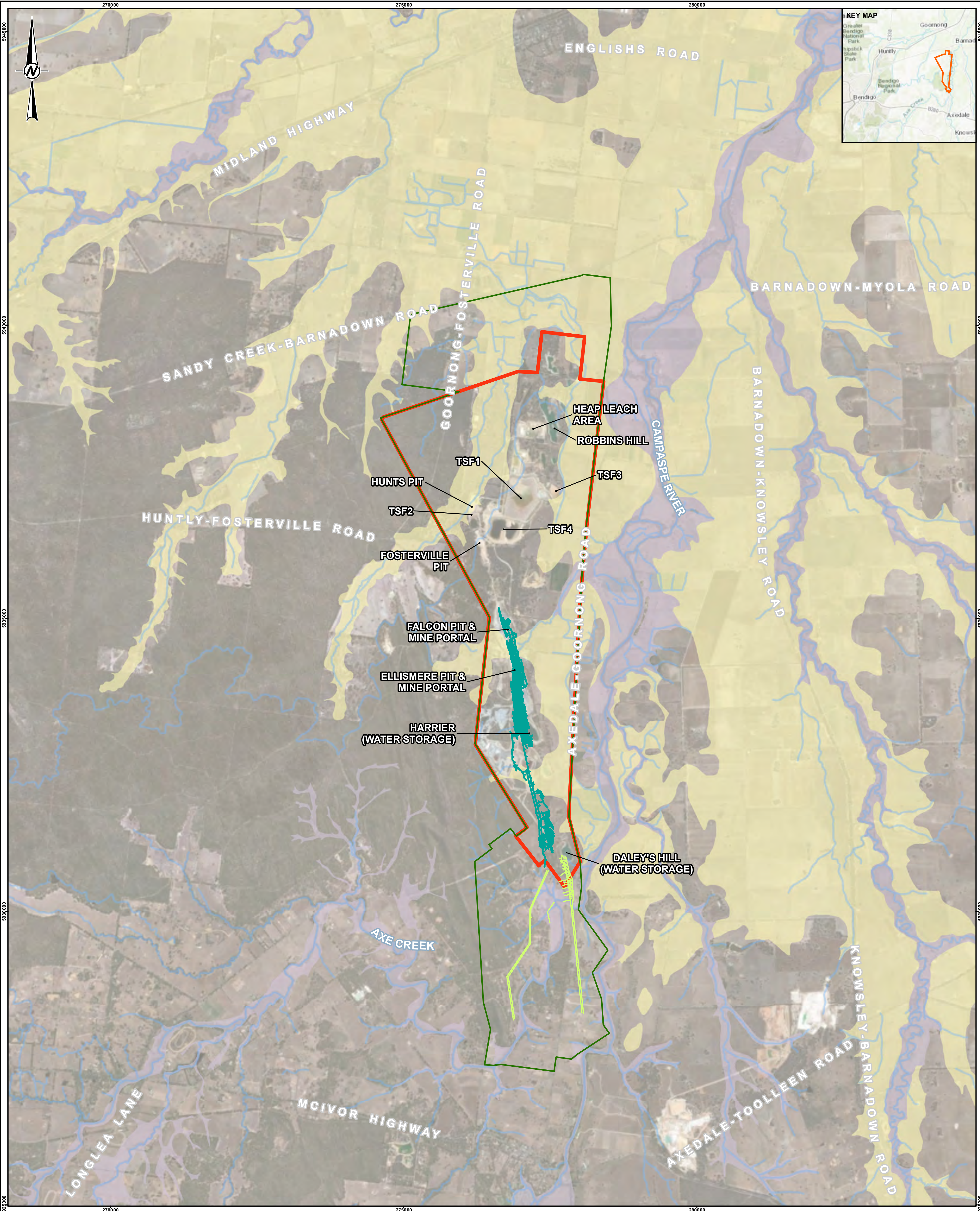

LEGEND

- Underground Mine Plan
- Southern Mine Extension
- Waterbody
- Mining Lease Boundary
- Extended Mining Lease Boundary (MIN5404)
- Shepparton Formation
- Quaternary Sediments

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NOTE(S)
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REFERENCE(S)
1. IMAGERY AND LOCATION MAP SOURCED FROM ESRI ONLINE BASEMAPS.
2. WELL INFORMATION SOURCED FROM AUSTRALIAN GROUNDWATER TECHNOLOGIES.
3. ROAD AND WATERBODY INFORMATION SOURCED FROM WWW.DATA.VIC.GOV.AU

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CONSULTANT
GOLDER

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PREPARED	CJS
REVIEWED	JVDA
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PROJECT
FOSTERVILLE GOLD MINE EXTENSION
GROUNDWATER ASSESSMENT

TITLE
SITE LOCATION PLAN

PROJECT NO.	CONTROL	REV.	FIGURE
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1.4 Outline of this report

This report is structured as follows.

- Chapter 2 provides an overview of historic mining, current mining and proposed mining operations for the southern extension area.
- Chapter 3 provides an overview of the regional setting.
- Chapter 4 provides an overview of the hydrogeological setting and existing receptors, based on groundwater investigations undertaken on site over the past 20 years.
- Chapter 5 provides an overview of the main updates performed on the numerical model (including model re-calibration).
- Chapter 6 provides details of model simulations and their results.
- Chapter 7 provides a summary of model limitations.
- Chapter 8 provides the conclusions of this study.
- Chapter 9 provides a summary of recommendations and future works.

2.0 MINING

2.1 Historic mining

Mining at the Fosterville Gold Mine has historically been conducted using a series of open-cut pits in the 1990's, which later shifted to underground mining in 2004. The points below provide a brief summary of the Fosterville Mine history.

- A feasibility study investigating a combined open pit and underground mining operation feeding 0.8 Mtpa (mega tonnes per annum) of sulphide ore to a processing plant was completed in 2003.
- Work on the processing plant and open-pit mining commenced in early 2004.
- Commercial sulphide-hosted gold production commenced in April 2005, and up to the end of June 2019 had produced 2,000,000 ounces of gold.
- Underground mining development commenced in March 2006 with first production recorded in September 2006.

2.2 Current mining operation

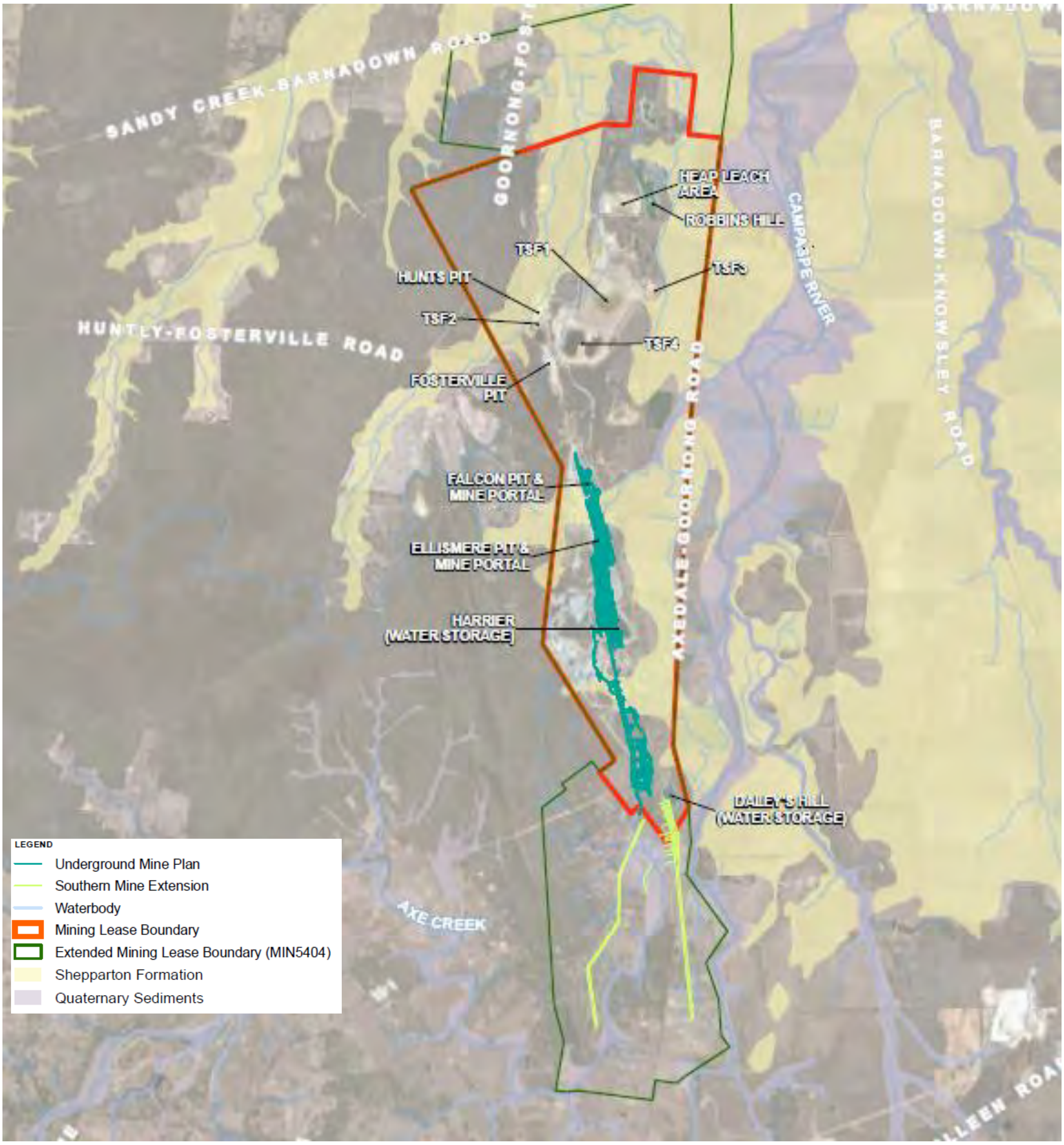
Underground mining is currently focussed in two main areas, the Phoenix orebody and the Harrier ore body. The maximum depth of current mining operations is approximately 1,2000 m bgl. Several of the open cut pits have been converted to Residue Storage Facilities (RSF) (Hunts, Fosterville and O'Dwyers South), while others are used for mine water storage (Harrier, Johns, Daley's Hill and Robbins Hill) (locations shown on Figure 1).

The latest groundwater assessment for current mining was undertaken in 2018 as described in Golder (2018).

2.3 Proposed southern mine extension

The proposed southern mine extension will occur over a period of about 5 years and at depths ranging from 600 m bgl to 1,600 m bgl (deepening to the south). The southern extension will pass beneath Axe Creek at depths of about 970 m bgl. The Axe Creek is a tributary of the Campaspe River (Figure 2).

Figure 2: Current mine areas and proposed mine extensions



3.0 REGIONAL SETTING

The topography and surface drainage feature of the site is presented in Figure 3. The Fosterville Gold Mine lies at the foot of a north-north-west trending ridge with maximum elevation about 265 mAHD at Mt Sugarloaf. There is a low ridge (170 mAHD) across the site that runs NNW-SSE along the Fosterville fault (Coffey 1988b). The site is flat to very gently undulating, with an overall slope towards the east-northeast.

The main surface drainage in the Fosterville region is the Campaspe River, approximately 1.5 to 2.0 km east of the site (Figure 3). The Campaspe River flows northwards from 144 mAHD at the southern lease boundary to 138 mAHD at the Barnadown weir and flows into the Murray River further downstream. The land near the river is flat forming the river's flood plain (Coffey 1988c). The west of the mine site extends to the foot of the Sugarloaf Range (265 mAHD).

The northern part of the mine site is drained northwards by a small ephemeral watercourse, the Gunyah Creek, which traverses west of the Fosterville Pit and the northern end of the Hunts Pit towards the Bendigo Creek. The southern part of the site is drained by several intermittent watercourses eastwards across the site toward to the flooding plain of the Campaspe River. Of relevance to the southern extension is Axe Creek, an ephemeral creek, which flows around the Sugarloaf Ranges and merges with the Campaspe River (Figure 3).

The climate at Fosterville mine is 'Oceanic', which is typically dry and mild, with cold winters and high temperatures throughout summer.

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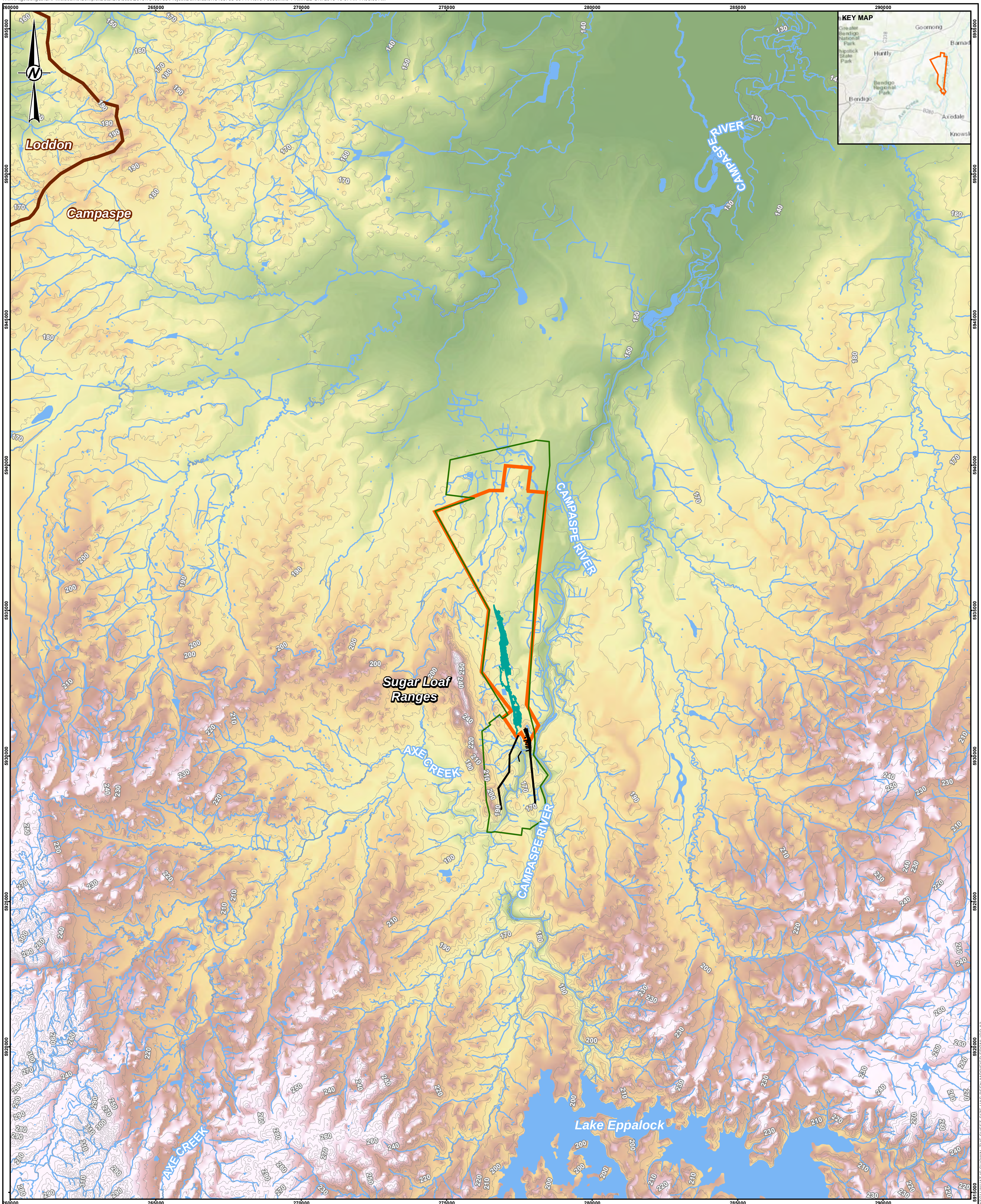

LEGEND

- Underground Mine Plan
- Southern Mine Extension
- Waterbody
- Surface Elevation Contour (mAHD)
- Mining Lease Boundary
- Extended Mining Lease Boundary (MIN5404)
- Groundwater Catchment Boundary

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NOTE(S)

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REFERENCE(S)

1. IMAGERY AND LOCATION MAP SOURCED FROM ESRI ONLINE BASEMAPS.
2. REGIONAL INFORMATION SOURCED FROM WWW.DATA.VIC.GOV.AU.

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PROJECT

FOSTERVILLE GOLD MINE EXTENSION GROUNDWATER ASSESSMENT

TITLE

REGIONAL SETTING

PROJECT NO.	CONTROL	REV.	FIGURE
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4.0 CONCEPTUAL GROUNDWATER MODEL

4.1 General

Long-term groundwater monitoring from over 40 FGM monitoring bores, together with information collected during various hydrogeological investigations (PCA 1996; URS; 2003; Coffey 2010; Coffey 2013; AGT 2015; and AGT 2017) has resulted in a significant amount of hydrogeological data and information. This information was used to develop a conceptual hydrogeological model of the area, which has been refined over time.

The initial conceptual model for the area is reported in Coffey (2013). This was updated in 2017 (AGT 2017) by extending the study area a substantial distance northward (relative to the area described by Coffey, 2013) to include the groundwater systems north of the mining lease.

Further updates to this conceptual model were undertaken as part of this scope to include the groundwater systems south of the current mining lease (around the southern extension area) as shown in Figure 1 and Figure 2. The conceptual groundwater model for the southern extension area was based on,

- results of a focused drilling investigation undertaken in December 2019 to assess current day groundwater conditions in the south;
- available information obtained from historic monitoring bores drilled by Perseverance Exploration in 2000 throughout much of the southern extension area;
- publicly available data (from the Visualising Victoria Groundwater (VVG) archive); and
- structural geological information supplied by FGM.

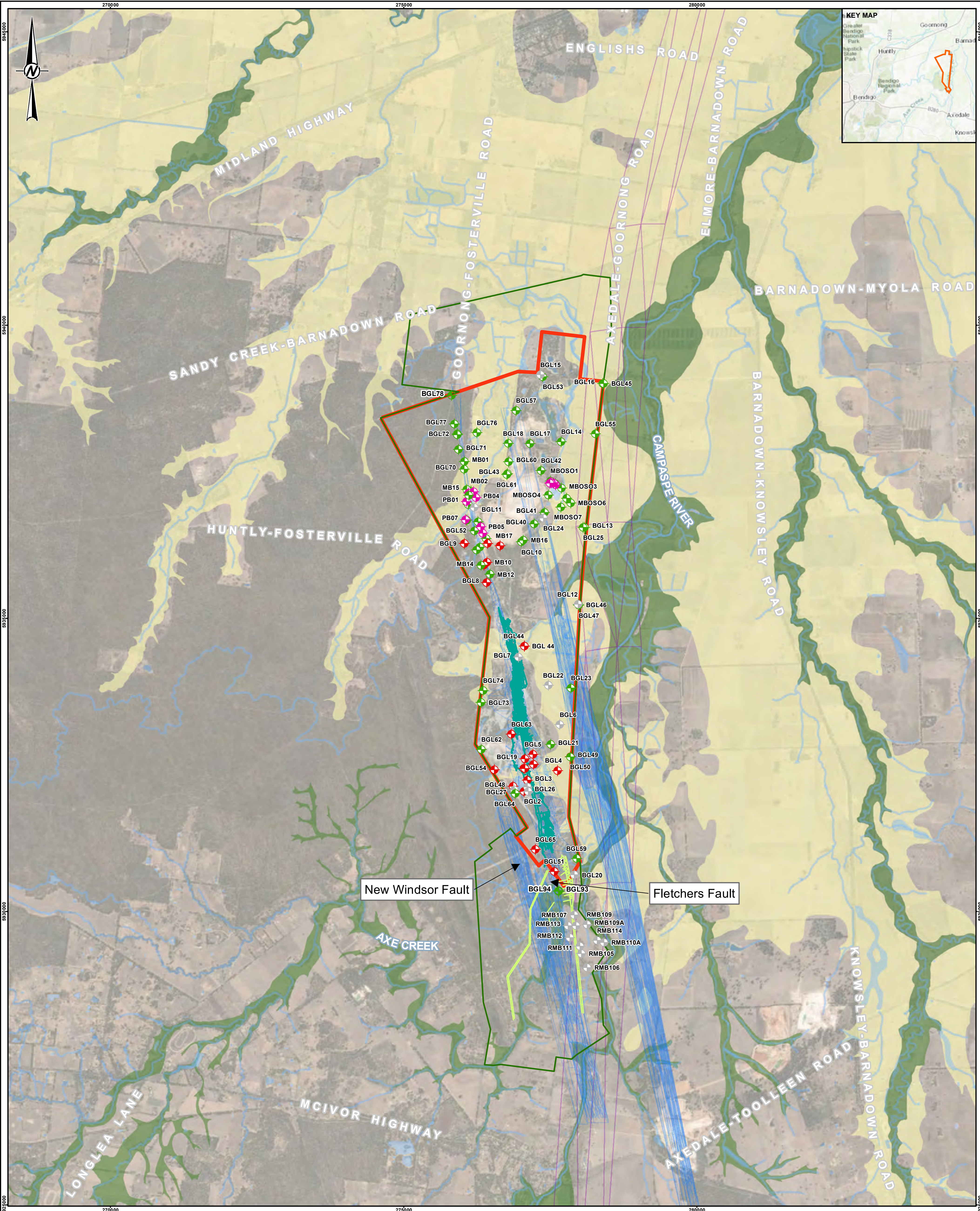
The following presents an overview of the hydrogeological conceptual model based on information provided in the above reports.

4.2 Hydrostratigraphic units

The hydro-stratigraphic units within the Study Area are:

- Alluvial Aquifer Systems, which are best developed around the Campaspe River and about 1 km to the north of the mining lease; and;
- The underlying Fractured Rock Aquifer (FRA).

A surface geological map and cross section showing alluvial and fractured rock aquifer systems is presented on Figure 4 and Figure 5.



LEGEND

- Current Bore
- Decommissioned Bore
- Dry Bore
- In-pit Extraction Bore
- Unknown
- Underground Mine Plan
- Southern Mine Extension
- Waterbody
- Fosterville Fault
- Redesdale Fault
- Mining Lease Boundary
- Extended Mining Lease Boundary (MIN5404)
- Shepparton Formation
- Quaternary Sediments

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GROUNDWATER ASSESSMENT

CONSULTANT

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TITLE

SURFACE GEOLOGICAL MAP

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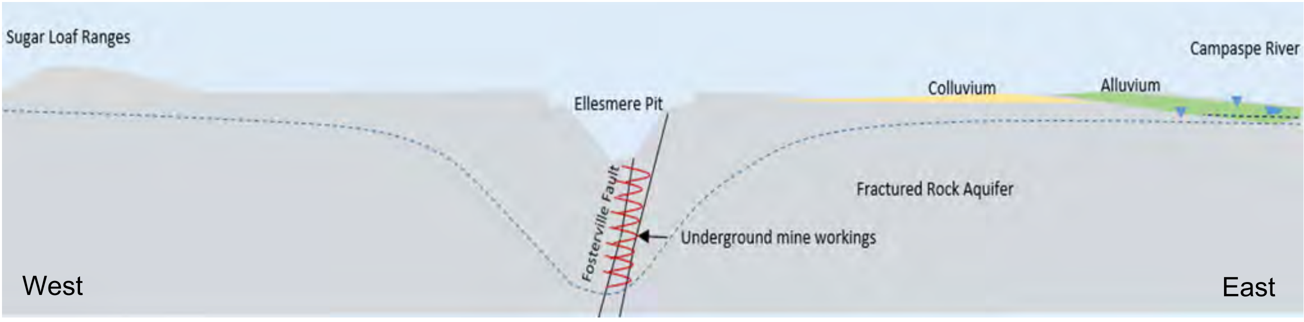
Figure 5: Geological cross section (east to west profile)



4.3 Alluvial aquifers

The alluvial aquifer systems comprise the Tertiary Campaspe Deep Lead and The Shepparton Formation. The extent of these aquifer systems based on surface geological maps are shown on Figure 4.

The Tertiary Campaspe Deep Lead (comprising the Calivil Formation) is a major regional aquifer that runs along the eastern margin of the FGM mining lease (Figure 4). The Campaspe Deep Lead trends north – south and is joined by the east west trending Huntly Deep Lead about 5 km to the north of the mining lease.

Three FGM monitoring bores (BGL16, BGL46 and BGL49) intercepted alluvium along the eastern boundary of the mining lease (Figure 4) and indicated that the saturated thickness ranges from 4 m to 11 m. South of the current mining lease, two historic bores (RMB110A and RMB109) located 95 m and 150 m west of the Campaspe River reported saturated thicknesses of 3 m and 5 m, whilst recently installed monitoring bore (BGL94) located above the proposed southern extension area and historic monitoring bores (RMB107, -108, -113 and -114) showed the alluvium was unsaturated (Perseverance Exploration 2000) (locations shown on Figure 4).

To the north of the mining lease, the Tertiary Campaspe Deep Lead alluvial aquifers are overlain by colluvium and alluvium sediments of the Shepparton Formation. A groundwater study conducted by AGT (2017) showed the Shepparton Formation aquifer is located to the north of the mining lease, where it deepens to more than 25 m bgl and is targeted by several stock and irrigation bores. Whilst the surface geological map on Figure 4 shows the Shepparton Formation to extend inside the mining lease (along Gunyah Creek), drilling investigations conducted in this area have showed that the Shepparton Formation Aquifer is absent in this area (AGT, 2017).

Surface geological mapping and geological records from 42 bores obtained from the VVG portal, FGM monitoring bores and Perseverance Exploration, 2000 (in the case of the southern extension area) were used to delineate (via both kriging and manual interpretation) the extent and depth of the alluvium. Contours of alluvium thickness and depth were developed for the numerical model and this is discussed further under section 5.2.

Groundwater salinity

Available groundwater salinity data from site monitoring bores (BGL16, -46, -49) along the eastern boundary of the current mining lease, and historic bores (RMB110A and RMB109A) in the southern extension area indicated the groundwater salinity ranges from 250 mg/L to 600 mg/L. BGL94, which was recently installed in alluvium near the confluence of Axe Creek and Campaspe River, is dry.

Results of groundwater sampling of private bores undertaken as part of a bore census conducted by FGM in 2015 (reported in AGT, 2015) revealed groundwater salinities of the Shepparton Formation to the north of the mining lease were typically less than 1,200 mg/L.

Groundwater levels and flow direction

Based on the available groundwater level data (obtained from FGM monitoring bores and the VVG database), AGT (2016) showed that the regional groundwater flow in the alluvial aquifers is directed towards the north-northeast, potentially discharging to the Campaspe River to the north east of the mining lease.

Paired monitoring bores positioned on the eastern margin of the mining lease (which monitor the alluvium and the shallow FRA) showed groundwater levels in the alluvium aquifers are similar or slightly higher than pre-mining groundwater levels of the underlying FRA.

There is no evidence in site monitoring data to indicate that mine dewatering from the FRA has impacted the alluvium aquifers (Shepparton Formation or Deep Lead) (AGT, 2017). For example, paired monitoring bores BGL49 (Alluvium) and BGL50 (FRA) located 750 m to the east of the mine show no discernible response to mine dewatering from the FRA. Furthermore, the extent of depressurisation in the FRA (discussed in the following section) has not spread beneath the alluvial sediments, as the extent of drawdown is constrained by faulting.

4.4 Fractured rock aquifer

Geological structures and permeability

The geology of the FRA comprises a folded and faulted sequence of Lower Ordovician marine sedimentary rock including sandstone, greywacke siltstones and shales. With respect to the groundwater flow conditions, the FRA system can broadly be subdivided into:

- Upper weathered zone about 30 m thick of low hydraulic conductivity and localised groundwater. This zone is inferred to be thicker in topographical lows and thinner on the topographical highs. Due to a high degree of weathering, the fractures associated with the main structural features tend to be closed and infilled with product of weathering resulting in a low permeability.
- Main fresh rock zone with hydraulic conductivity enhanced by regional faults and associated fractures. The major structural features in the area are the NNW-SSE trending faults, which are shown on Figure 4 and Figure 5. The Fosterville Fault and O'Dwyers Fault (both steep westerly dipping) within the current mining lease are of considerable hydrogeological importance. Previous investigations (Coffey 2016; URS 2003; PCA 1996; and AGT 2017) identified the Fosterville Fault and O'Dwyers Faults as zones of higher permeability (hydraulic conductivities (K) of 0.3 m/d to 0.4 m/d). Outside of these fault zone, the bedrock has low permeability (K = 0.01 m/d) and bore yields are generally low. The other NNW-SSE faults which extend in the southern extension area include Mills, Fletchers and New Windsor Faults (Figure 4), however the hydraulic properties these faults have not been assessed by hydrogeological investigations.

Table 1: Summary of aquifer properties

Investigation bore	Zone	Transmissivity (m^2/d)	Hydraulic Conductivity K (m/d)	Storage (-)
BGL70 to 72 and BGL75	Fosterville Fault Zone	15 – 30	0.3 – 0.6	1×10^{-6}
PB-02, -08, -06	Fosterville Fault Zone	21	0.43	5×10^{-6}
MB-03 to 09	Outside of Fosterville Fault	<1	0.01	
SP108 to 180	Fosterville Fault Zone	10 – 14		1×10^{-4} – 1×10^{-5}
GT-01 to -04	Fosterville Fault Zone	28 – 56		1×10^{-4} – 1×10^{-5}
	O'Dwyers Fault Zone		0.1	5×10^{-4}

An important consideration with the above permeabilities is that the investigation drilling and aquifer testing have occurred within the upper 200 m of the FRA, and therefore, properties of the FRA have not been evaluated at greater depths. It is expected that hydraulic conductivity of the deeper regional groundwater system of the FRA will reduce with depth. Crustal permeability is expected to decrease at substantial depth (greater than 1 km), while relatively shallower rock permeability is likely to be both higher in magnitude and more variable (Manning and Ingebritsen 1999).

Groundwater levels

Pre-mining groundwater contours produced from groundwater levels obtained from BGL series monitoring bores (1991) and RMB series monitoring bores (2000) suggest that groundwater flowed from the Sugarloaf Ranges to the E-NE and SE direction (Figure 6). The contraction of groundwater level contours in the downstream part of the Campaspe River in the north east suggest the river may be gaining groundwater,

This groundwater flow pattern has since been altered by mine dewatering. The long-term groundwater levels in several monitoring bores that target the FRA show the drawdown effects of mine dewatering, and this has also allowed the aquifer anisotropy to be assessed. When the groundwater drawdowns are presented spatially, the aquifer is strongly anisotropic in a north-south direction, along the Fosterville Fault (Figure 7). This structure acts as a regional drain to the regional FRA groundwater system under hydraulic gradients established by mine dewatering, and thus represents the dominate mode for regional groundwater flow to the mine.

The drawdown cone (shown on Figure 7) was first established when the Falcon and Ellesmere Pits were dewatered between 2004 and 2007. The estimated dewatering rate was in the order of 1.25 ML/d during this period. The drawdown cone has since been maintained by dewatering of the underground mine (from the Falcon and Phoenix vents) at average rates of 2.2 ML/d.

The groundwater contours also show that the effects of mine dewatering are localised, with steep gradients around the mining perimeter. This indicates low hydraulic connectivity with strata outside the fault (i.e. minimal drawdown across the strike).

To the south of the mining lease, the current groundwater elevation in BGL93 (installed in December 2019) is 117 mAHD, which is some 29 m lower than pre-underground mining groundwater elevation of 146 m AHD inferred from RMB series bores. This indicates the cone of drawdown from current mining operations has emanated towards the southern extension area (Figure 7).

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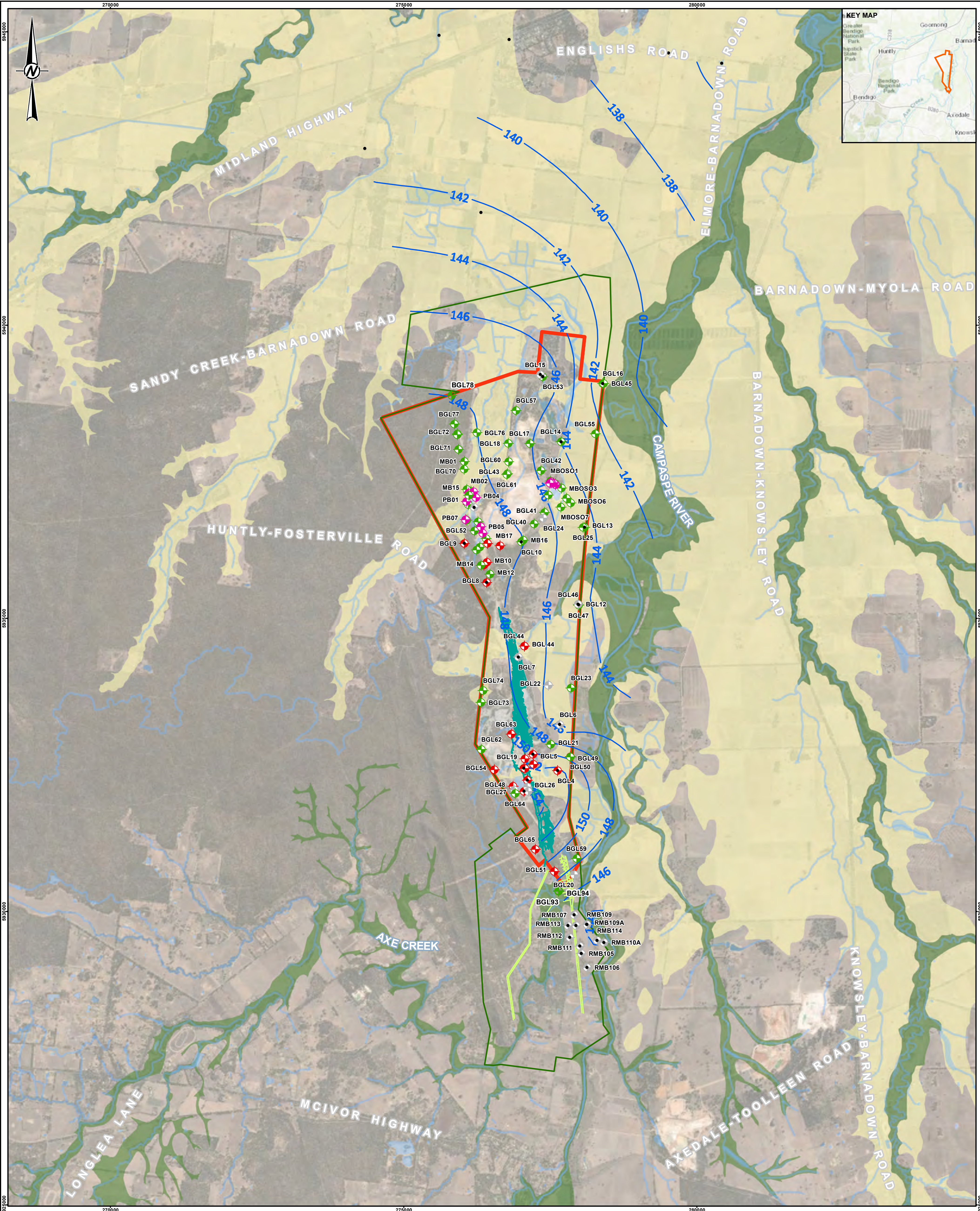

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LEGEND

- Current Bore
- Decommissioned Bore
- Dry Bore
- In-pit Extraction Bore
- Unknown
- Steady State Groundwater Levels
- Pre-mining Observed Groundwater Level Contours (AHD)
- Underground Mine Plan
- Southern Mine Extension
- Waterbody
- Mining Lease Boundary
- Extended Mining Lease Boundary (MIN5404)
- Shepparton Formation
- Quaternary Sediments

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NOTE(S)

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PREPARED	CJS
REVIEWED	JVDA
APPROVED	JVDA

PROJECT
FOSTERVILLE GOLD MINE EXTENSION GROUNDWATER ASSESSMENT

TITLE
PRE-MINING GROUNDWATER ELEVATIONS

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Groundwater salinity

FGM groundwater monitoring bores within the current mining lease indicate that the FRA is typically saline (3,000 mg/L to 12,000 mg/L TDS), however there is evidence of fresher groundwater (< 2000 mg/L) within the upper most water bearing section of the FRA beneath alluvial sediments and near the near the Campaspe River (BGL47, -50, -46 and -23) along the eastern margin of the mining lease).

Groundwater salinity graphs of monitoring bores surrounding the current mining operations are presented on Figure 8 and aside from BGL74, which is located on the western side of the underground mine, groundwater salinity has been stable during current mining operations. The increasing salinity trend in BGL74 is unknown but due to its close proximity to the underground mine it is possible that lowering groundwater levels in the FRA next to the mine may be drawing in deeper more saline groundwater.

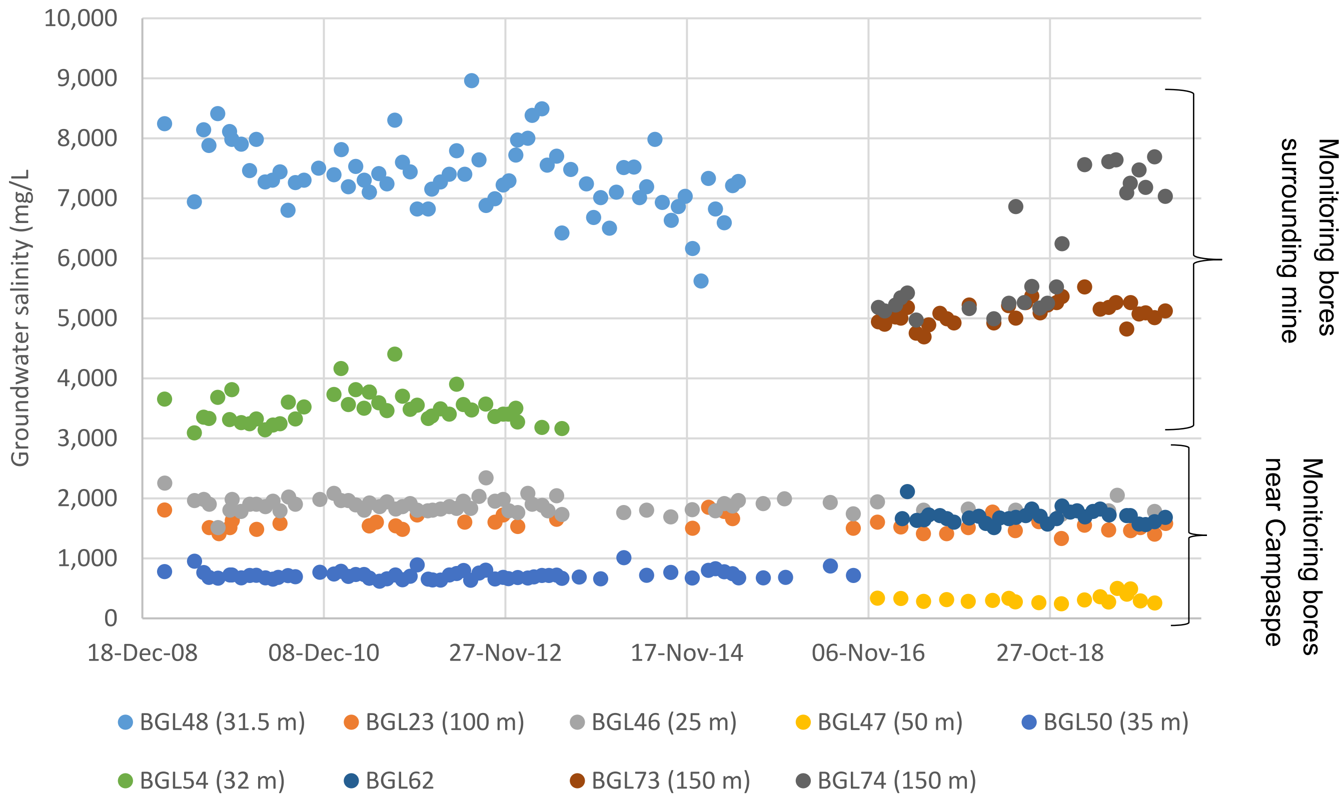


Figure 8: Groundwater salinity near current underground mining operations

The RMB series monitoring bores drilled by Perseverance Exploration to the south of the mining lease target the uppermost water bearing zone of the FRA (at depths of 30 m to 40 m bgl) and showed that groundwater salinity of the FRA is more variable, ranging from 1,380 mg/L to 7,380 mg/L. The groundwater salinity of BGL93 (recently installed to a depth of 100 m bgl) was 2,390 mg/L, which falls within the above range.

Lower groundwater salinities were observed in bores (RMB106 and RMB109) located closer to the Campaspe River and reflect zones that are closer to recharge (i.e. leakage form the overlying alluvium or the Campaspe River).

Recharge

Recharge to the FRA is thought to occur by direct infiltration of rainfall in areas where the bedrock is exposed or as leakage from the overlying alluvium. Rainfall recharge rates based on the chloride mass balance method was typically in the range of 1 mm/y to 5 mm/y (AGT 2017). Lower chloride concentrations measured at one private bore on the Sugar Loaf road suggest slightly higher recharge rates of 13 mm/y may prevail in the Sugar Loaf Range. This is also consistent with the conceptual understanding of Sugarloaf Range as a highly faulted anticline, which is more receptive to infiltration recharge.

Paired monitoring bores which monitor the upper-most water bearing horizon of the FRA (BGL45) and alluvium (BGL16) at north-east boundary of the mining lease, revealed slightly higher heads in the alluvium, indicative of potential downward leakage to the FRA, however this rate has not been quantified, but expected to be low owing to lower permeability associated with weathering in the upper 30 m of the FRA.

Currently seepage from approved mine water storage pits Harrier, Johns, Daley’s Hill and Robins Hill – Figure 1) represent localised sources of recharge of groundwater in the FRA. Mine water storage facilities, Daley’s Hill, John’s and Harrier Pits, are located above underground mine workings and groundwater leakage from these pits flows towards the underground mine area (migration of pit water is controlled by the cone of depression). The influence these pits have on groundwater post mining are discussed under section 7.5.

Groundwater discharge

Regional groundwater discharge is assumed to occur into the aquifer system toward the Campaspe River to the north east of the mining lease (Figure 6).

All seepage to the open cut pits and the underground mine was assumed to occur from the FRA. Mine dewatering rates are in the order of 2.5 ML/d, which is discharged to water storage facilities. From there the water evaporates or is reused in the mining operations.

Mine water quality

The mine water, which is pumped from the underground mine, comprises of groundwater that seeps into the underground mine workings from the FRA. Water quality parameters of mine water based on the long-term average concentration measured in mine water storage facilities are summarised in Table 2. These are compared to the native groundwater surrounding the mine and ANZECC (2000) guideline values for protection of aquatic ecosystems (95% protection level) as this is typically also protective of most other beneficial uses of groundwater.

The average TDS of mine water is ~6,500 mg/L, which is consistent with surrounding groundwater in the FRA near the mine (3,000 mg/L to 9,200 mg/L). and consistent with the classified groundwater segment (Segment C).

The mine water (emerging from backfilled voids and underground workings) contains high concentrations of antimony (Sb) (average ~ 3.3 mg/L to 4.4 mg/L) and slightly elevated arsenic (As), which are above the ANZECC (2000) guideline for aquatic ecosystems (0.009 mg/L Sb and 0.013 mg/L As). These are also naturally present in native groundwater at concentrations which exceed the ANZECC (2000) guideline for aquatic ecosystems (Table 2). Other metal concentrations in mine water (dissolved copper, lead, manganese and cadmium) are predominantly low in concentration, and are also similar to concentrations in native groundwater (Table 2).

This risk of mine water on the surrounding groundwater system is considered under section 7.5.2.

Table 2: Mine water quality in approved mine water storage facilities

Analyte	ANZECC guideline criteria freshwater ecosystems	Native groundwater quality	Harrier Pit	John's Pit
pH			8.33	8.52
Antimony-Dissolved (mg/L)	*0.009*	0.002 - 0.005 (0.07)[1]	4.44	3.31
Arsenic-Dissolved (mg/L)	*0.013*	0.004 - 0.08	0.24	0.20
Arsenic-Total (mg/L)			0.27	0.29
Cadmium-Dissolved (mg/L)	*0.0002*	0.0001 - 0.08	0.0006	0.0027
Calcium-Dissolved (mg/L)			160.93	82.23
Chloride, Cl (mg/L)			3025	2531
Copper-Dissolved (mg/L)	*0.0014*	0.002 - 0.038	0.0034	0.0136
Electrical Conductivity @ 25C (uS/cm)			10403	
Iron-Dissolved (mg/L)			0.16	0.38
Lead-Dissolved (mg/L)	*0.003*	<0.001 - 0.02	0.0010	0.0334
Magnesium (mg/L)			267.50	283.00
Manganese-Dissolved (mg/L)		0.01 - 1.8	0.0111	0.0633
Nitrate as N (mg/L)	*1.7*		14.28	10.09
pH (pH Units)			8.23	8.46
Sulfate as SO4 - Turbidimetric-Dissolved (mg/L)		45[2] - 900	958.20	552.86
Sulphate, SO4 (mg/L)		45[2] - 900	1196.81	1300.39
Zinc-Dissolved (mg/L)	*0.008*	0.015 – 0.1	0.0145	0.0538
Total Nitrogen (as N) (mg/L)			16.03	14.41
Total dissolved solids (mg/L)		727[2] - 9,200	6518	6480

[1] Maximum concentration measured in one monitoring bore
[2] Concentrations of monitoring bores near the Campaspe River

Groundwater and surface water interactions

Flows in the Campaspe River are regulated by release from Lake Eppalock (Figure 3), which has effectively turned the Campaspe River into a perennial system, whereas before there were periods of no flow (DSE 2012). Leakage from the Campaspe River is therefore a potential source of groundwater recharge for the Deep Lead Aquifer, mainly at the upstream part of the river.

Further downstream, within the study area, groundwater elevations in both the FRA and alluvium are either similar or slightly higher than Campaspe River levels, which suggest some potential for groundwater leakage to the Campaspe River. Pre mining groundwater contours shown on Figure 6, suggest this may be occurring to the north of the mining lease, although any baseflow contributions from the FRA are likely to be small owing to low permeability of the FRA.

In the southern extension area, historic groundwater levels (obtained from RMB series bores in 2000) were similar in elevation to the Campaspe River (144 mAHD), which suggest the river was neither gaining or losing but indicates the potential for groundwater and surface water interaction (Figure 9). The Axe Creek is a tributary to the Campaspe River. Historic groundwater levels (RMB107, RMB113 and RMB112) measured adjacent to Axe Creek were similar in elevation to Axe Creek, which also suggest that Axe Creek was was neither gaining or losing, but indicates the potential for some baseflow contribution.

Under current day conditions however, the alluvium associated with Axe Creek is dry (BGL94) and the groundwater level in the underlying FRA (BGL93) is too deep (42 m bgl) to be interacting with overlying watercourses (Figure 9).

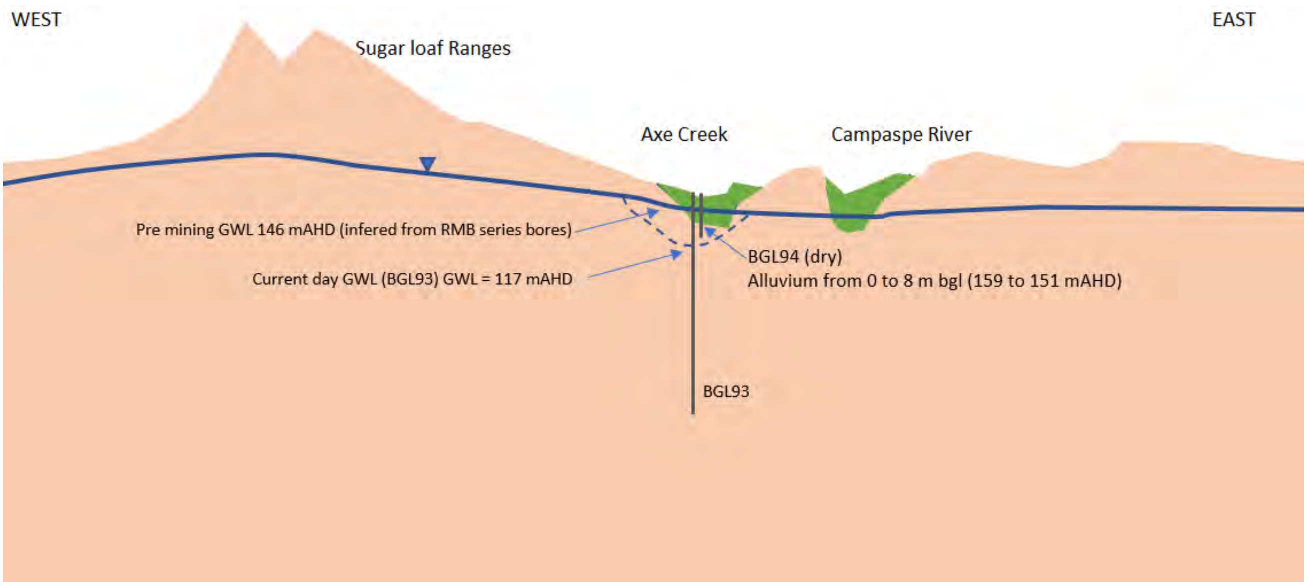


Figure 9: Cross section showing Pre underground mining (2000) and current day groundwater levels (2020) across the southern extension area

Gauging station (No. 406201), which monitors flows in the Campaspe River downstream of the FGM at Barnadown shows daily flows are typically less than 1000 ML/d (long term average of 480 ML/d) and the gauging station located upstream of Axedale (No 406214) shows daily flows are typically less than 100 ML/d (long term average of 30 ML/d) (Figure 10). As outlined above these flows are dominated by surface water flows rather than groundwater discharge.

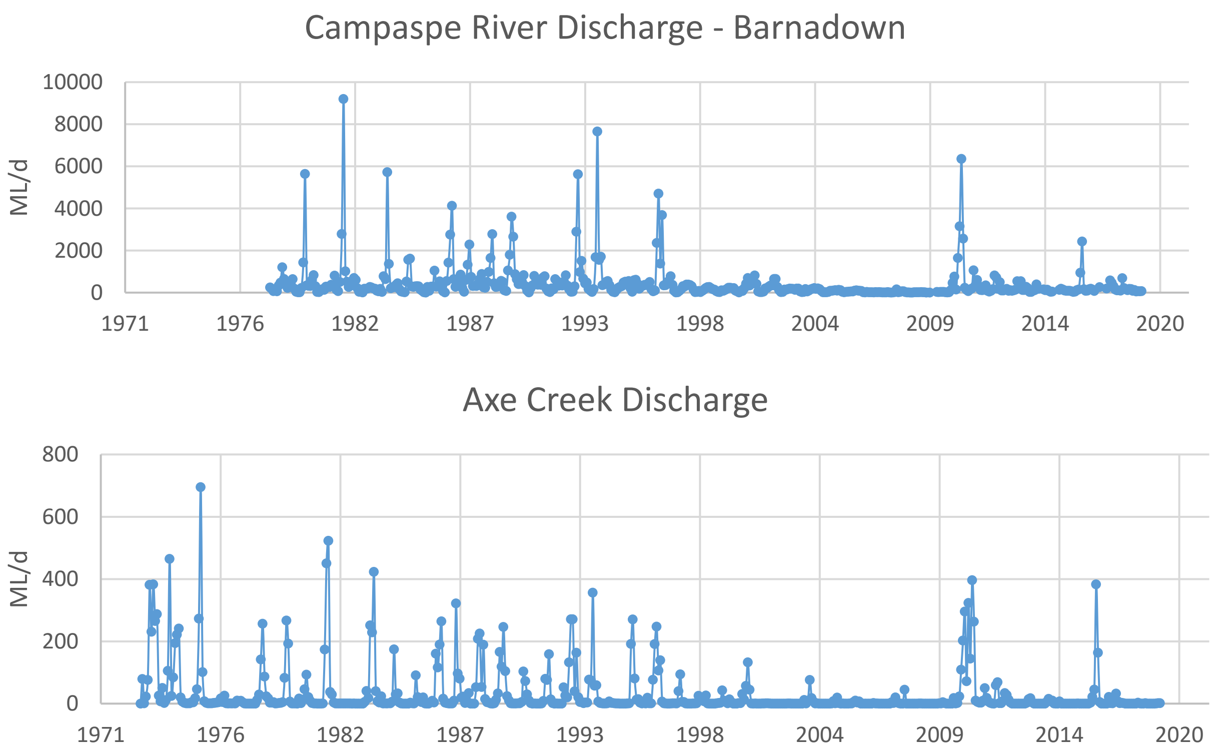


Figure 10: Campaspe River Discharge - ML/d

4.5 Groundwater dependent ecosystems

Groundwater dependent ecosystems (GDE's) are ecosystems that utilise groundwater to meet some or all of their water needs. The Department of Sustainability and Environment (DSE, 2012) reported that satellite imagery has been used along with groundwater levels data to determine the potential locations of GDE's in the Lower Campaspe Valley (SKM, 2011). Investigations suggest that GDE's are likely to exist along watercourses, such as River Red Gums along the Campaspe River, accessing shallow groundwater.

As groundwater salinities in the FRA are higher than river water and connected alluvial aquifers that support these GDE's, it is unlikely to be a significant inflow from the FRA into the alluvial aquifers. Regulation of the Campaspe River can influence shallow groundwater levels and leakage is controlled by underlying clays and upper weathered zone in the FRA. This suggests there is little risk to riparian vegetation from groundwater pumping (DSE, 2012). The report also suggested non-regulated streams may also have some GDE's, but sensitivity analysis indicates lower sensitivity to groundwater system changes than along the Campaspe River (DPI, 2011).

The report also states that lowering groundwater levels could induce further leakage from the river and may reduce water availability for GDE's. However, the report also indicates that field investigations are required to confirm the presence of GDE's and ongoing monitoring should be established for high value GDE's to determine their water requirements.

Furthermore, there are paired groundwater monitoring bores along the eastern margin of the mining lease to detect changes in groundwater levels in both the FRA and shallow alluvium near the Campaspe River (locations shown on Figure 4). Groundwater level monitoring to-date has not detected any impacts to the shallow alluvium along the western terrace of the Campaspe River.

Stygofauna

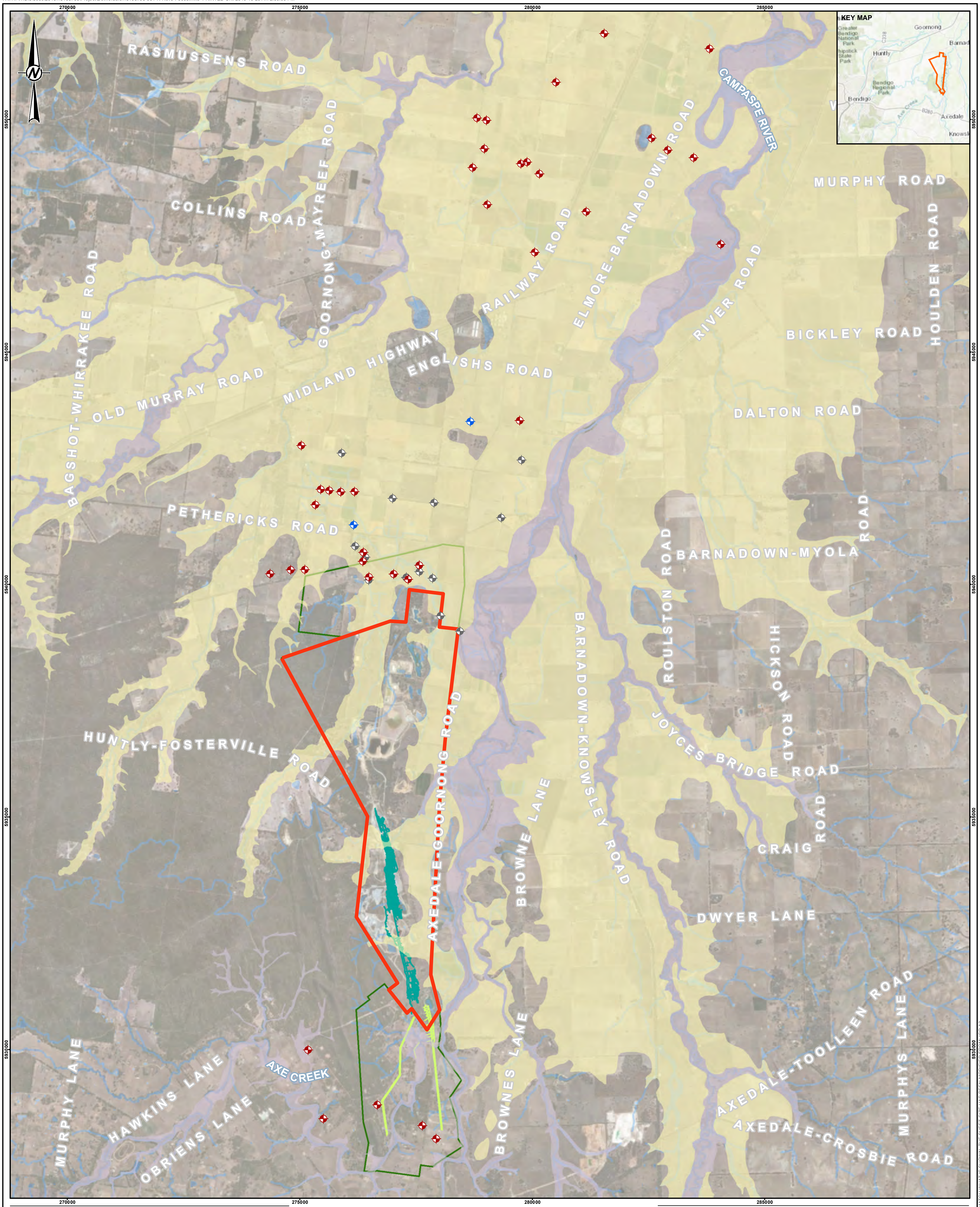
Stygofauna is a term that encompasses a variety of different types of organisms that are found in groundwater, and includes animals that are obligate, groundwater-adapted organisms (stygobionts). The presence of stygofauna has not been investigated in Victoria (no publicly available stygofauna survey reports are available) and therefore their presence is not well understood. FGM have recently undertaken a desktop study to assess their potential presence in MIN5404 and the surrounds (Stygoecologica, 2019). The results show the natural conditions in the FRA are considered unsuitable to the existence and maintenance of stygofauna whilst further field sampling of the alluvial aquifer has been recommended (Stygoecologica, 2019).

4.6 Existing groundwater users

There are no private bores which target the FRA near the current underground mine areas owing to the high salinity of groundwater in the FRA. Therefore, in this area the primary source of water for agriculture use is from the Campaspe River. The Axe Creek is ephemeral and has no allocations.

The majority of private bores target the Shepparton Formation to the north of the mining lease where the aquifer deepens. The location and status of private bores was confirmed during a bore census undertaken in 2015 (see AGT, 2017). The results of this bore census are shown on Figure 11, which shows that the nearest groundwater users are at least 250 m to the north of the current mining lease boundary (and greater than 5 km north of the current underground mine area).

Five operational private bores have been documented by FGM to exist within or in the vicinity of the southern extension area. Three are located within the proposed southern extension, and two are outside, but near the mining lease boundary (Figure 11). These bores were sampled by FGM between 2018 and 2019 and laboratory results revealed groundwater salinities in the range of 1,090 mg/L to 5,900 mg/L. These bores are assumed to target the FRA as they are positioned outside the extent of mapped alluvium (Figure 11). The depth to water level in these bores has not been measured due to access limitations and groundwater extraction pump installation depths are unknown.



LEGEND

- Unknown
- Equipped
- Abandoned
- Underground Mine Plan
- Southern Mine Extension
- Waterbody
- Fosterville Fault
- Mining Lease Boundary
- Extended Mining Lease Boundary (MIN5404)
- Shepparton Formation
- Quaternary Sediments

0 1,250 2,500

1:75,000 METRES

NOTE(S)

-

REFERENCE(S)

1. IMAGERY AND LOCATION MAP SOURCED FROM ESRI ONLINE BASEMAPS.
2. WELL INFORMATION SOURCED FROM AUSTRALIAN GROUNDWATER TECHNOLOGIES.
3. ROAD AND WATERBODY INFORMATION SOURCED FROM WWW.DATA.VIC.GOV.AU

CLIENT

KIRKLAND LAKE GOLD LTD.

PROJECT

FOSTERVILLE GOLD MINE EXTENSION
GROUNDWATER ASSESSMENT

CONSULTANT

GOLDER

YYYY-MM-DD	2019-10-29
DESIGNED	-
PREPARED	CJS
REVIEWED	JVDA
APPROVED	JVDA

TITLE

THIRD PARTY BORES

PROJECT NO.	CONTROL	REV.	FIGURE
18108798	001-R	0	11

5.0 NUMERICAL GROUNDWATER MODEL

5.1 Overview

A new groundwater model was developed using the FEFLOW modelling code (version 7.2) to include the southern mine extension area. An earlier version of the model reported by AGT (2016) underwent several upgrades and modifications and this resulted in the 2018 model developed by Golder as described in Golder (2018). The 2018 model from Golder was used to predict the groundwater response to underground mine operations (up to year 2026) and post-mine-closure groundwater recovery. The newly developed model has been primarily based on the 2018 model from Golder (Golder 2018).

The key updates to the 2018 model, which were performed as part of this scope involved the following:

- Reconstruction of the model domain to extend it southward and to a greater overall depth, in order to accommodate the planned southern mine extension. This also involved reduction of the northward extent of the domain to maintain a manageable number of model domain nodes and achieve practical model run times.
- Rebuilding the model mesh, which includes topography and incorporation of key hydrogeological features such as the faults (including Fosterville Fault, O'Dwyer's Fault, Fletcher's Fault and New Windsor Rush Fault), the Campaspe River and Axe Creek, and the alluvial aquifer system. Vertical discretisation of the model (i.e. model layer structure) was revised so that mine development could be represented adequately.
- Refinement of model mesh in new mining areas to ensure the dimensions of the planned new mine workings could be reasonably represented and to promote numerical stability during dewatering simulation.
- Reassignment of model boundary conditions. This included conversion of the southern reach of the Campaspe River – which comprised a lateral model boundary in the previous versions of the model – to an internal boundary condition, as the planned southern mine extension necessitated expansion of the model domain further south than the Campaspe River). New regional groundwater inflow boundaries were required to be added, representing northward groundwater flow driven by Lake Eppalock and from higher ground to the west (towards the upstream reaches of Axe Creek and its tributaries).
- Re-parametrisation (assignment of aquifer properties and recharge) to model elements representing different hydrogeological units (i.e. faulted and non-faulted areas of the fractured rock aquifer and overlying alluvium).
- Model calibrations. This involved adjusting model parameters (within tested bounds) until there was a close match between historic observations and model predictions. This involve a
  - Steady state calibration - to ensure pre-mining groundwater levels are represented. The same groundwater records were used (BGL series bores), with additional historic groundwater level records obtained for the southern extension area (RMB).
  - Transient calibration - involving historical mine dewatering and pit lake dynamics and comparing the modelled groundwater level response to observed groundwater level response.

5.2 Model set up

5.2.1 Mesh and layering

The model domain covers an area of approximately 91 km^2. The model mesh is comprised of a total of 1,208,208 elements (i.e., 50,342 elements per layer, over 24 layers). The model mesh and layer structure is displayed in Figure 12 and Figure 13, respectively.

Model layer 1 represents the alluvial aquifers which includes the Tertiary Campaspe Deep Lead formation along the terraces of the Campaspe River and overlying Shepparton Formation. Layers 2 to 24 represent the FRA. The large number of model layers within the FRA were required to represent features spanning a vast range of depths, including open cut mine pits and underground mine workings, as well as vertical changes in aquifer hydraulic properties, for example the reduction of hydraulic conductivity with depth due to high pressures causing fracture aperture reduction (K_x and K_y were reduced by 50% below -500 mAHD to represent this).

The elevation of the top of layer 1 is defined by high resolution surface topography data provided by FGM. This is displayed in Figure 14. Surface geological mapping and geological records from 42 bores obtained from the VVG portal, FGM monitoring bores and the Perserverence Exploration (2000) (for the southern extension area) were used to delineate the extent and depth of the alluvium via both kriging and manual interpretation. This defines the thickness of model layer 1, which is displayed in Figure 15. In areas where alluvium is absent, a default minimum layer thickness of 1 m was specified for numerical reasons[1].

The depth of the model has been extended to -1600 mAHD to allow the deepest currently projected underground mine workings at -1420 mAHD to be accomodated.

[1] This is necessary as zero layer thickness is not permitted in the employed structued mesh numerical method. However, this does not influence model results as these areas of layer 1 are assigned the hydraulic properties of the underlying FRA, rather than the alluvium.)

Figure 12: Model domain and mesh.

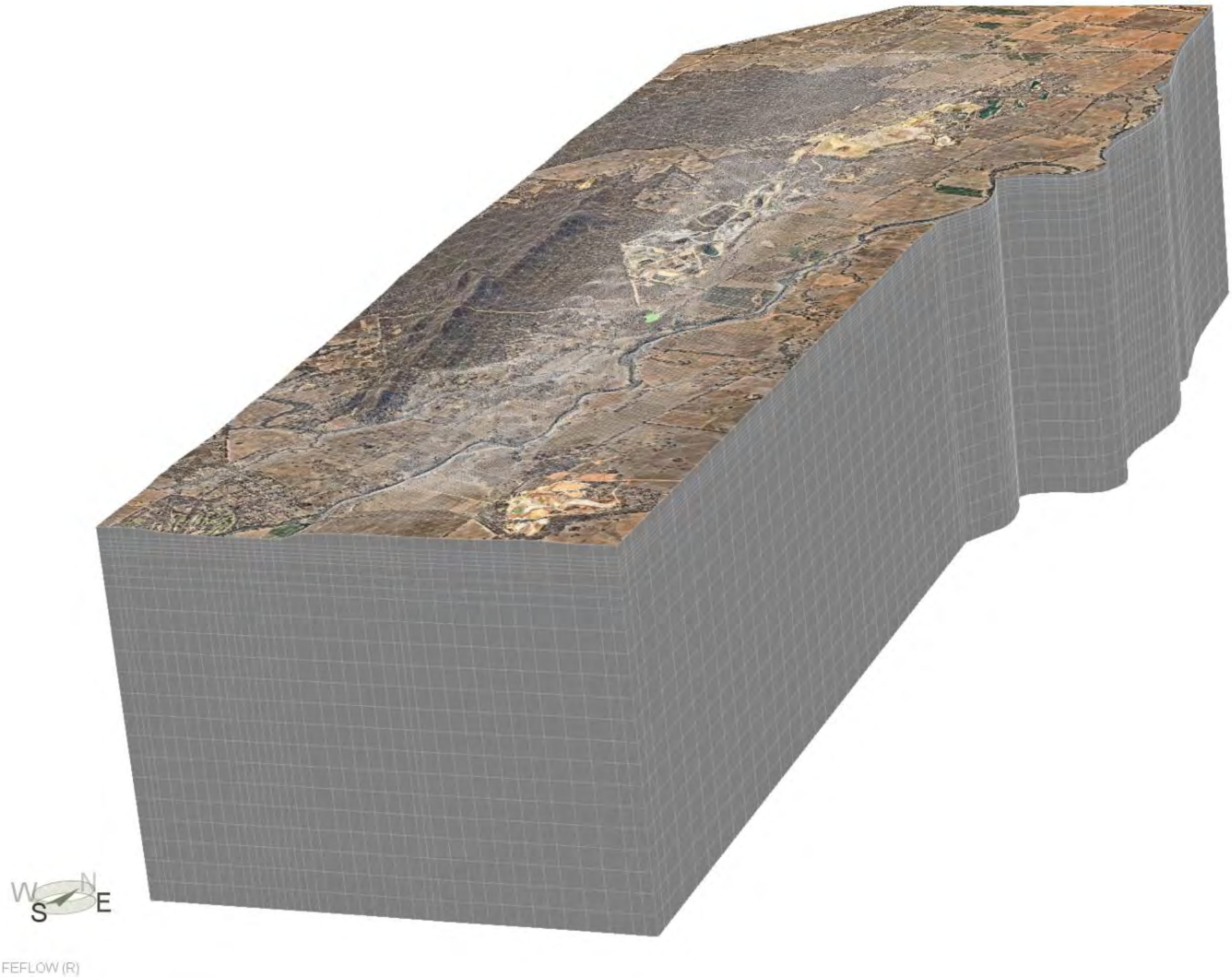


Figure 13: Three-dimensional view of model domain showing layer structure (note that a 2:1 vertical exaggeration is applied for display purposes).

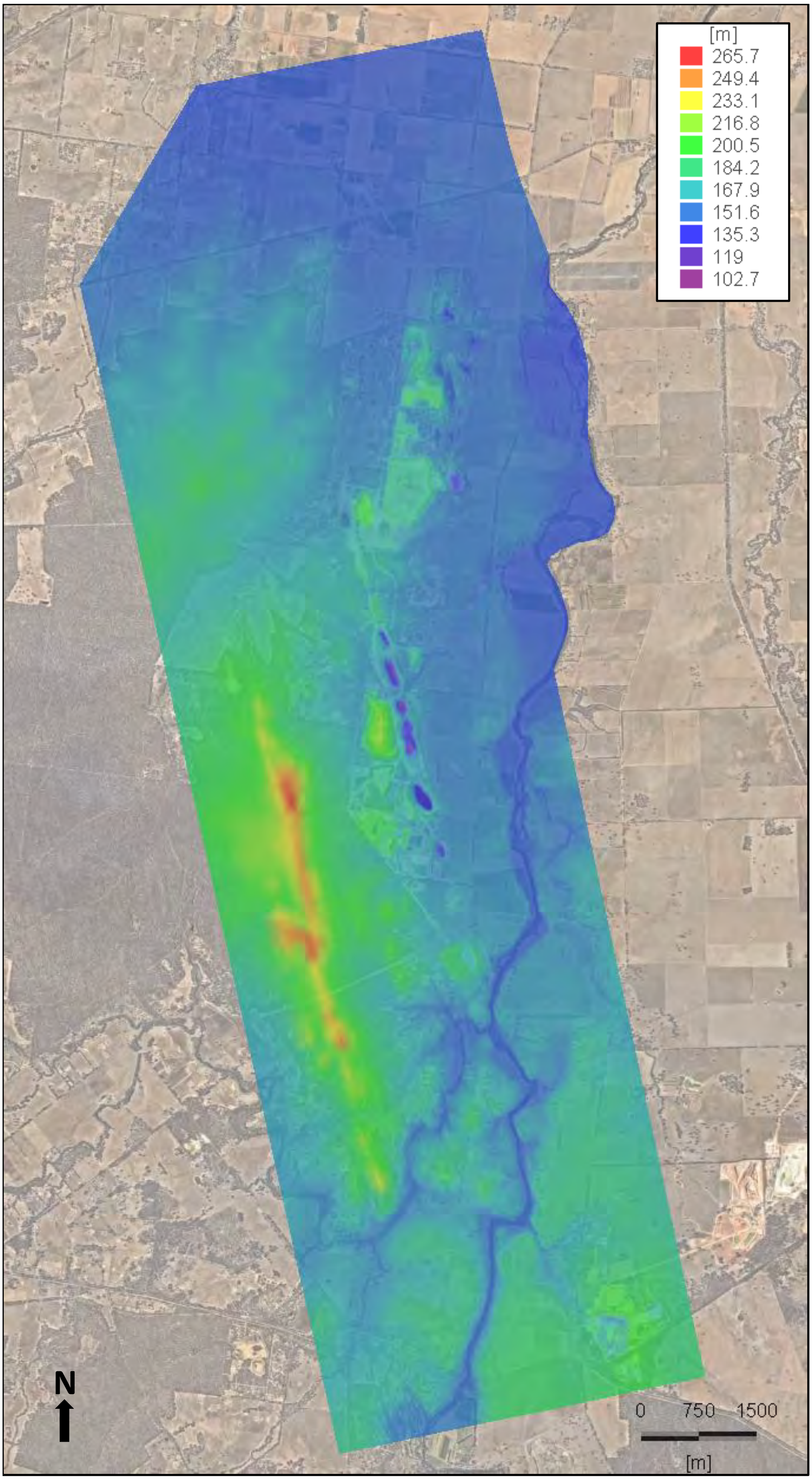


Figure 14: Surface elevation (model layer 1)

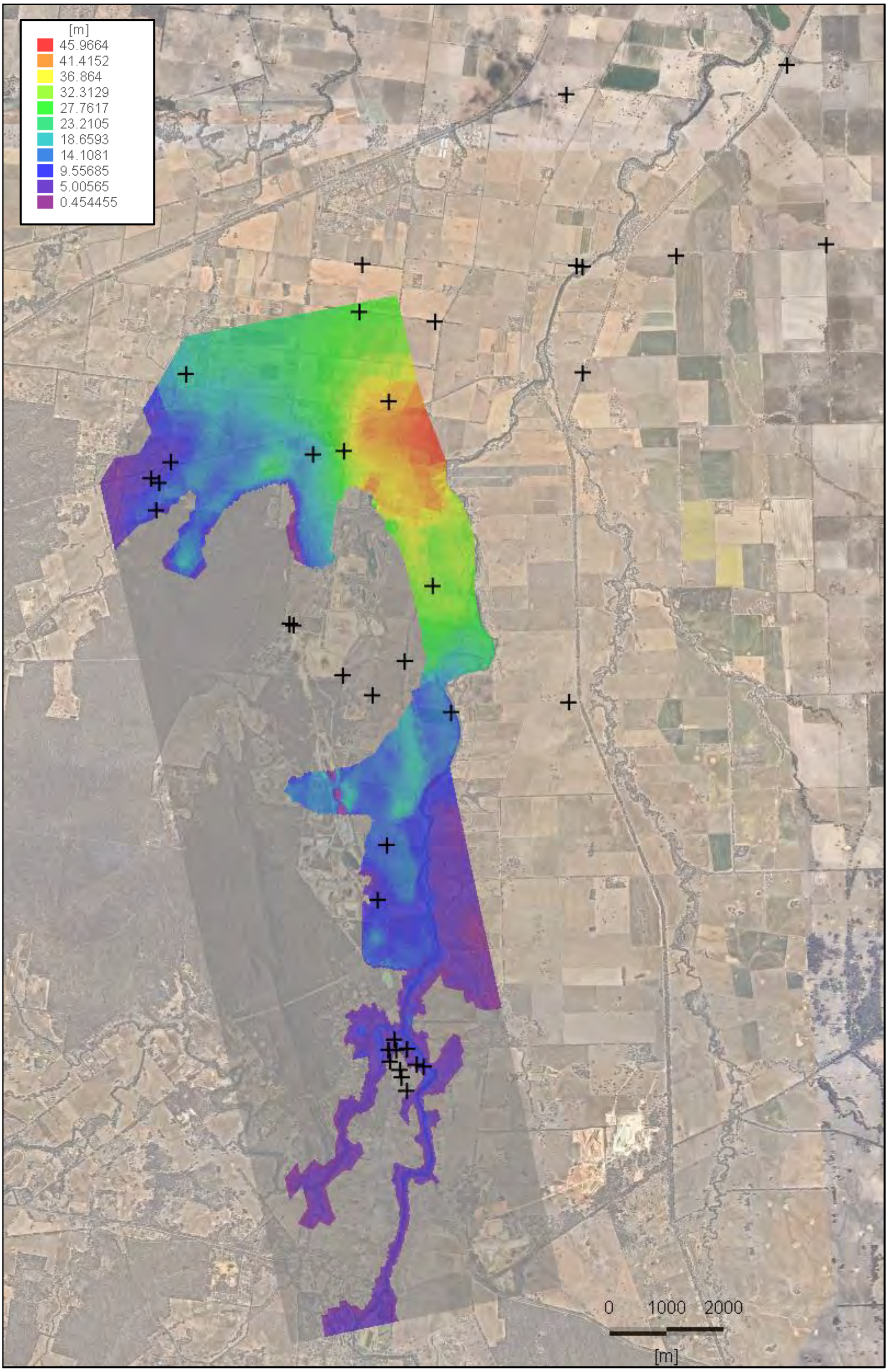


Figure 15: Modelled thickness of alluvium (layer 1), overlaid by locations of borehole data used to create this layer.

5.2.2 Boundary conditions and recharge

Groundwater recharge

Infiltration recharge values were based on estimates obtained through the chloride mass balance (CMB) method (AGT 2017), and the model calibration processes (described below in section 5.3). Recharge estimates obtained via the CMB method provide a recharge range across the majority of study area in the order of 1 to 5 mm/year, and higher recharge (13 mm/y) in the Sugar Loaf Ranges.

Recharge was applied to model layer 1 in a zonal distribution that is based on the adopted hydraulic conductivity zones (described in section 5.2.3 below). That is, higher recharge was applied to the areas of alluvium and faults, while lower recharge rates were applied to areas of exposed fresh rock. The Sugarloaf Range area was assigned the zone of highest recharge based on the conceptual understanding and elevated CMB method estimate discussed above.

The groundwater recharge zones are shown in Figure 16.

Boundary conditions

Figure 17 displays the distribution of model boundary conditions. Fluid-transfer boundary conditions were applied to the lateral model domain boundaries to represent regional groundwater flow through the site. These boundaries drive the pre-mining steady-state groundwater flow pattern throughout the model domain. However, it is important that model boundary conditions do not artificially constrain transient model behaviour. The influence of these boundary conditions was tested by repeating the transient simulation with all lateral fluid transfer boundary nodes removed (defaulting to no-flow boundary conditions). The effect of this upon simulated drawdowns and mine inflows was negligible.

Specified head nodes were applied as both internal and lateral boundary conditions to represent significant streams in the study area (namely the Campaspe River and one of its tributaries in Axe Creek). The distribution of fluid-transfer and specified head boundary condition values is displayed in Figure 16a. These values were guided by previous FGM models (i.e., Coffee, 2010; AGT, 2016a; 2016b; 2017 and Golder, 2018) and were modified during the model calibration processes (detailed in section 5.3). The values of creek nodes were also guided by surface elevation data. Similar to the lateral fluid-transfer boundary conditions, the influence of the specified head river boundaries upon model predictions was tested by repeating the transient simulation with the specified head nodes representing rivers disabled. The effect upon simulated mine inflows and regional-scale drawdowns was negligible.

Figure 17b displays the distribution of boundary conditions used to represent FGM mining operations (both historical and planned). Open-cut pits are represented by specified head nodes and underground mine workings are represented by fluid-transfer boundary conditions. Details pertaining to these boundary conditions are provided in section 6.1.

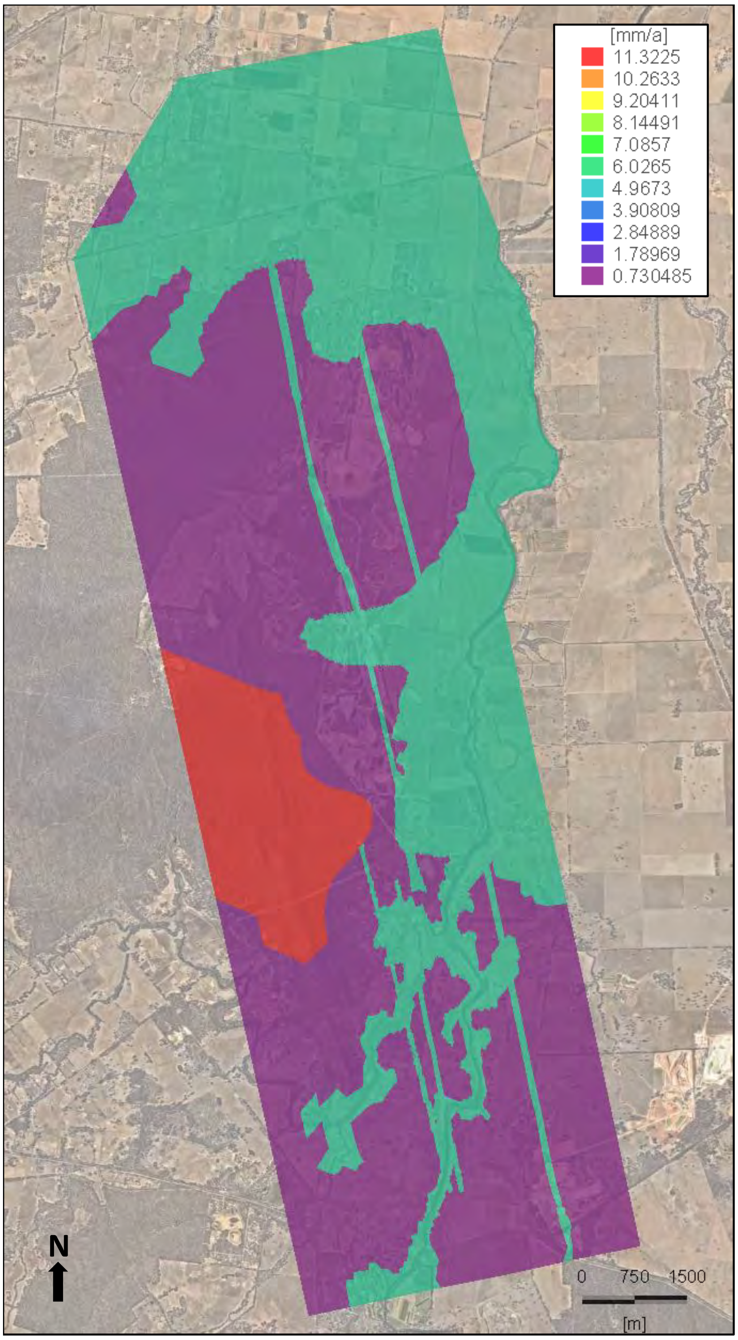


Figure 16: Infiltration recharge distribution (applied to model layer 1)

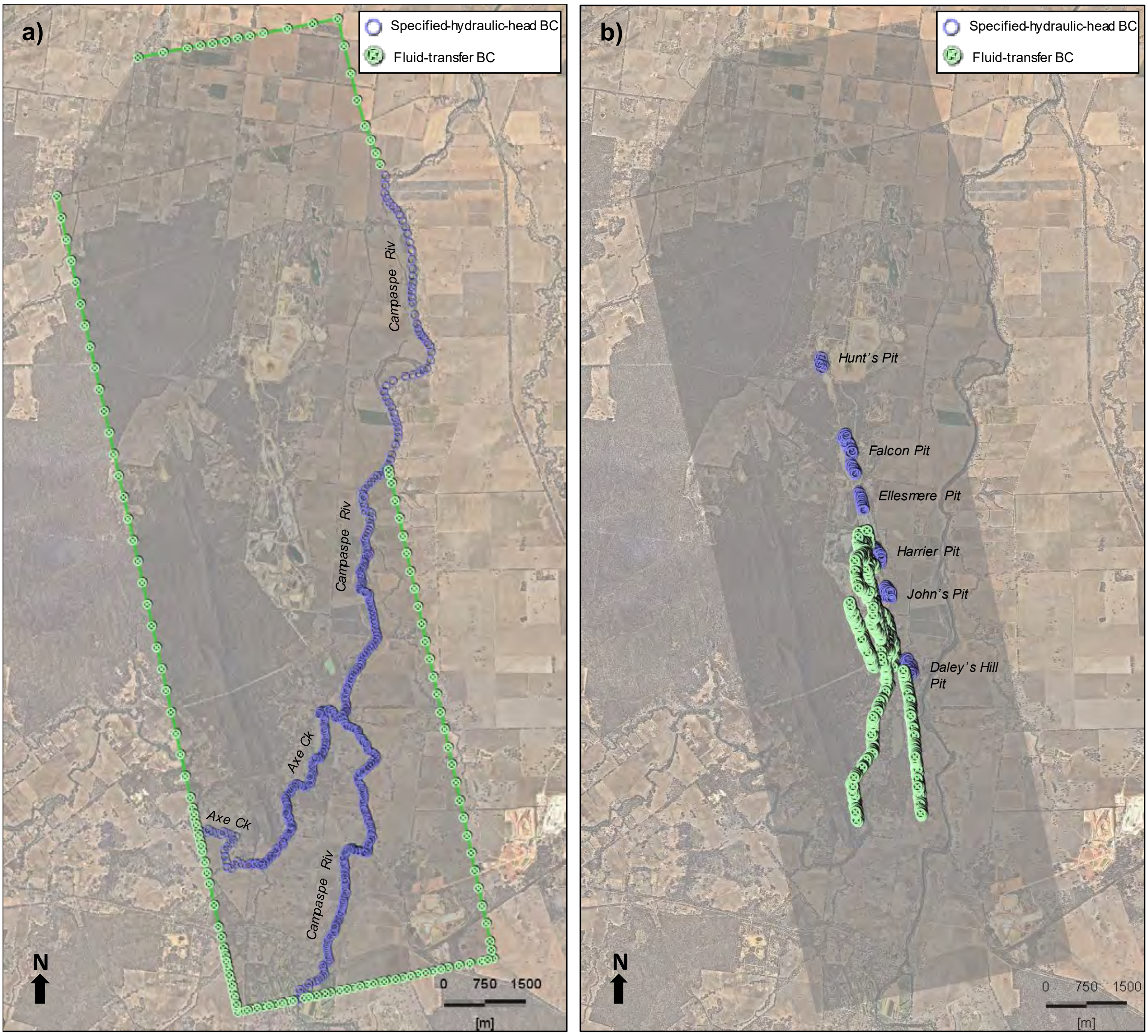


Figure 17: a) model boundary conditions for pre-mining steady-state simulation and b) model boundary conditions representing mining operations (more details provided in section 6.1), added for transient simulations (note: steady-state boundary conditions displayed in 'a)' remained active during transient simulations).

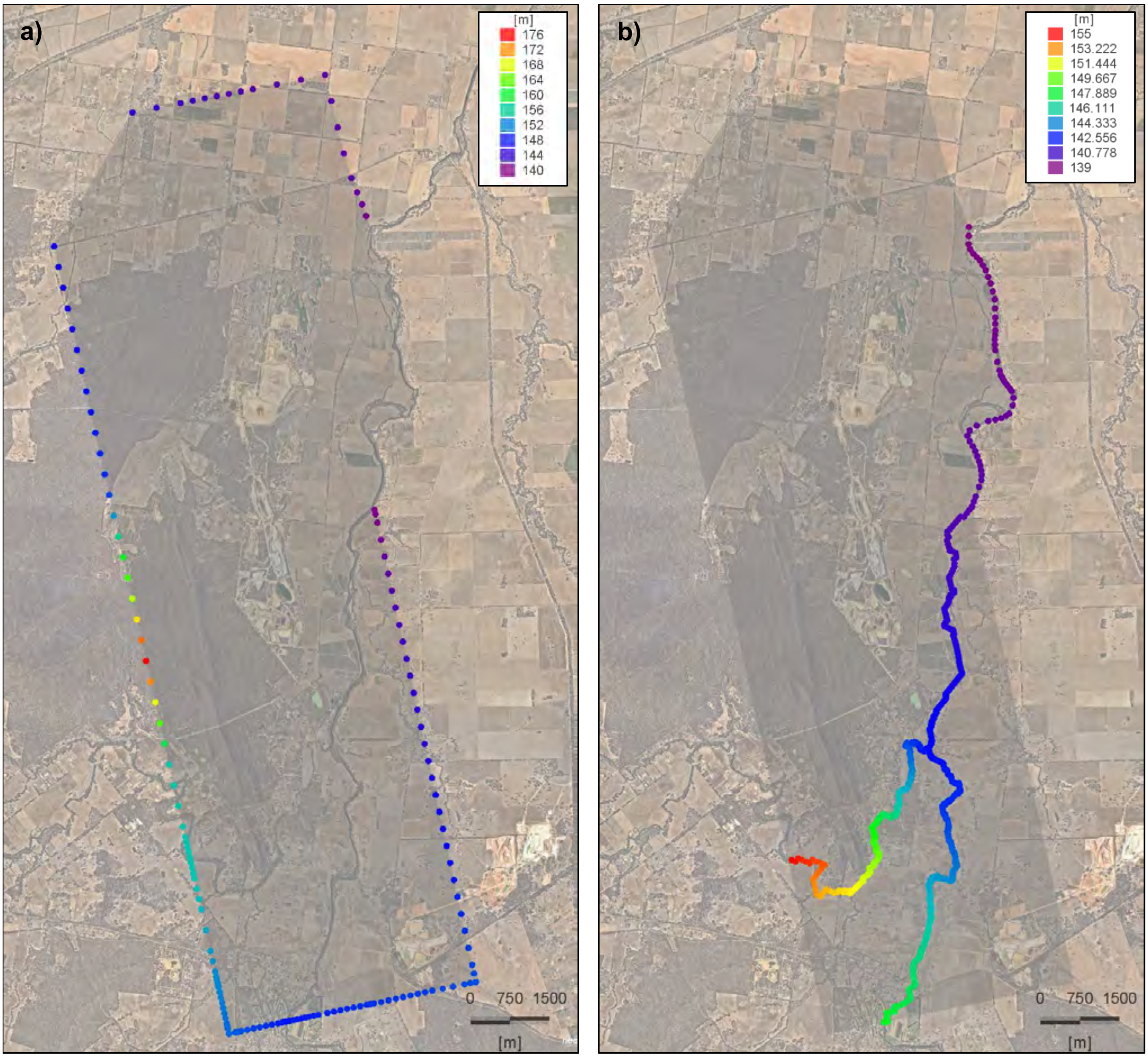


Figure 18: Hydraulic head values (m AHD) associated with a) fluid-transfer boundary conditions and b) specified-hydraulic head boundary conditions (representing streams) as displayed in Figure 15a).

5.2.3 Hydraulic properties

Figure 19 and Figure 20 display the hydraulic conductivity distributions in model layer 1 and layers 2-24, respectively. The geometry of these zonal distributions represent the main hydrogeological units and features in the region. These include the alluvial sediments, the fractured rock, and the faults within the fractured rock., Whilst the hydraulic properties of the Fosterville Fault near the current mine areas have been evaluated by several pumping tests (Clifton 1996, Coffey 2010 and AGT, 2017), elsewhere there are limited field-based estimates of hydraulic properties available and the introduction of more heterogeneity in hydraulic properties cannot be justified. Furthermore, hydraulic properties of the FRA in the southern extension area have not been assessed. Hydraulic properties were optimised during model calibration as described in section 5.3 below.

General hydraulic conductivity anisotropy was applied throughout the model domain for the FRA. The principle directions of hydraulic conductivity were adjusted to align with the dominant strike of faults within the study area, estimated as 347°T. This was incorporated in the model by setting Euler angle ϕ = 13°. The resultant anisotropy axes are represented graphically in the bottom left corner of the hydraulic conductivity plots in Figures 17 and 18.

The values assigned to each of these zones were based on model calibration, detailed in section 5.3 below.

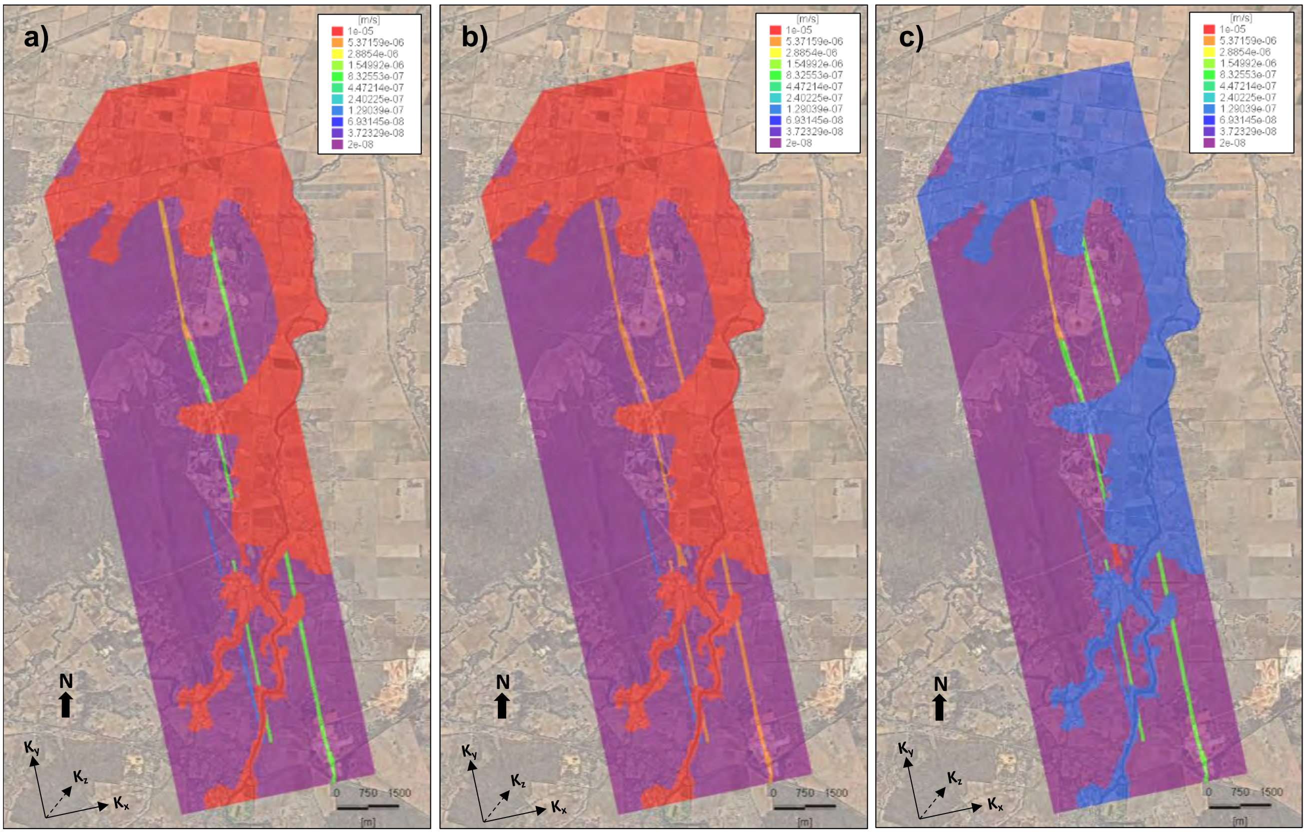


Figure 19: Model layer 1 hydraulic conductivity distributions a) K_x b) K_y and c) K_z.

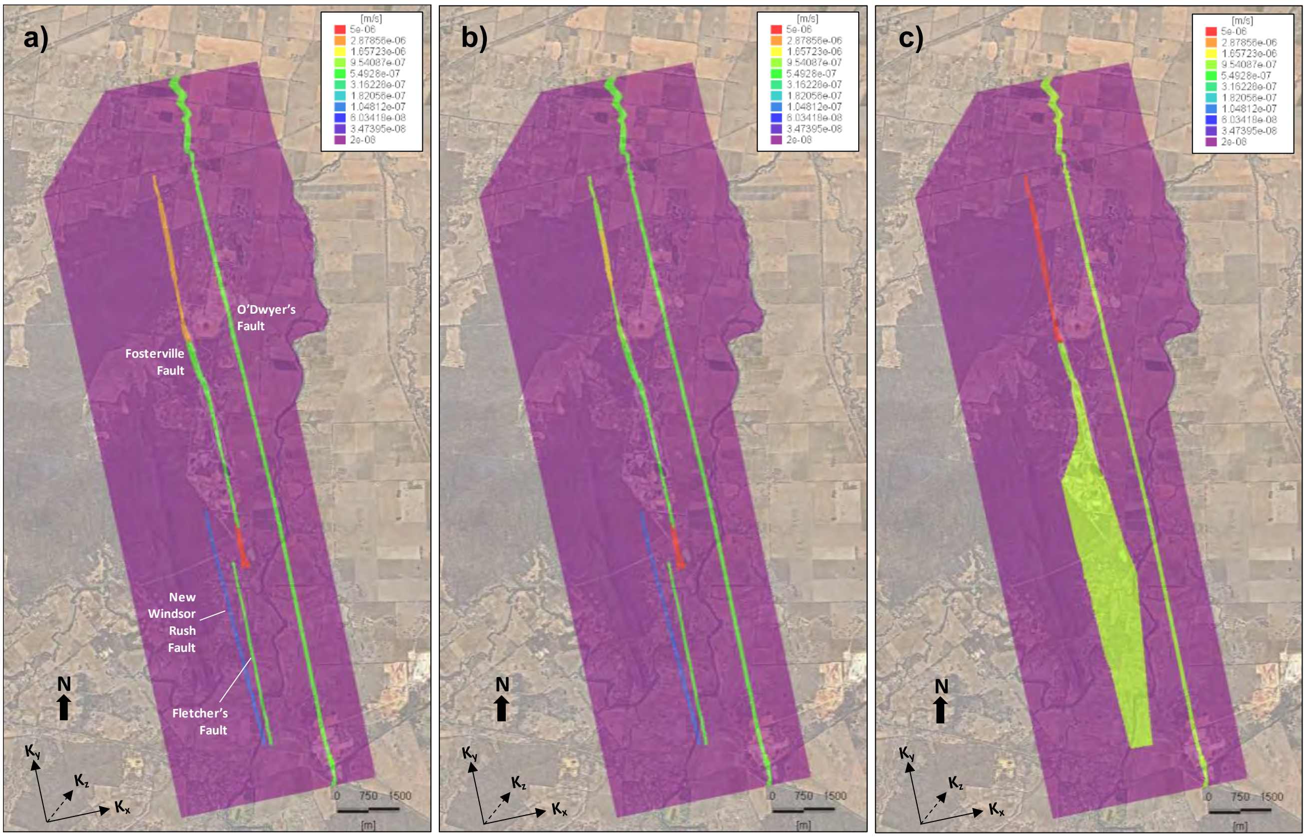


Figure 20: Model layers 2-24 hydraulic conductivity distributions a) K_x b) K_y and c) K_z. Note that small zone of higher K_x and K_y at southern end of Fosterville Fault only applies to layers 2-5. In layers 6-24 K_x and K_y do not increase at the southern end of Fosterville Fault. Additionally, horizontal conductivity (K_x and K_y) is reduced by 50% below -500 mAHD to represent fracture aperture reduction under increasing pressure.

5.3 Model calibration

Model calibration is the process of adjusting model inputs (such as aquifer properties) within reasonable ranges until model outputs fit historical measurements/observations to an acceptable level. This increases confidence in the model to represent the groundwater system and prepares the model for the making of future predictions. Model calibration for this study involved steady-state calibration followed by transient calibration, both of which are described below. Although these are separate, sequential processes, model input adjustments made during the transient calibration may affect the steady-state calibration results, and vice-versa. As a result, both phases were required to be repeated multiple times in an iterative process until satisfactory calibration performance was achieved for each.

5.3.1 Steady-state calibration

Steady-state calibration was undertaken to represent the pre-mining state of the groundwater system and provide initial conditions prior to mining operations for the transient simulation. Pre-mining, the groundwater flow at the site is influenced only by natural recharge and discharge processes (such as rainfall infiltration, groundwater interaction with streams, and lateral groundwater flow to/from areas outside the model domain).

During the steady-state calibration process, model boundary conditions (including internal boundary conditions such as the Campaspe River and Axe Creek), which allow groundwater to flow into and out of the model, infiltration recharge (from rainfall) rates and aquifer material properties were adjusted until the model sufficiently reproduced regional pre-mining groundwater elevations. Pre-mining groundwater elevations comprised the same groundwater dataset used by the previous model (AGT 2016), as well as from the historic RMB monitoring bores (Perseverance Exploration, 2000) located near the southern extension area. Pre-mining groundwater levels obtained from a total of 33 monitoring bores (locations shown in Figure 19) were used in the steady-state calibration process.

A scatterplot of observed pre-mining groundwater elevations and those computed by the model is presented as Figure 22. The modelled pre-mining groundwater elevation contours for the Alluvium and FRA are presented in Figure 23.

The scaled root mean square (SRMS) error between recorded and modelled groundwater levels is 15%. The scatterplot in Figure 22 includes three clear outliers, which are circled. These three wells are also circled in Figure 23 and shows they are located within close proximity of each other. If these outliers are excluded from the scatterplot, the SRMS value becomes 6%. This indicates that the general regional flow pattern is adequately represented within the model. Accurate simulation of the pre-mining heads at the location of these outliers would require the introduction of a localized feature within the model that result in a significant local minimum, constituting a local reversal of the hydraulic gradient. However, available field data does not support this hydrogeological characteristic. Moreover, due to the localized nature of this group of outliers, the influence of this error upon model predictions of regional-scale drawdown and mine water inflows is likely to be negligible.

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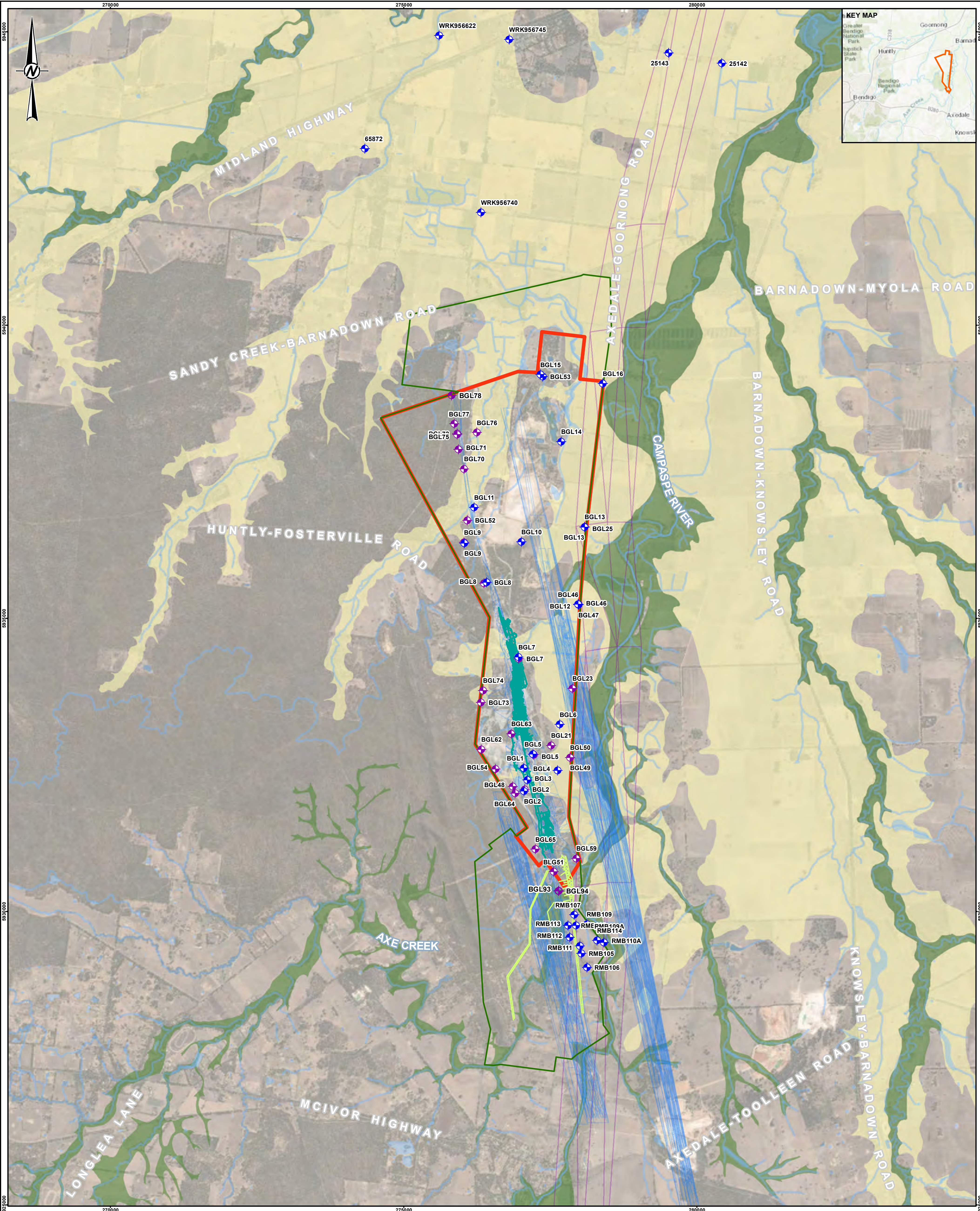

LEGEND

- Steady State Calibration Point
- Transient Calibration Point
- Underground Mine Plan
- Southern Mine Extension
- Waterbody
- Fosterville Fault
- Redesdale Fault
- Mining Lease Boundary
- Extended Mining Lease Boundary (MIN5404)
- Shepparton Formation
- Quaternary Sediments

0 1,000 2,000
1:60,000 METRES

NOTE(S)
-

REFERENCE(S)
1. IMAGERY AND LOCATION MAP SOURCED FROM ESRI ONLINE BASEMAPS.
2. WELL INFORMATION SOURCED FROM AUSTRALIAN GROUNDWATER TECHNOLOGIES.
3. ROAD AND WATERBODY INFORMATION SOURCED FROM WWW.DATA.VIC.GOV.AU

CLIENT
KIRKLAND LAKE GOLD LTD.

PROJECT
FOSTERVILLE GOLD MINE EXTENSION
GROUNDWATER ASSESSMENT

CONSULTANT
GOLDER

YYYY-MM-DD	2020-02-25
DESIGNED	-
PREPARED	CJS
REVIEWED	JVDA
APPROVED	JVDA

TITLE
LOCATIONS OF STEADY-STATE AND TRANSIENT CALIBRATION POINTS

PROJECT NO.	CONTROL	REV.	FIGURE
18108798	001-R	0	21

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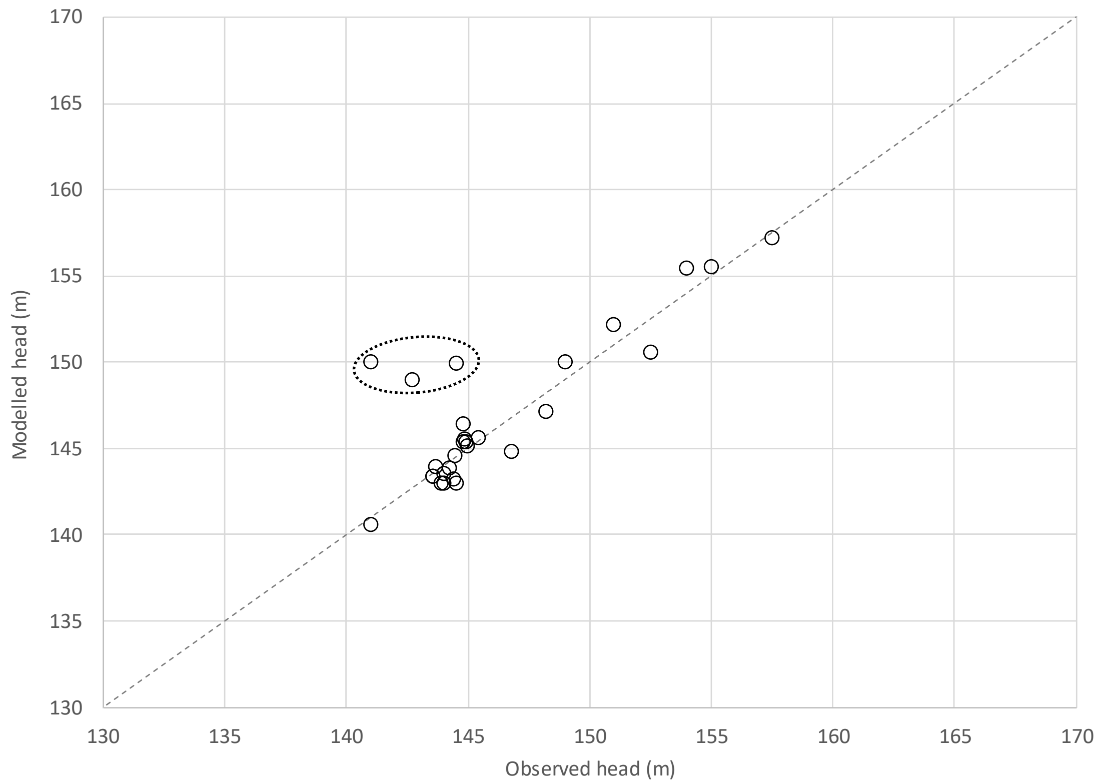

Figure 22: Steady-state calibration scatterplot

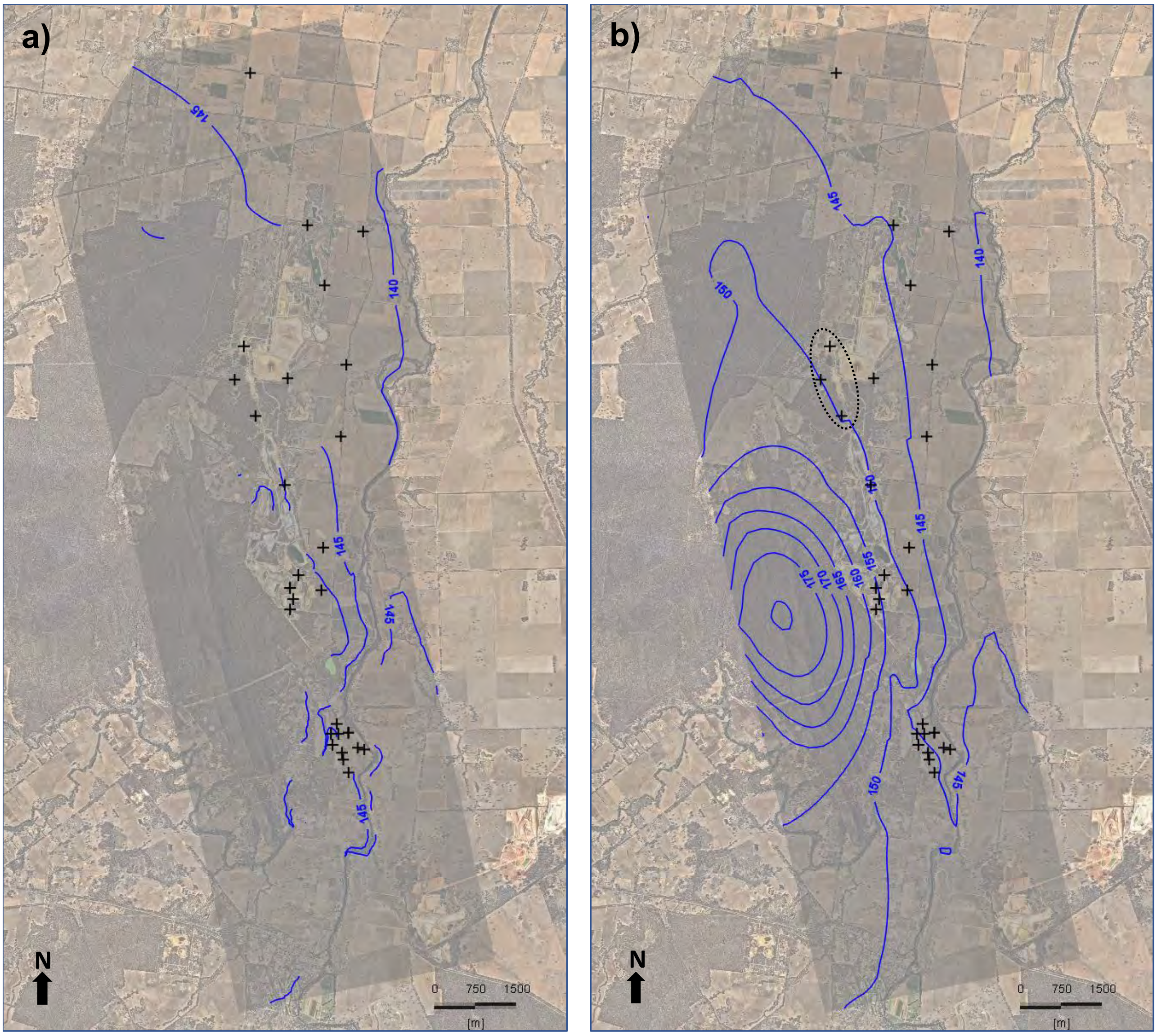

Figure 23: Simulated pre-mining (steady-state) groundwater level contours in a) the Alluvium and b) the FRA (approx. 100m depth).

5.3.2 Transient calibration

A regional-scale transient calibration was undertaken by simulating past mining operations (including both open cut and underground) and comparing the simulated groundwater level response in both the FRA and alluvial aquifers and mine inflows to observed groundwater level response and mine inflows, respectively. Transient groundwater level records obtained from 31 monitoring bores were used for the transient calibration process (locations of monitoring bore locations used for the transient calibration are shown on Figure 19). This includes a combination of long-term records, some of which date back to 1991, as well as limited short-term records. This data was used for comparison with simulated groundwater response for calibration purposes. Figure 24 to Figure 28 displays plots of groundwater level timeseries for each of the 31 monitoring bores used for transient calibration purposes.

Inspection of Figure 24 to 28 demonstrates that the model reproduces the general mine dewatering-induced drawdown trends satisfactorily in the majority of monitoring bores. Many of the observed timeseries include various short-term fluctuations that are not reproduced by the model. These are related to short-term climatic fluctuations or operational factors (e.g. short-term variations in mine progression rates and filling/emptying of leaky ponds) that are not included in the model as there is limited information available to include these in the model.

Several monitoring bores exhibit consistent offset exists between modelled and observed transient trends. This is a function of initial (i.e., steady-state) groundwater level discrepancies, as these differences are carried over from the steady-state calibration process. These offsets do not reflect an inability of the model to predict transient groundwater responses to future operations. For a transient model, more important than the matching of absolute values is its ability to reproduce historical rates of change in the groundwater system, as this is controlled by its storage parameters and thus reflects its ability to predict future aquifer dynamics (e.g., Doherty and Hunt, 2010; Peeters et al., 2011; Knowling and Werner, 2017).

A plot showing observed and model-predicted mine inflows is presented as Figure 29. The model somewhat overpredicts total mine inflows. There exist several factors that may contribute to this discrepancy. This includes the difficulty in accounting for all inflows in the field. Despite this, comparison of simulated underground mine inflows to the regression line fitted through recorded inflows (Figure 29) indicates that the model satisfactorily reproduces the long-term rate of change in inflows. This supports use of the model for predicting relative changes in inflows due to future mine progression.

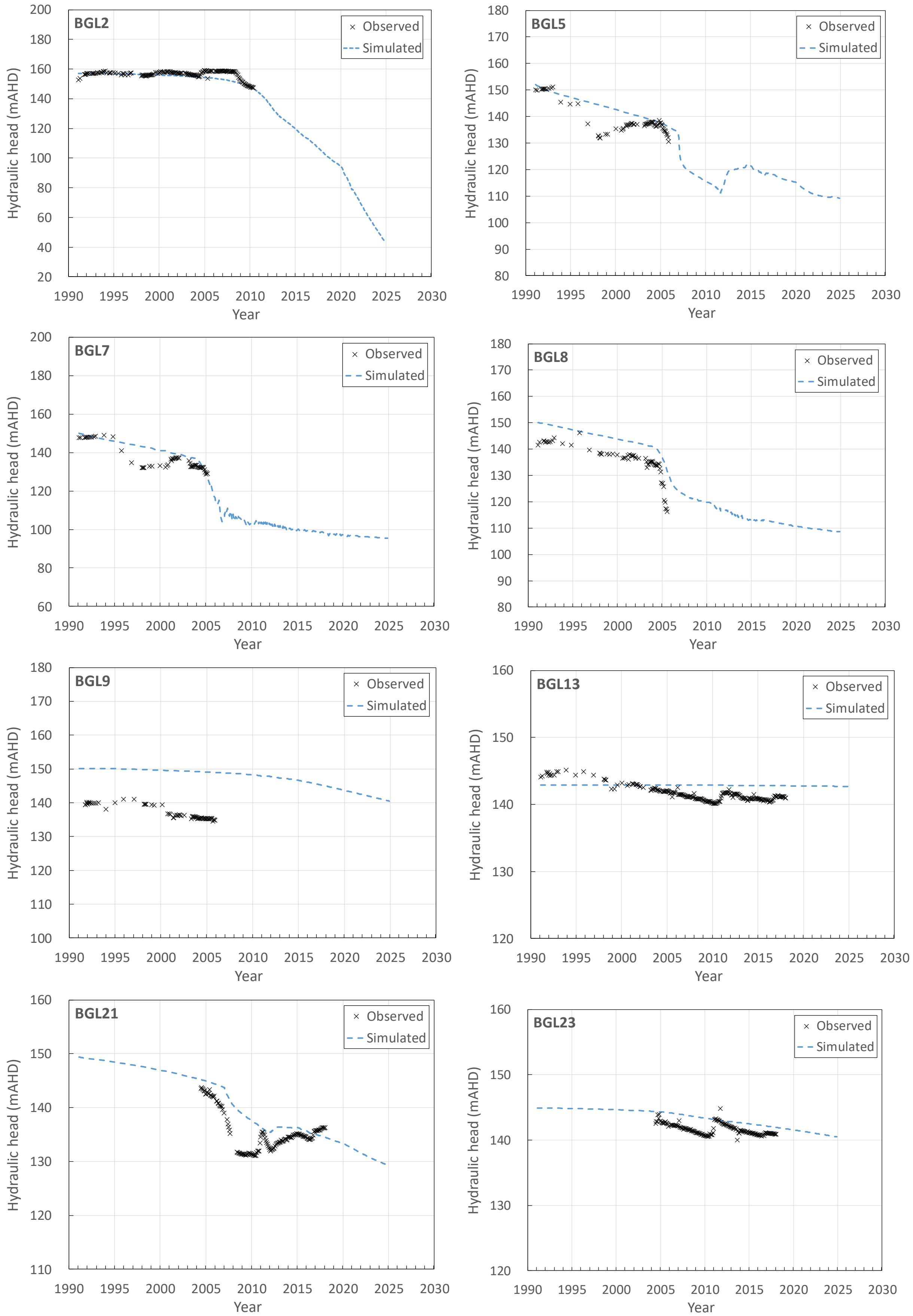

Figure 24: Predicted and observed groundwater level timeseries

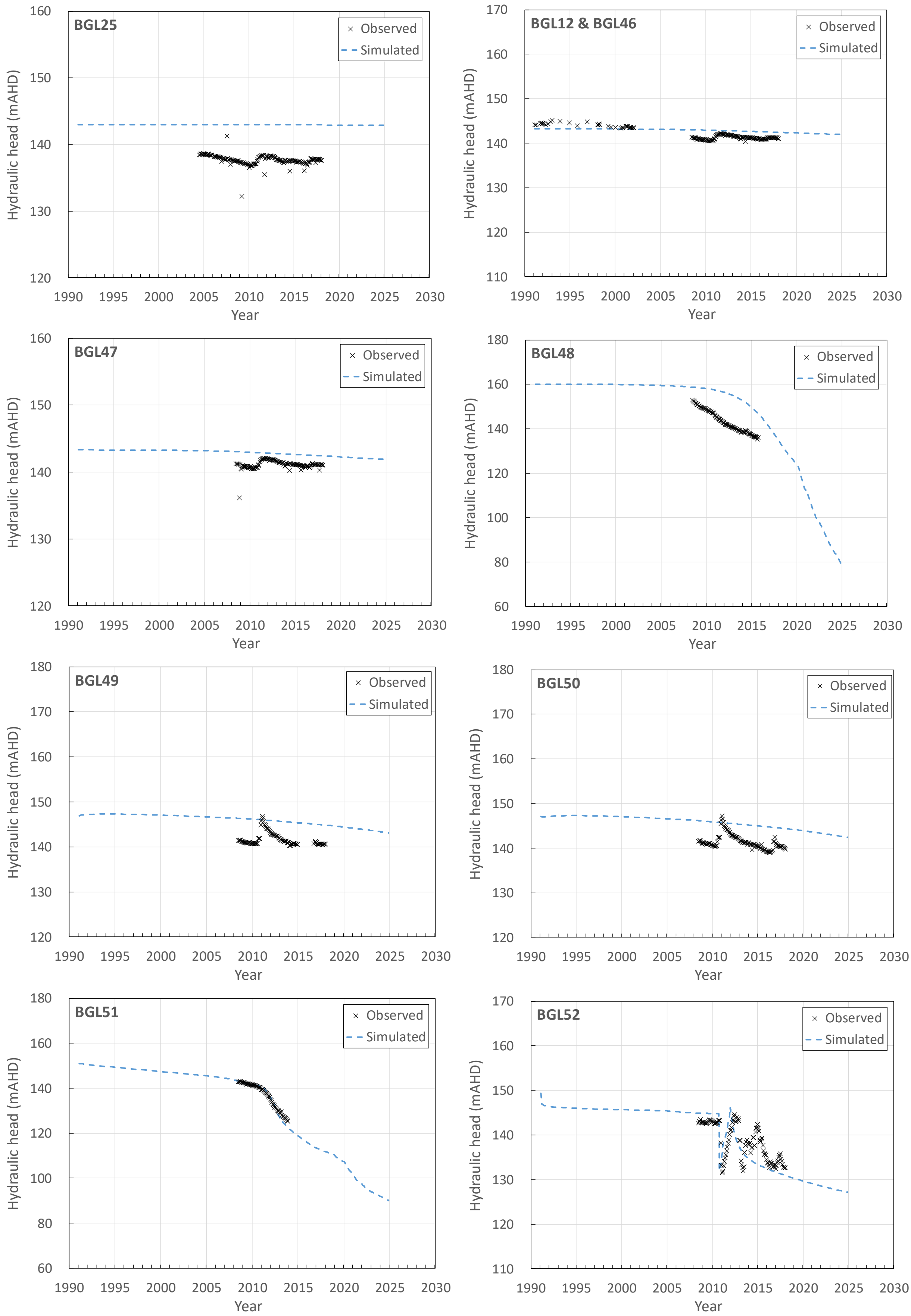

Figure 25 (contd.): Predicted and observed groundwater level timeseries

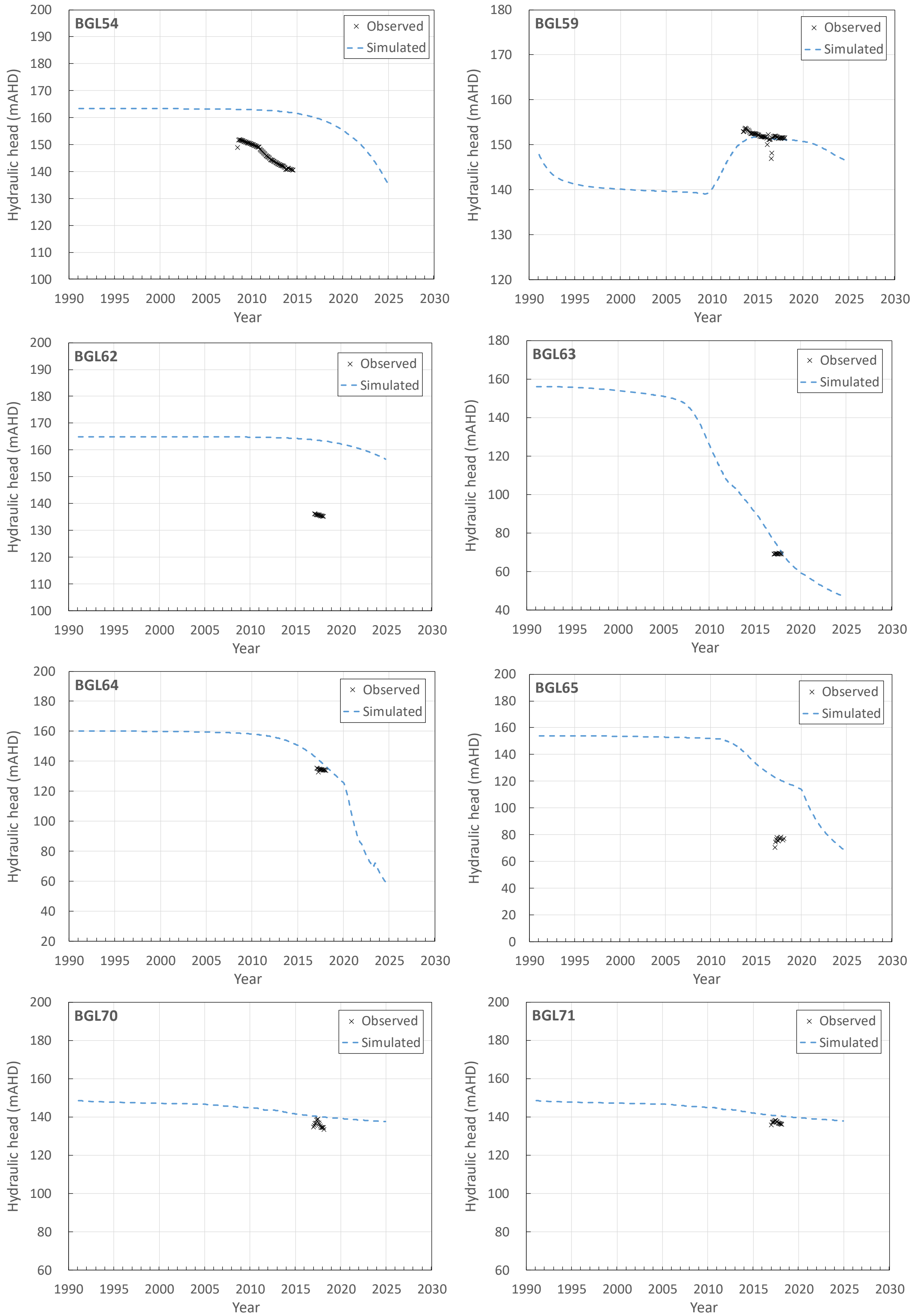

Figure 26 (contd.): Predicted and observed groundwater level timeseries

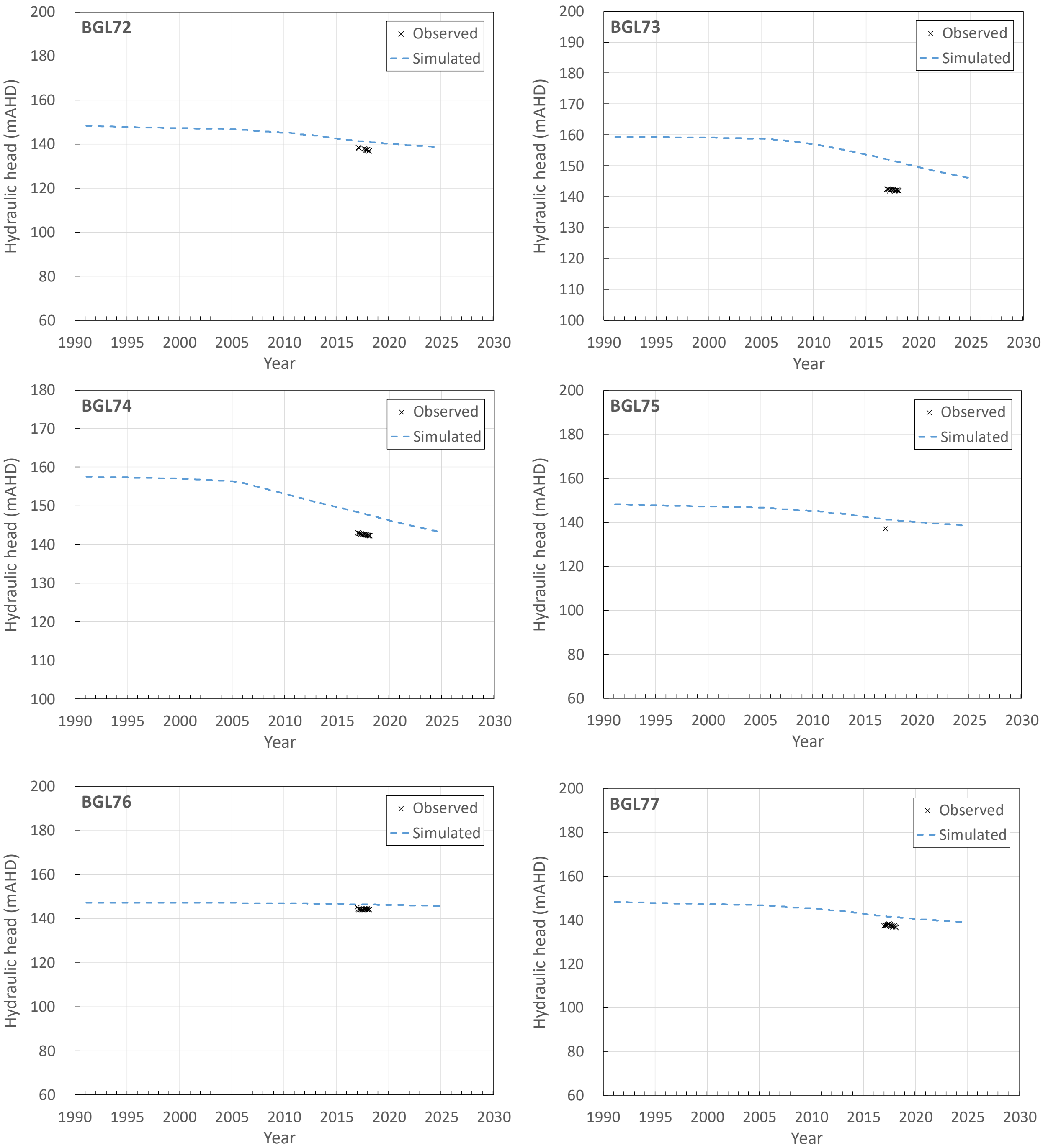

Figure 27 (contd.): Predicted and observed groundwater level timeseries

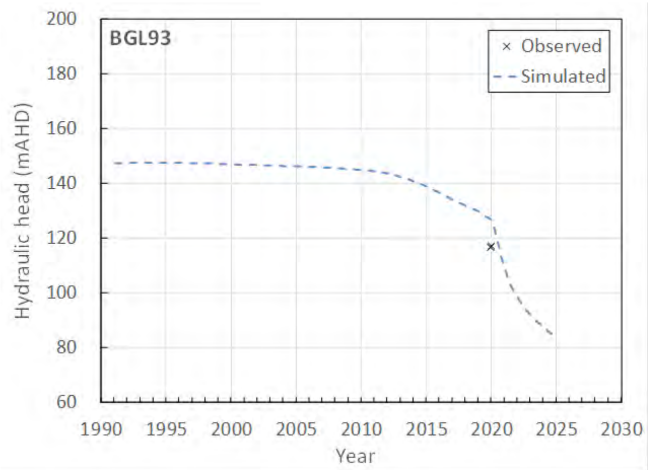

Figure 28: (contd.): Predicted and observed groundwater level timeseries

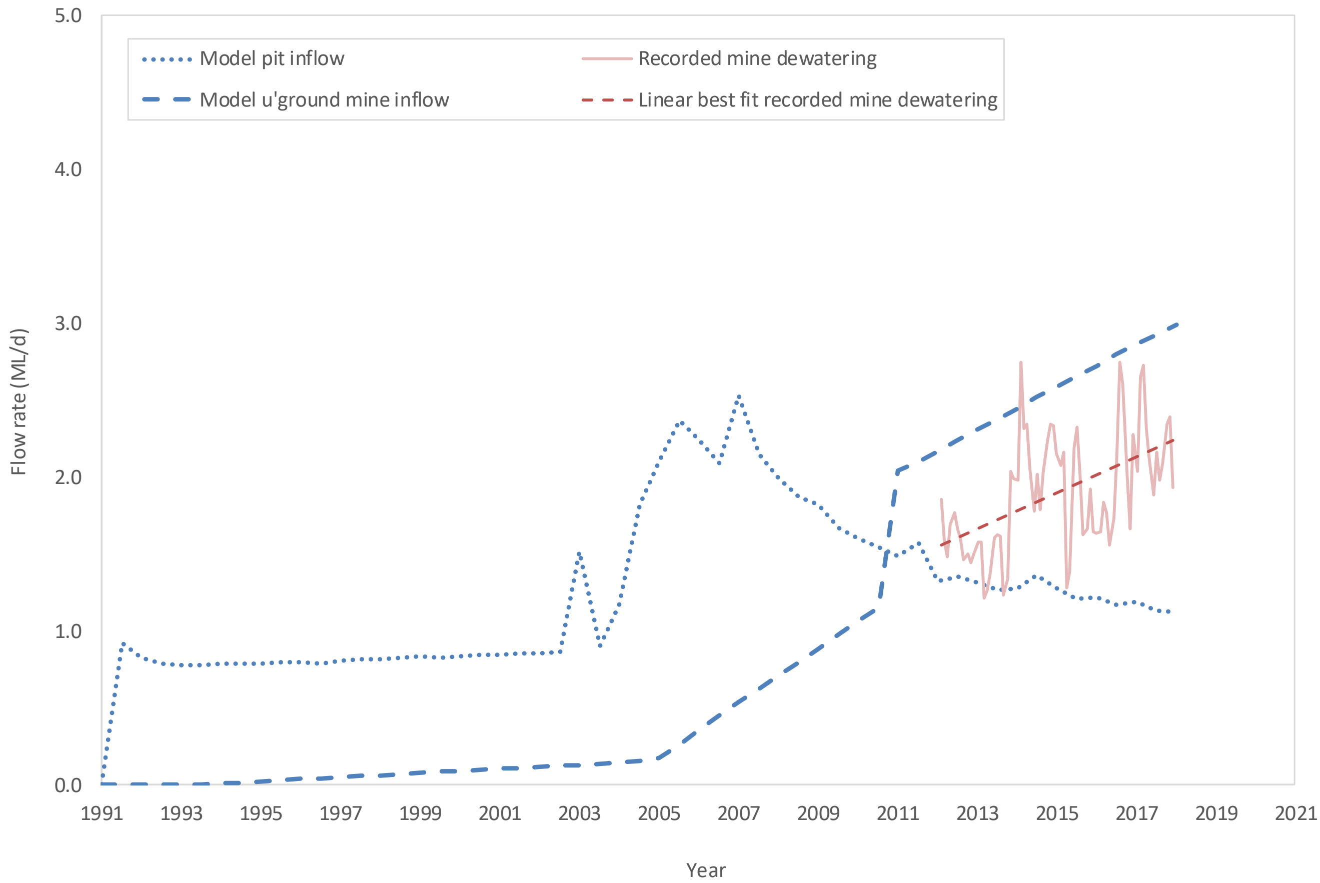

Figure 29: Simulated versus observed mine inflows

6.0 MODEL SIMULATIONS

6.1 Mining simulations

Figure 30 summarises all details of simulated mining operations. Time-variant fluid-transfer boundary conditions were applied to model nodes representing the existing and future underground mine areas. In all simulations, mining operations were simplified to increase computational efficiency and achieve practical model run times. The fluid-transfer boundary areas within the model were based on spatial distributions of underground mine workings provided by FGM. The conductance (out-transfer rate in FEFLOW) was treated as a calibration parameter in order to accommodate the fact that the true detail in underground mine workings, and therefore the true surface area through which inflows occur (smaller in reality in the model), cannot practically be represented in the regional scale model, and therefore discharge to the areas of underground mine workings must be constrained by conductance.

Mining progression rates were assumed to be uniform over specific time periods that were based on information provided by FGM. As such, fluid-transfer boundary condition values at the mining nodes were defined by piecewise linear functions. These boundary conditions were constrained to allow for groundwater discharge only (i.e., representing mine dewatering).

Open-cut pits that are currently being used for water storage (Daley's Hill Pit, Harrier Pit, John's Pit and Hunt's Pit) were included in the model (as specified-head boundary conditions to represent recorded pit water levels). As the mine water will be treated and reused (for processing) there will be less water in the mine water circuit and a reduced reliance of water storage facilities. For this reason the current pit water levels were maintained in the model during the future prediction period (as represented by the transition of dashed lines into dotted lines in Figure 27), rather than simulating rising water levels representing ongoing filling of these pits.

6.2 Post mining simulations

The status of the historic open cut pits (open or backfilled) at the time of mine closure were also represented in the model, as these will influence the groundwater recovery rate, groundwater flow direction and therefore the movement of mine water from underground mine / backfill areas.

The open cut pits which are currently dry, such as Falcon and Ellesmere Pits can turn into pit lakes as groundwater levels recover above the pit floors (or backfill levels), which will range from 108 – 120 m AHD (Falcon Pit) and 111 – 136 m AHD (Ellesmere Pit). The historic groundwater elevation in this area ranged from 147 m to 152 m AHD (BGL-2, -5 and -7), and is higher than the proposed pit backfill levels, which suggests pit lakes will form post mining.

Once pit lakes are formed, evaporation rates can exceed influx rates, causing the pit lake to function as a groundwater sink, with water levels in the pit remaining below surrounding groundwater levels. Open cut pits used as mine water storage facilities (such as Johns, Harrier and Daley's Hill pits), which are a source of groundwater recharge during mining, may later function as groundwater sinks (post mining), and thus the model needed to reflect this change in function.

Post-mining groundwater behaviour was simulated by using the predicted end-of-mining 2024 groundwater level distribution as the initial condition and deactivating all model boundary conditions representing mining operations, i.e. assumes the mining activities and dewatering stop at once in all workings. These included deactivation of the fluid-transfer boundary conditions representing the underground mine workings and deactivation of specified-head boundary conditions representing the open-cut pit areas (as well as underground mine portal/shallow workings). An evaporation flux (based on annual potential evaporation) was applied to simulate evaporation losses from the open cut pits, which was activated once groundwater levels recovered above the final pit floor or backfill level. Further details on mine closure and model inputs can be found in previous mine closure assessment undertaken by Golder 2018.

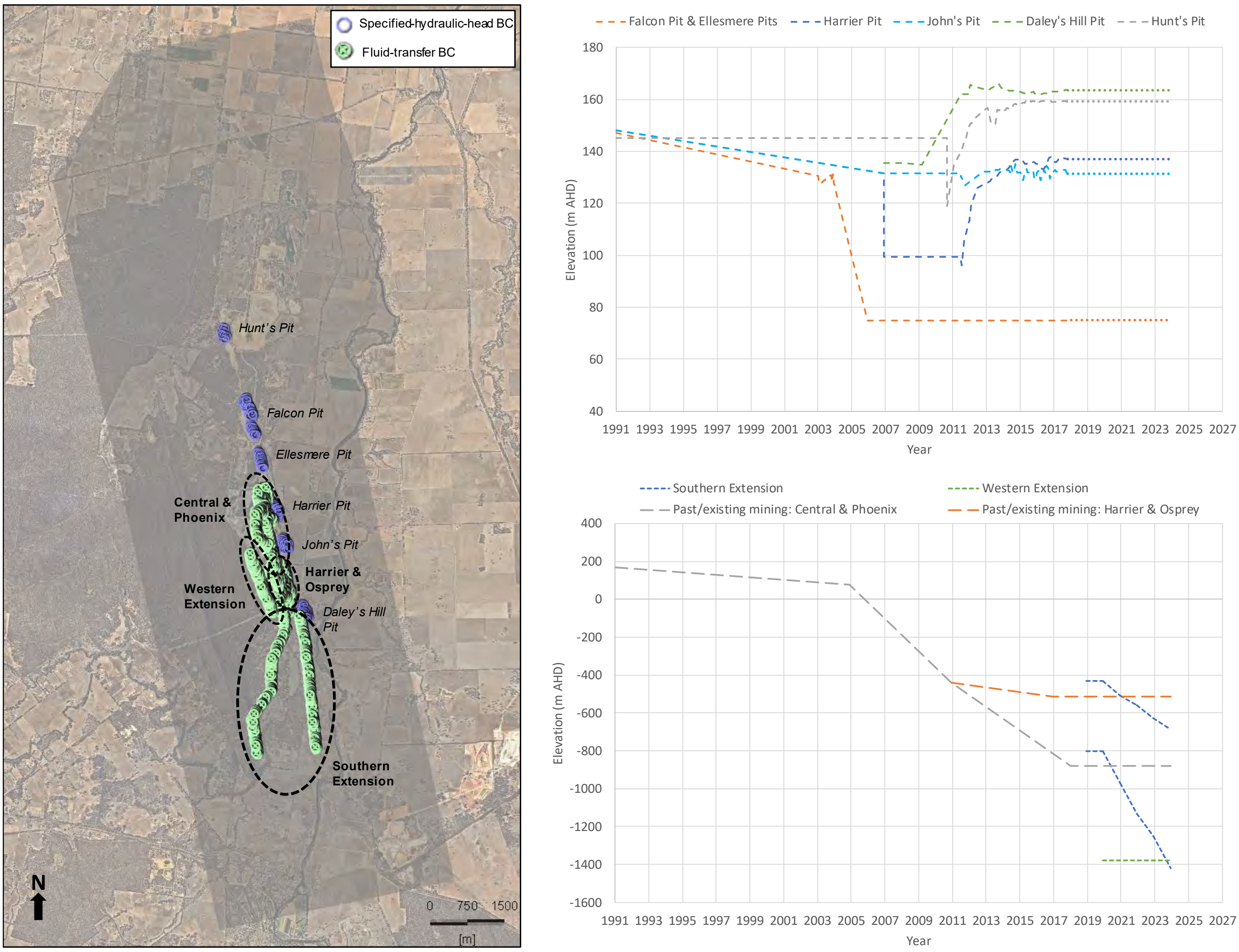

Figure 30: Spatial distribution of model boundary conditions representing mining operations (left) and associated time-variant values assigned to them (right), including both past/existing mining and future mining.

7.0 MODEL RESULTS

7.1 Mine inflows

Figure 31 displays the predicted mine inflow rates for both the existing underground mine area and future underground mine areas (post 2020). The measured mine inflow rates are also shown on Figure 31 for reference. It is important to note that the intricacies of previous underground mine development (dating back to 2006) could not be incorporated in detail and were simplified by the model in terms of mine plan (excavated workings) and mining schedule. The model does not account for progressive backfilling of mine voids. The simplification of past underground mining has resulted in the model over predicting past groundwater inflows into the mine, which in-turn presents a conservative approach to the model results and predicted impacts.

Whilst the current mine inflows (2.25 ML/d) are over predicted by the model (~3 ML/d), the total mine inflows into the current and future mine areas were predicted to increase by about 1 ML/d by the end of mining and as such, the total predicted mine inflows of >4 ML/d by the end of mining may not be realised. An important consideration is that mine inflow rates will react to mining activities, such as the interception of faulted or non-faulted areas, which have not been assessed by hydrogeological investigations in the southern extension area. This may result in mine inflow rates being different to model predictions. Furthermore, the current exploration drive towards the southern extension area has not encountered measurable groundwater inflows to date.

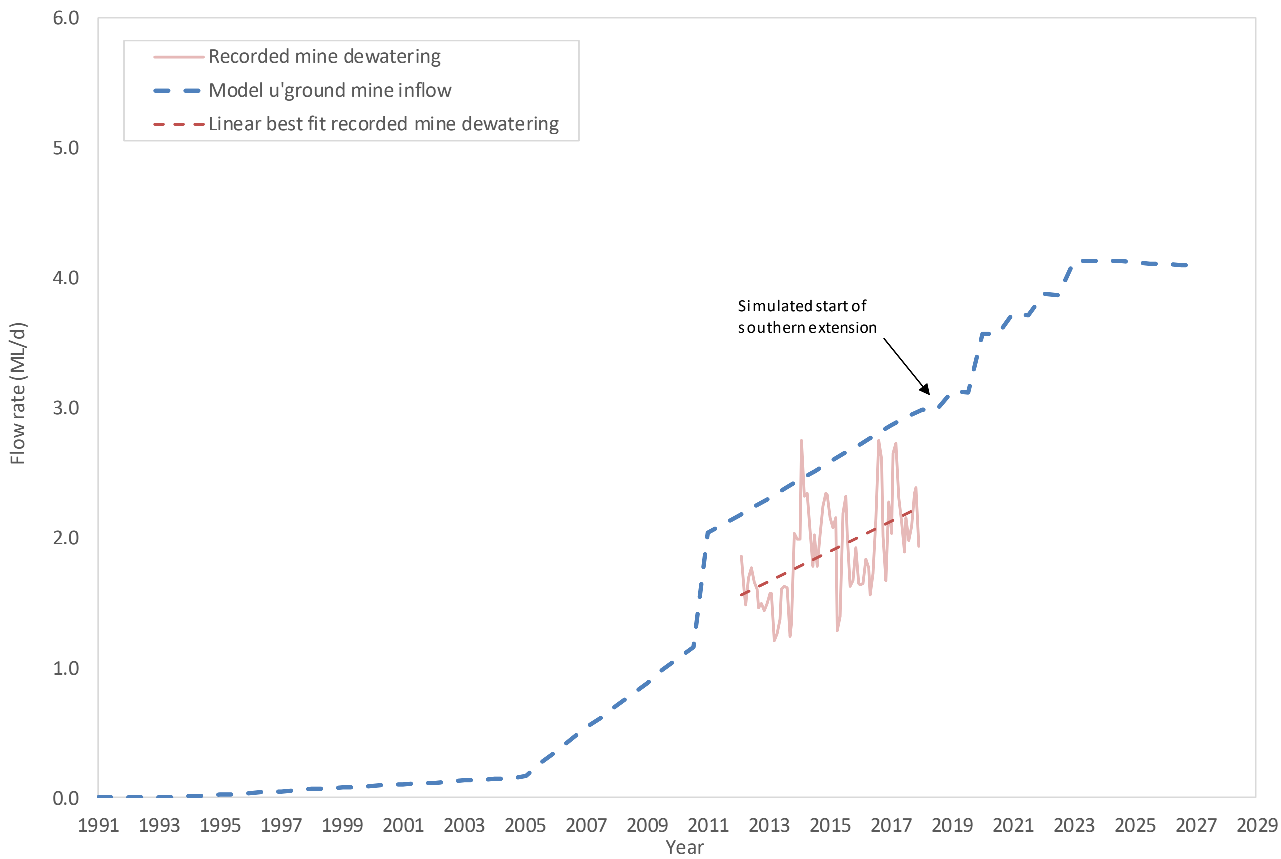

Figure 31: Predicted underground mine inflows – ML/d

7.2 Groundwater level response to mining

7.2.1 Fractured Rock Aquifer

Mine dewatering reduces the groundwater levels in the surrounding FRA. The extent of groundwater decline is dependent on the hydraulic properties and presence of boundary conditions, such as faulting in the FRA. The groundwater model calculated the extent of the zone of groundwater drawdown within all model layers by comparing the groundwater levels with and without the mining operation.

The groundwater level elevations and drawdown representing current day mining (2019) and end of mining in the southern extension area (2024) are shown on Figure 32 and Figure 33. Note, the end of mining (2024) contours shown on Figure 32 and Figure 33 represent the cumulative effects of both the current mine area and the southern extension area. The phreatic groundwater levels representing current day (2019) conditions and end of mining are also shown on east to west cross section (Figure 34) such that the potential interaction with overlying watercourses can be observed.

The following observations can be made:

- The cone of drawdown that is currently in place (represented by the 2019 contours) was first established between 2004 and 2007 due to the active dewatering of the Falcon and Ellesmere pits. The cone of drawdown has since been maintained by ongoing dewatering of the underground mine, and has emanated into the southern extension area.
- A tight cone of drawdown is predicted to occur around the new southern mine area, with groundwater level drops in the order of 20 m to 80 m occurring in close proximity to the southern mine extension. The extent of groundwater level drawdown was predicted to be quite localised and will be generally contained within the southern mining lease boundary.
- Groundwater level declines in three private bores situated within the mining lease boundary and near the southern extension area were predicted to range from 2 m to 10 m. The current pump installation depth and depth to water in these bores is unknown (as head plates restrict access for water level measurements).

Figure 32: Simulated groundwater drawdown for current day left) and end of mining in the southern extension area (right). (Note: innermost unlabelled contour in righthand plot is the 100 m drawdown contour.)

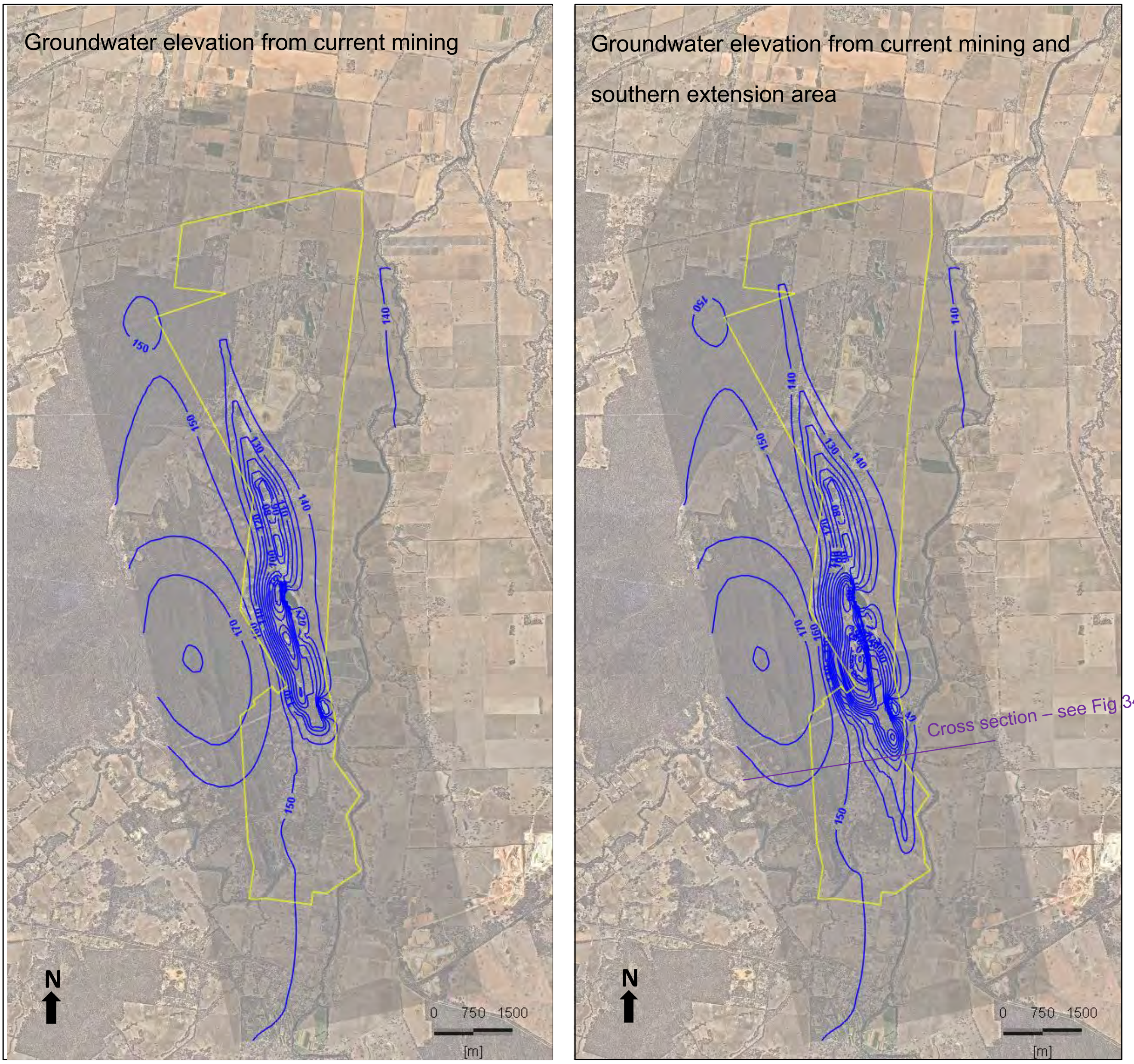

Figure 33: Simulated groundwater level (mAHD) for current day (left) and end of mining (right) in the southern extension area

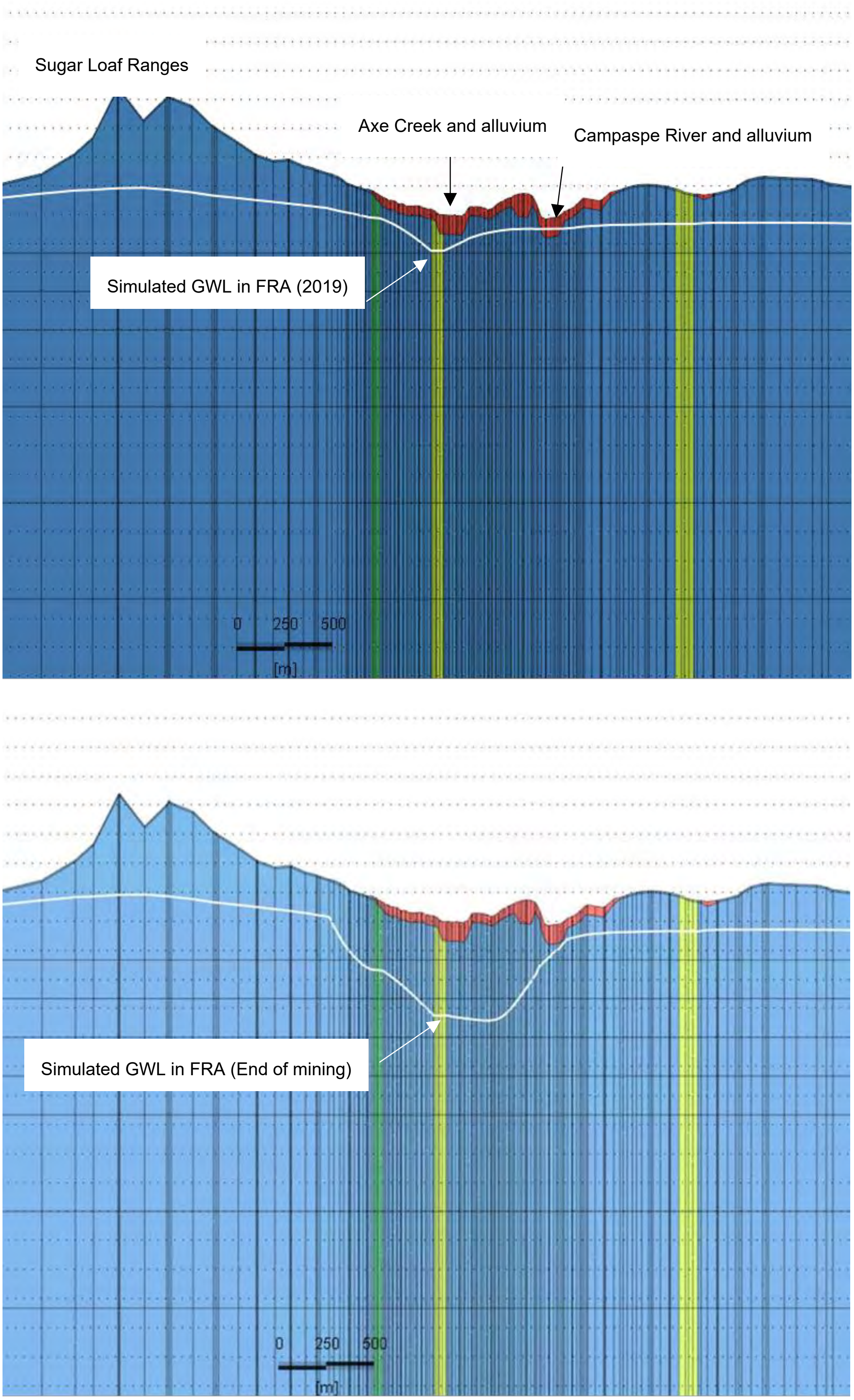

Figure 34: Cross section showing simulated phreatic surface for current day conditions (top) and end of mining (bottom) in the southern extension area

7.2.2 Alluvium

A key aspect of this assessment was to determine the potential impact of the proposed southern mine extension on groundwater within the alluvium in proximity to the Campaspe River and Axe Creek.

The simulated saturated thickness in the alluvium representing current day mining (2019) and end of mining in the southern extension area (2024) are shown on Figure 35.

During the mining of southern extension area, the maximum reduction of saturated thickness of alluvium is simulated to occur in a localised area near the confluence of Axe Creek and Campaspe River where the mine passes beneath the creek at an RL of -970 m AHD. At the time of model development, the saturated thickness of alluvium along the Axe Creek was estimated to be in the order of 5 m, which is simulated to become desaturated across a localised area, as is evident from inspection of Figure 35. However, recent drilling investigations (from December 2019) revealed that the alluvium is unsaturated at the drilled location (BGL94), next to Axe Creek.

Most of the alluvium is simulated to experience drawdowns of less than 1 m throughout mining in the southern extension area.

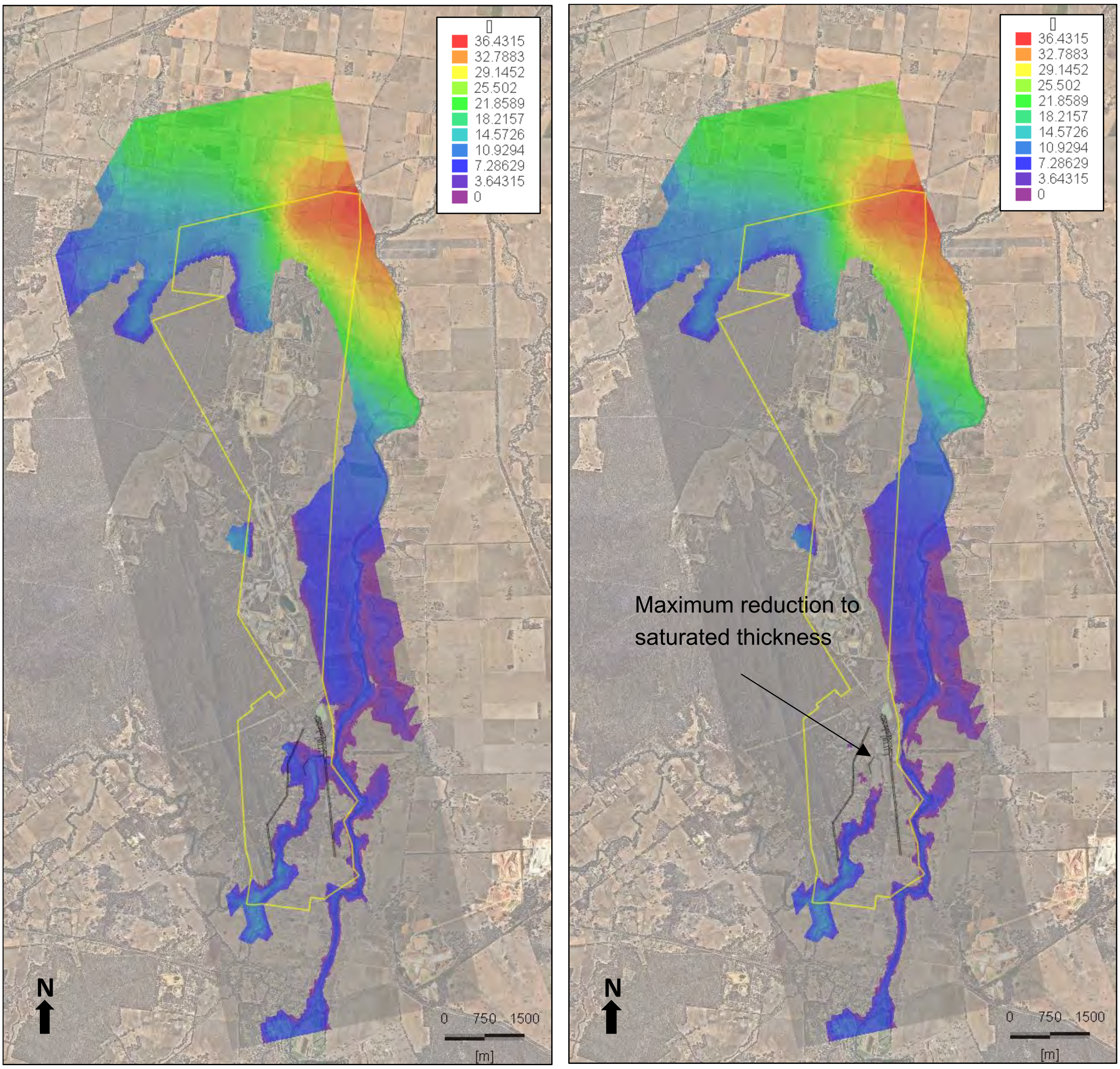

Figure 35: Predicted saturated thickness of the alluvium aquifers for current day and end of mining in the southern extension area

7.3 Baseflow

Flows to Campaspe River are dominated by water release from Lake Eppalock and the Campaspe River is generally known to lose water to the alluvial and FRA groundwater systems.

Within the reach passing through the model domain, groundwater levels were observed to be similar or slightly higher than river levels, which suggest there could be areas where there is baseflow to the Campaspe River and Axe Creek (see section 4.5).

The model results show the lowering of groundwater levels in the FRA result in some reduction in baseflow to the Campaspe River and Axe Creek. The predicted impact (shown on Figure 36) is a very small reduction in baseflow contribution to the Campaspe River (from 0.45 ML/d to 0.29 ML/d) and Axe Creek (from 0.08 ML/d to <0.01 ML/d) from past and future underground mining phases.

Model results show the overall baseflow contribution and reduction to baseflow is negligible in comparison to overall measured flows in these watercourses, representing 0.03% of average flows (480 ML/d) for the Campaspe River and 0.2% of average flows (30 ML/d) to Axe Creek.

Overall falling groundwater levels in the FRA would have little impact on flow over this reach of the Camapspe River.

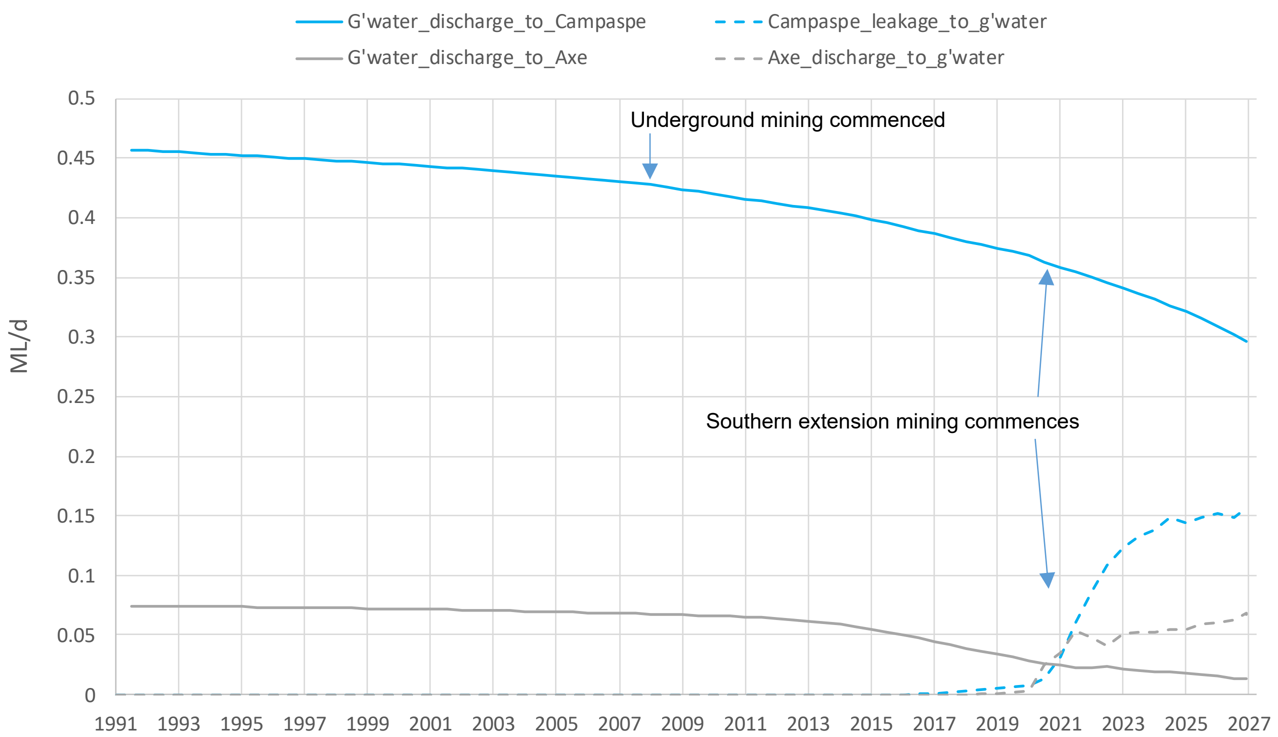

Figure 36: Groundwater interaction (inflow/outflow in ML/d) with the Campaspe River and Axe Creek

7.4 Risk to groundwater dependent ecosystems

Whilst the presence of GDE's have not been confirmed, DSE 2010 suggest that riparian GDE's are likely to exist along watercourses, such as River Red Gums along the Campaspe River, accessing shallow groundwater. GDE's are unlikely to be supported by groundwater from the underlying FRA.

Regulation of the Campaspe River can influence shallow water levels in the alluvium and leakage is controlled by underlying clays and upper weathered zone in the FRA. This suggests there is little risk to riparian vegetation from season groundwater pumping (DSE, 2012). The report also suggest non-regulated streams may also have some riparian GDE's, but they are less sensitive to groundwater system changes.

The modelled lowering of groundwater levels will not impact surface water flows and is unlikely to reduce water availability to any potential GDE's associated with these watercourses. Notwithstanding the above, a reduction in saturated thickness to the shallow alluvium was predicted near Axe Creek (Figure 35), however a field investigation involving the drilling of paired monitoring bores (BGL93 and BGL94) revealed the depth to water in the FRA is too deep to be interacting with overlying watercourses and overlying alluvium is unsaturated (dry to 8 m). Further discussion is provided in section 9.

The recent desktop study commissioned by FGM to assess the potential presence of Stygofauna in MIN5404 and the surrounds (Stygoecologica, 2019) show the natural conditions in the FRA are considered unsuitable to the existence and maintenance of stygofauna. Further work has been commissioned to investigate their presence in the shallow alluvium aquifer, however the main risks to stygofauna (such changes to water table levels, water table fluctuations, river baseflow and natural changes to groundwater salinity) due to mining influences have not been observed in FGM alluvium monitoring bores to date. Likewise, predictive modelling shows that alluvium (where saturated) will experience a temporary drawdown of < 1 m, with no measurable impact to river baseflows.

7.5 Post mining groundwater risk

7.5.1 Groundwater level recovery

The groundwater contours simulated at 100 years post mining are presented on Figure 37. They show in the current underground mining area, the groundwater recovery is predicted to be slow and the cone of drawdown around Ellesmere and Falcon pits is expected to persist for some time. Ellesmere and Falcon pits will behave as a groundwater sinks, owing to evaporation for the foreseeable future and control migration of groundwater and potential contaminants leaching from flooded mine voids (assessed under section 7.5.2 below).

Groundwater levels in the southern extension area recover to about 144 m AHD, which is about 1 m to 2 m below pre mining groundwater levels. The phreatic groundwater levels representing 5 years, 10 years, 30 years and 100 years post mining are also shown on east to west cross section, which spans across the southern extension area (Figure 38 and Figure 39).

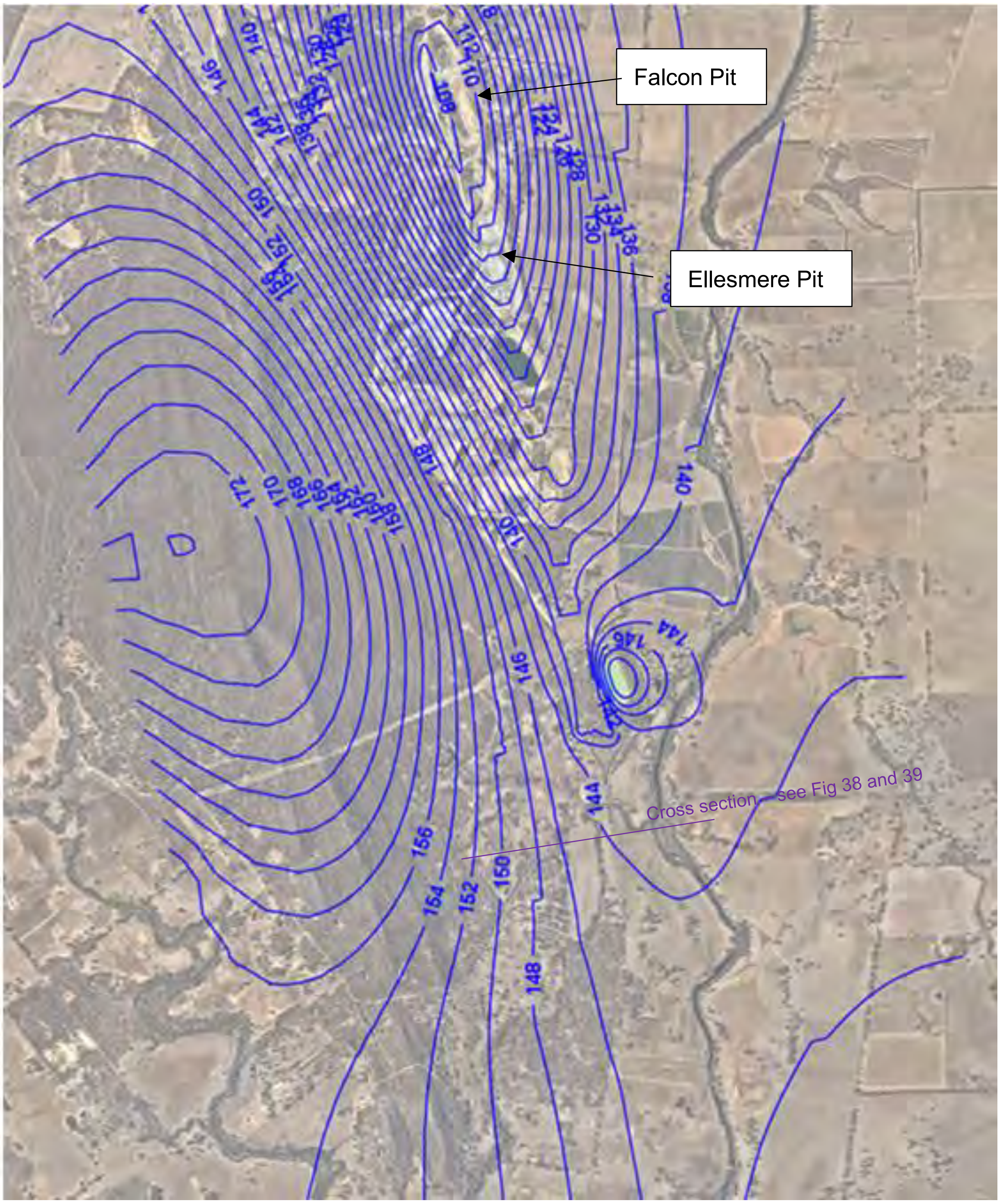

Figure 37: Groundwater contours 100 years post mining (m AHD)

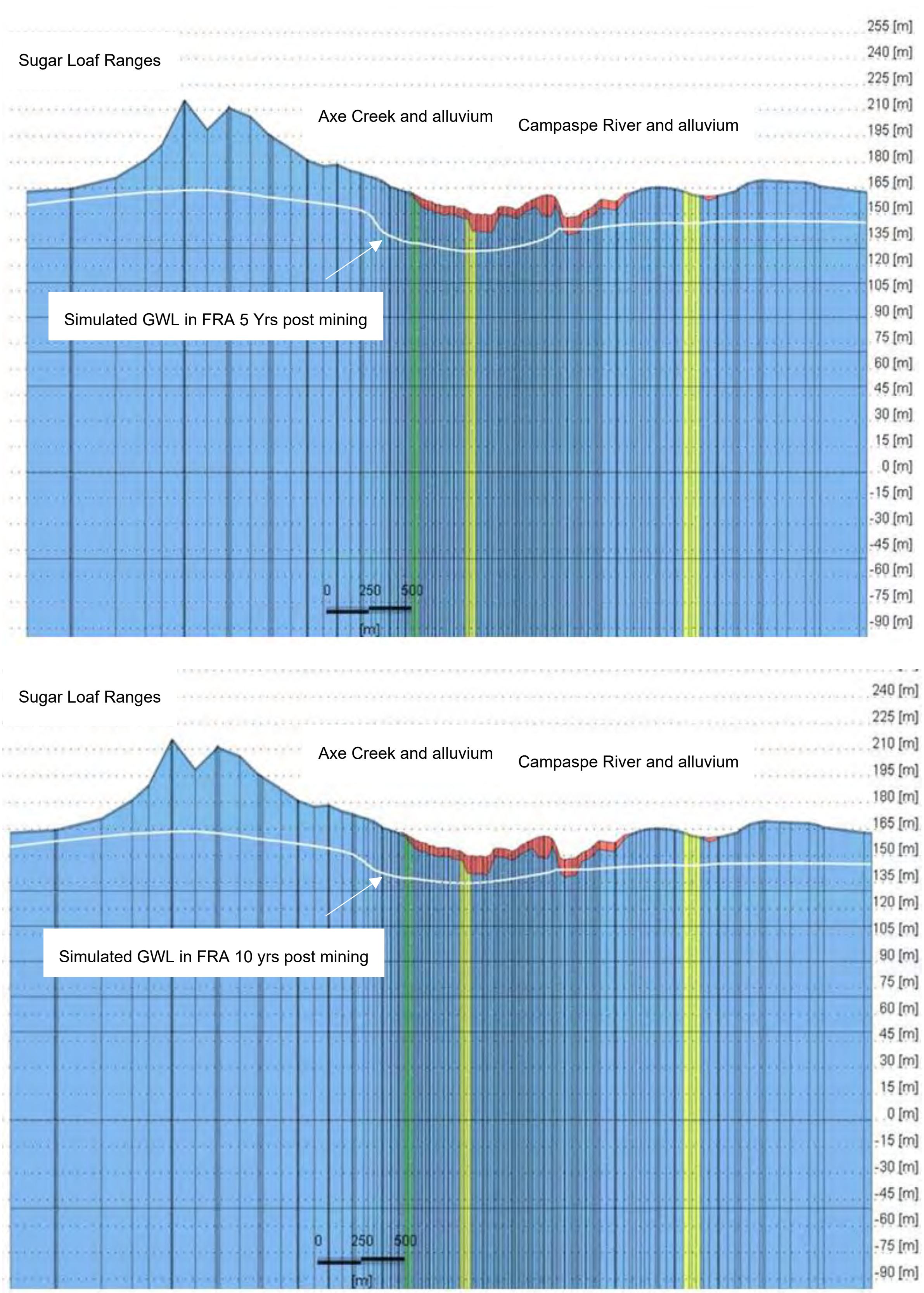

Figure 38: Groundwater level recovery at 5 years (top) and 10 years (bottom) post mining

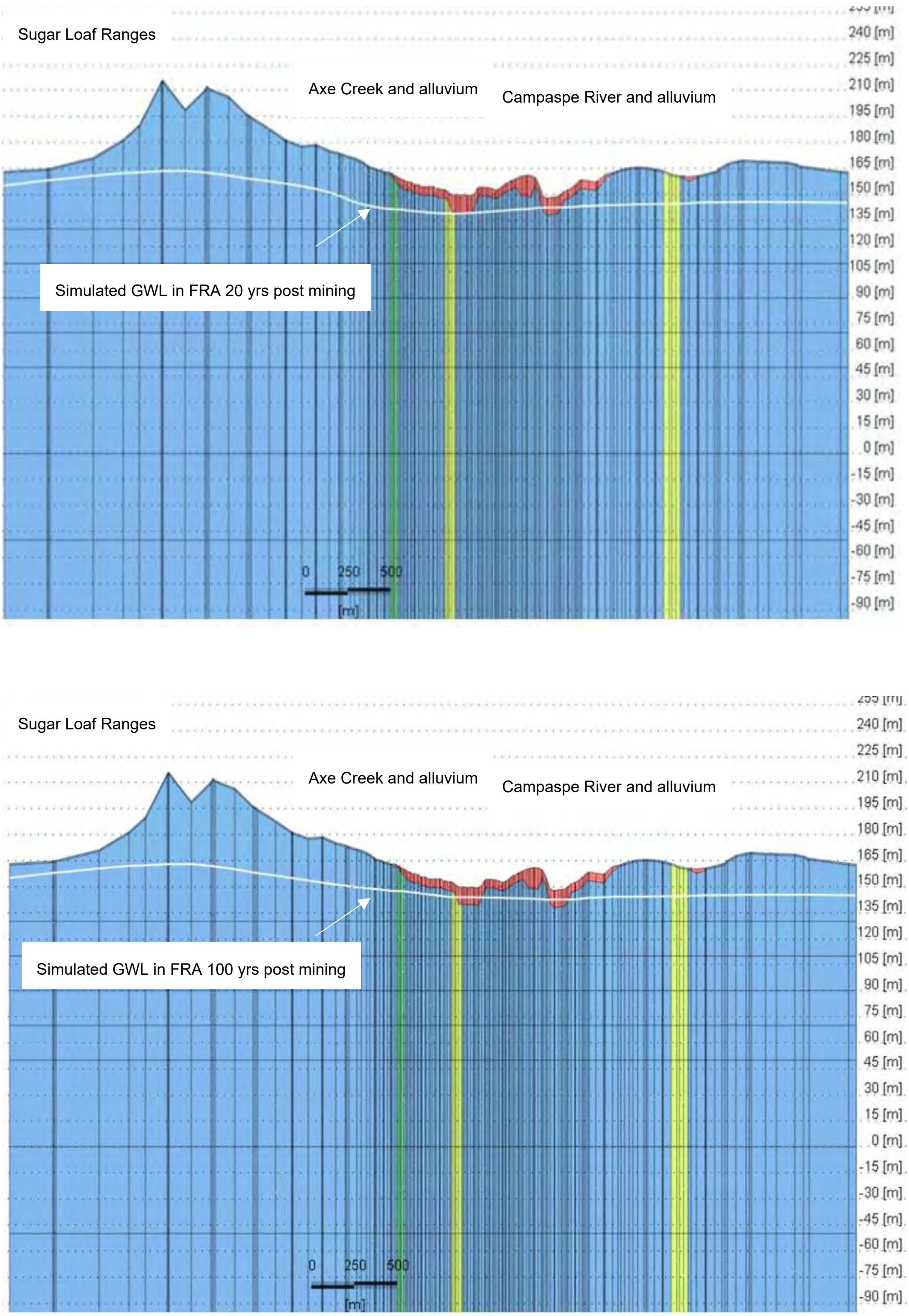

Figure 39: Groundwater level recovery at 20 years (top) and 100 years (bottom) post mining

7.5.2 Post mining water quality risk

Assessment of water quality risk from groundwater exposed to paste back fill and mine workings

The post mining water quality risks of groundwater exposed to paste backfill in the underground mine has been assessed previously by EGI (EGI, 2018), together with groundwater simulations of elemental leaching (focusing on Sb and As release) of paste fill being undertaken by Golder, 2018. Source concentrations of contaminates in mine water (from elemental leaching) were derived from paste leach tests, which showed dissolved concentrations in the eluents ranged from 0.07 mg/L to 1.1 mg/L for As and 0.20 mg/L to 1.13 mg/L for Sb.

The potential release of contaminants from groundwater interaction with cemented backfill or mine workings have not been assessed however key groundwater pumped from the mine shows evidence of elevated Sb (4.4 mg/L) and As (0.23 mg/L) concentrations in groundwater. In contrast, the mine water porduced from the southern extension exploration drive has to date revealed mush lower concentrations of Sb (0.001 mg/L to 0.004 mg/L) and As (0.002 mg/L to 0.003 mg/L). These metals are also naturally present in the native groundwater at concentrations which exceed the ANZECC (2000) guideline for aquatic ecosystems (Table 2). Table 2 also showed that all other dissolved metals in mine water were generally low in concentration and are similar to concentrations in native groundwater.

Furthermore, the FGM monitoring program includes acid-base accounting of waste rock samples and kinetic column leach tests, which to date has shown the waste rock generated from underground mining is non-acid-forming. There is high sulphur content black shale material however, column leach data from one sample has not indicated significant concentrations of antimony or arsenic were being leached from the sample and the pH has remained circumneutral to date (EGI, 2019). Black shale material is intercepted in relatively low volumes during mining and therefore presents a low risk.

Model simulation of post mining water quality

The post mining model simulations of mine water quality reported in Golder 2018 was essentially extended to assess post mining water quality risk in the southern extension area. The potential post mining effects of groundwater interaction with mine workings, backfill areas (including paste fill areas) on the surrounding aquifer was simulated by assigning a constant mass-concentration boundary conditions to model nodes representing mine void at the end of mine life. The concertation applied to the model nodes was an arbitrary value of 100 with ambient aquifer salinity of zero, thus the degree to which groundwater from the mine area is predicted to change the ambient groundwater quality is presented in a range from 0 to 100 percent of the mine water quality.

The simulated migration and travel times account only for advective transport and do not account for other processes governing contaminant transport (e.g. sorption). Figure 40 and Figure 41 shows that the influence of mine water quality on surrounding groundwater are low, overall there is little movement of potential contaminant in mine water out of the mine area after 100 years with the 5% contour extending a distance of ~50 m from the mine. Post mining groundwater elevation contours are also shown for reference. An important consideration is that the concentration predicted at significant depth (500 m bgl to 1,100 m bgl) in the FRA. Figure 41 shows there is little vertical movement towards the shallower part of the FRA (remaining at depths deeper than 500 m bgl) and therefore no foreseeable risk post mining to the Campaspe River, Axe Creek and associated alluvium.

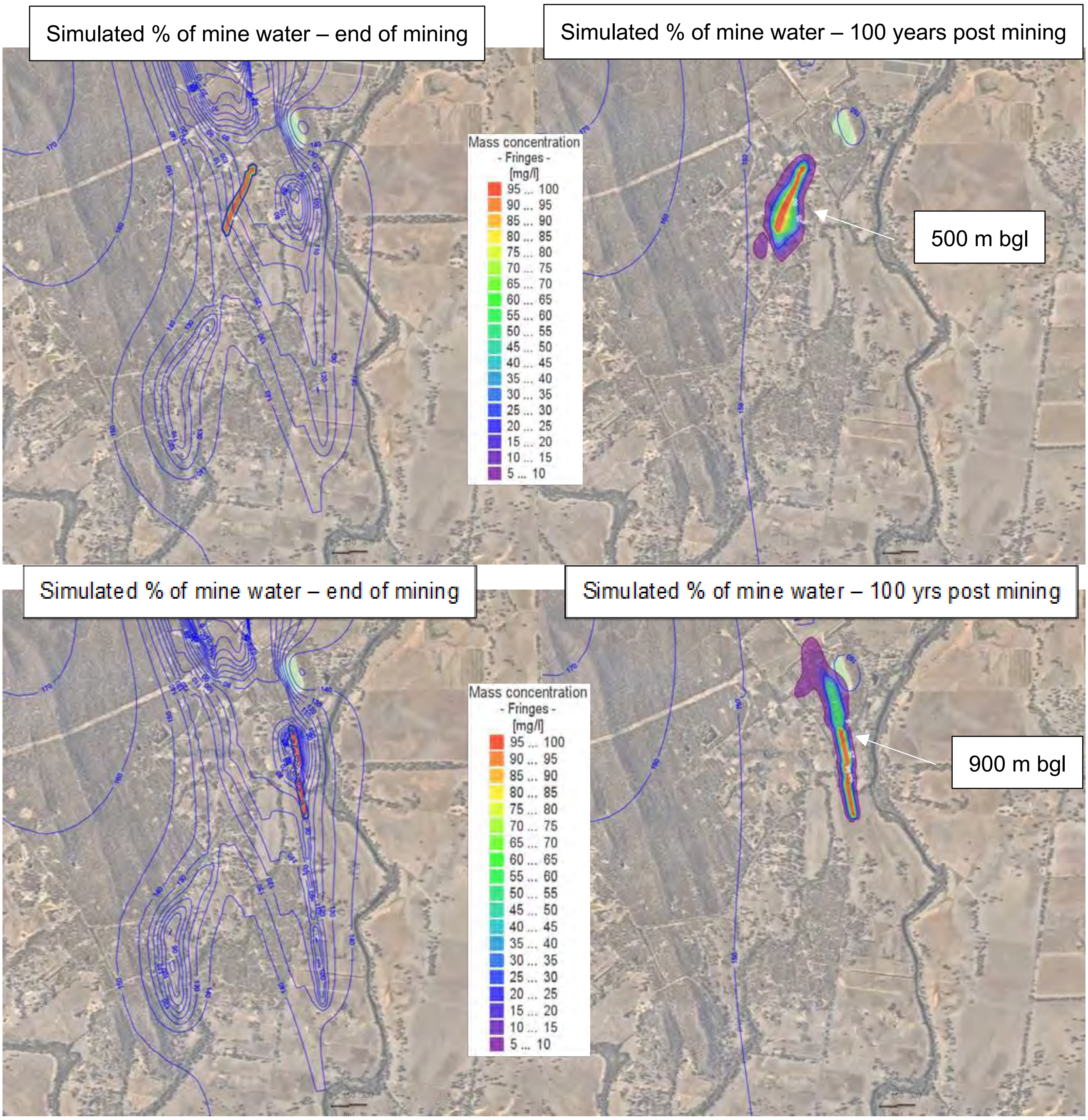

Figure 40: Mine water migration at end of mining and 100 years post mining, shown as a percentage of mine water

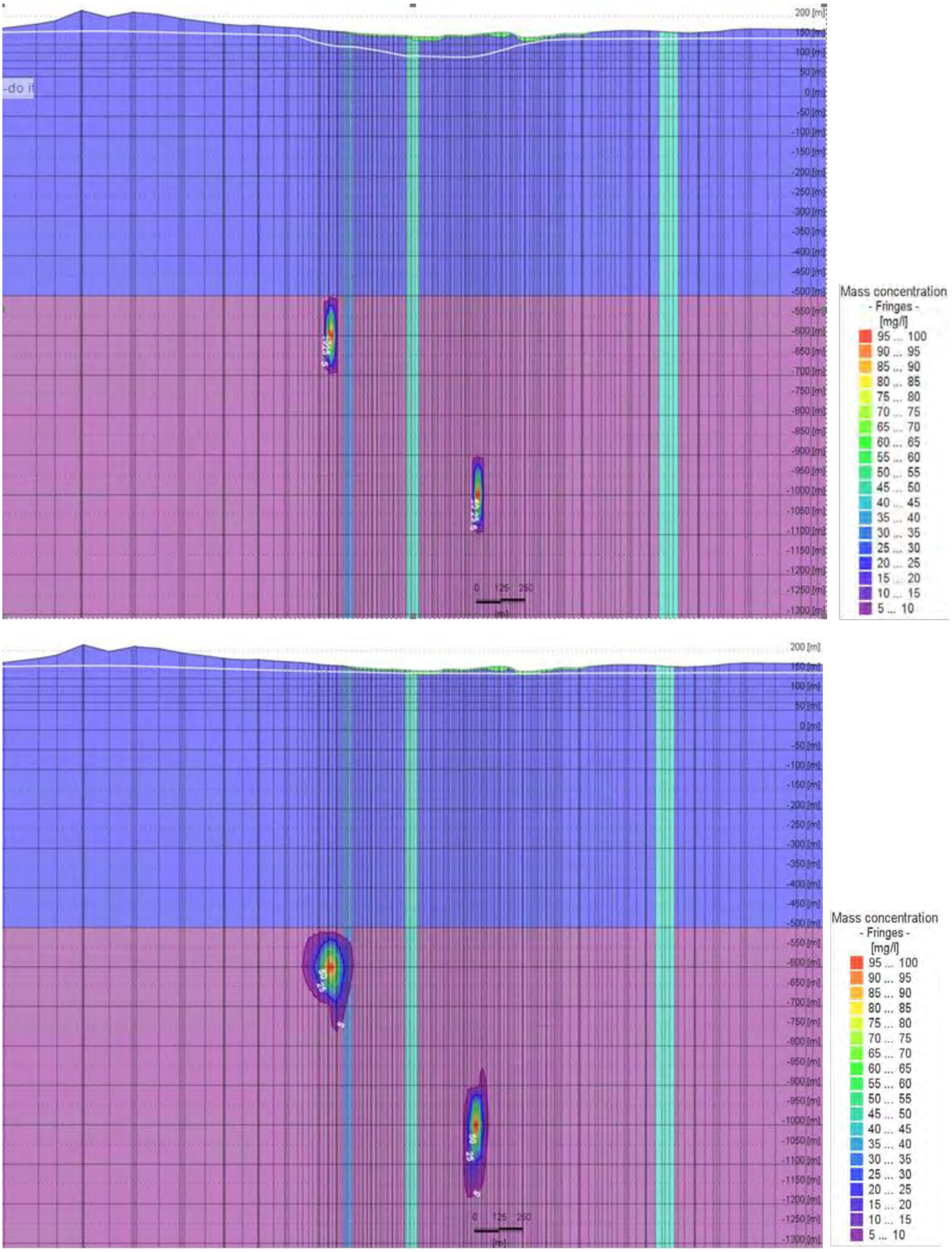

Figure 41: Post mining groundwater migration from the underground mine, shown for end of mining (top) and 100 years post mining (bottom)

8.0 MODEL LIMITATIONS

The model developed and presented in this report represents an approximation of the groundwater flow system for the study area. The groundwater level coverage and historical level data is limited over the study area and is generally concentrated in the vicinity of the current mine areas. The available data, however, is considered to be sufficiently detailed to allow the conceptual model to be developed and risks associated with the proposed extension to be better understood.

The main limitations of the model are considered to be as follows and the results from this model should be considered with these limitations in mind:

- The groundwater level coverage was limited to the area in the vicinity of the current mine area. A number of the bores have been installed in the alluvium and FRA near the southern extension area, however groundwater level measurements for of some wells were recorded only after the commencement of underground mining operations. The influence of past mining on groundwater levels in this southern area has not been determined.
- The vertical extent of the model was limited to a minimum elevation of RL -1600 m AHD, which is about 180 m below the deepest mining level currently proposed for the southern mine extension. The vertical flux from below this depth was assumed to be insignificant and therefore was not considered in the model.
- No hydraulic testing data were available for the alluvium and FRA (faulted and non-faulted areas) near the southern extension area. The assignment of aquifer properties in this area (during the model recalibration process) was guided by the assumption that these properties are similar to those in the existing mine areas.
- No data (pre-mining or current) were available for groundwater baseflow to creeks and local drainage lines within the study area. However, existing surface water monitoring indicates that creeks are dominated by surface flows.
- The FRA was represented in the model as an effective porous medium, which is a common approach for regional modelling. No discrete linear elements were included in the model to simulate individual fractures. Representation of the major faults as distinctive vertical parameter zones is a simplified approach to the angled faults and fault zones.
- The mining plan was simulated as a top-down operation and as such it was simulated to occur through the full thickness of the model layers. The underground mining operation, however, includes access drives, stopes/voids, shafts and declines with intact rock remaining between individual underground mine elements/levels. The mine plan adopted for the hydrogeological model presents a simplified version of the southern mine extension, based on the best available information at the time of reporting.
- Mine inflows into new extension area are uncertain as hydraulic properties of faulted and non-faulted areas have not been assessed through hydrogeological investigations.
- An uncertainty analysis has not been undertaken.

Notwithstanding the above limitations, the modelling work completed is considered to be adequate for an assessment of potential effects of the southern mine extension on the groundwater and surface waters within the study area. Further validation is recommended as additional monitoring bores are installed and during the mining operation. This is discussed further under section 9.

9.0 MONITORING AND MANAGEMENT

9.1 Groundwater model development and verification

The groundwater model has been developed as a tool to inform groundwater related risk and was last recalibrated as part of this scope of work. Circumstances which may trigger further development or refinement of the groundwater model include:

- A significant change to the mine plan.
- Acquisition of new hydrogeological information, such as groundwater levels and aquifer properties (i.e. hydraulic conductivity) which are different to calibrated values used in the model; and
- Groundwater drawdown and inflows which significantly exceed model predictions for that stage of mining.

Furthermore, after the first year of mining in the southern extension area, a comprehensive review of the performance of the groundwater system will be undertaken. This will include re-running the groundwater model in transient calibration mode, to verify that the actual inflow rates and groundwater level impacts are in accordance with the model predictions described in this report. If necessary, further adjustment would be made to the model at that time, and new forward predictions of mine inflows and water level impacts would be undertaken.

9.2 Impact assessment criteria

Impact assessment criteria are recommended for:

- Mine inflow rate
- Mine inflow water quality
- Near surface groundwater levels, in particular groundwater levels near Campaspe River
- Watercourses
- Impacts on surficial groundwater levels and/or creek base flows
- Impacts on existing licensed groundwater users (private bores)

In the event of any adverse impacts or water quality degradation beyond predictions in the groundwater assessment, FGM will commission an assessment of the causes, will develop a staged response to mitigate the adverse impacts, and will attempt to establish and implement measures to limit further adverse impact.

9.3 Trigger action and response plan

The identification process and response protocols to potential adverse outcomes are provided in the trigger action response plan (TARP) provided in Table 2. The responses proposed incorporate a staged assessment and development of management measures deemed appropriate for each individual event should it occur.

The groundwater model and more recent monitoring data provide guidelines for trigger levels and take into account predicted responses to mining. Specific trigger levels have been designed to alert FGM to observed parameter responses which are outside of normal variation and/or predicted responses, or where observed parameter values do not follow anticipated trends.

The Trigger Action Response Plan (TARP) provides appropriate triggers and corresponding response actions for prevention or mitigation of adverse impacts to nearby water users or the natural environment as a result of mining.

The monitoring program has been designed to detect changes to groundwater levels, groundwater quality or inflow rates, or to indicate that an abnormal condition relating to mining has developed.

Trigger levels have been set for particular impacts at which a response is needed, and to help define an appropriate response in each case (Table 3).

Aspects assessed to be at risk (section 7.0 of this report) and fully explored These include both predicted and unpredicted impacts, and include:

- Groundwater level.
- Groundwater quality.
- Hydraulic connection to Axe Creek and Campaspe River.
- Groundwater users (Private Bores).
- Mine water quality and acid-base accounting of waste rock samples and kinetic column leach tests

Table 3: Trigger action and response plan

Aspect	Parameter	Purpose	Trigger	Action	Response
Mine inflows	Flow rate	Identify unexpected high mine inflows and determine whether this will impact on near-surface groundwater or existing users in the FRA	Sudden inrush of groundwater into underground workings An observed inflow rate 50% in excess of the predicted flow rate at any stage during the mine life sustained for 3 consecutive months	Refer matter to hydrogeologist for review. Commence more frequent monitoring of inflow rate, inflow water quality and groundwater levels	Identify, investigate and report on drawdown impacts to existing users and watercourses. Recalibrate groundwater model and revise groundwater model predictions of inflows and groundwater drawdown

Aspect	Parameter	Purpose	Trigger	Action	Response
Mine inflows	Mine inflow water quality	Identify changes to the source of inflows Identify changes to mine water from possible groundwater interaction with mine walls, backfill areas Provide a leading indicator for potential mine water quality post mining	Changing trend in measured parameters (such as TDS, pH, metals, sulphate, NO3)	Refer matter to hydrogeologist for review. Commence more frequent monitoring of inflow rate, inflow water quality and groundwater levels	Identify investigate and report on water quality impacts
Groundwater monitoring	Groundwater level	To identify any water level impacts	FRA: An observed drawdown of 5 m in excess of the predicted drawdown at any stage during the mine life Alluvium: An additional drawdown of 1m relative to the predicted drawdown in the near surface groundwater levels	Repeat water level monitoring to confirm. Refer the matter to an independent hydrogeologist for review	Identify, investigate and report on drawdown impacts to existing users and creeks. Recalibrate groundwater model and revise groundwater model predictions

Aspect	Parameter	Purpose	Trigger	Action	Response
Groundwater monitoring	Groundwater quality (major ions, metals, filed parameters and nutrients)	To identify any water quality Impacts from the mining operation Maintain beneficial use category	Changing trend in measured parameters outside limits of baseline levels	Confirm trends by repeating water level sampling of impacted and adjacent bores as required. Engage a hydrogeologist to undertake a preliminary investigation and report on any identified changes.	Where investigations determine that impacts are the result of FGM operations or may potentially impact on adjacent bores or surface water users, inform landholders, relevant agencies on results of investigation Undertake investigation and assess possible mitigation measures in consultation with landholders and relevant agencies
Licensed groundwater users	Groundwater level	Ensure the landholder maintain the ability to use groundwater	FRA: An observed drawdown of 5 m in excess of the predicted drawdown in any monitoring bore at any stage during the mine life	Repeat water level monitoring to confirm. Refer the matter to an independent hydrogeologist for review Recalibrate groundwater model Assess the ability of landholder to access water (undertake pumping test)	Where investigations determine that impacts are the result of FGM operations or may potentially impact on adjacent bores Consider: 1) Supply landholder with water 2) Deepen bore 3) Drill new bore

Aspect	Parameter	Purpose	Trigger	Action	Response
Baseflow	Groundwater levels in the FRA and alluvium near watercourses	Hydraulic connection to watercourses	A water table drawdown in the alluvium in excess of 1 m of the predicted drawdown.	Repeat water level monitoring to confirm. Refer the matter to an independent hydrogeologist for review Recalibrate groundwater model	Inform relevant agencies of results of investigation

10.0 SUMMARY AND CONCLUSIONS

Fosterville Gold Mine plan to extend their existing underground mining operation towards to the south. Mining will occur in the FRA at depths of about 600 m bgl to 1600 m bgl over a period of 5 years. The proposed mine will pass beneath the Axe Creek at a depth of about 970 m bgl. Potential impacts on the Axe Creek and adjacent Campaspe River were therefore key considerations of this groundwater assessment.

Potential impacts of the southern underground mine extension on groundwater and surface water resources and other groundwater users, were assessed on the basis of groundwater modelling.

A transient groundwater flow model was designed to predict the cumulative impacts from all current mining operations and future mining of the southern extension area, each operating concurrently in accordance with their respective mine plans. The model predictions were made based on hydrogeological assumptions from past investigations undertaken onsite.

A key aspect of this assessment was to determine the potential impact of the proposed mining in the southern extension on groundwater in the alluvium, within the confines of the Campaspe River and Axe Creek. During the mining of southern extension area, the maximum reduction to saturated thickness in the Campaspe River and Axe Creek alluvium was predicted to occur in a very localised area near the confluence of Axe Creek tributary and Campaspe River (where the mine passes beneath the creek), however recent drilling in this area revealed that the alluvium near Axe Creek was currently unsaturated. Elsewhere, the alluvium should experience drawdowns of less than 1 m throughout mining in the southern extension area.

Larger drawdowns to groundwater levels are predicted to occur within the underlying FRA, which will be depressurised during mining. The extent of predicted drawdowns as a result of depressurisation is predicted to be quite localised and will be generally contained within the mine lease boundary. Groundwater level declines in three private bores situated within the extended mining lease were predicted to range from 2 m to 10 m.

The modelled lowering of groundwater levels in the FRA result in some reduction in baseflow to the Campaspe River and Axe Creek, however, flows in these watercourses are dominated by surface water rather than groundwater and associated ecosystems will not be impacted. Recent field investigations have established current groundwater levels in the FRA beneath Axe Creek are too deep to be interacting with the watercourse, reaffirming that Axe Creek will not be impacted by lowering groundwater levels in the FRA.

In the case of the Campaspe River, flows are regulated by release from Lake Eppalock, which has effectively turned this River into a perennial system. The predicted effect from both past and future underground mining phases is a very small reduction in baseflow contribution to the Campaspe River (from 0.45 ML/d to 0.29 ML/d) and Axe Creek (from 0.08 ML/d to <0.01 ML/d). Model results show the overall baseflow contribution and reduction to baseflow is negligible in comparison to overall measured flows in these watercourses, representing 0.03% of average flows (480 ML/d) for the Campaspe River and 0.2% of average flows (30 ML/d) to Axe Creek. Modelling shows lowering of groundwater levels will not impact surface water availability.

The recent desktop study commissioned by FGM to assess the potential presence of Stygofauna in MIN5404 and the surrounds show the natural conditions in the FRA are considered unsuitable to the existence and maintenance of stygofauna. Further work has been commissioned to investigate their presence in the shallow alluvium aquifer, however the main risks to stygofauna (such changes to water table levels, water table fluctuations, river baseflow and natural changes to groundwater salinity) from mining influences have not been observed in FGM groundwater monitoring bores to date.

Modelled groundwater inflows into the mine were predicted to increase by 1 ML/d, however inflow estimates are uncertain as the hydraulic properties of the FRA around the southern mining area have not been evaluated.

The groundwater recovery post mining is predicted to be slow and the cone of drawdown around Ellesmere and Falcon pits is expected to persist for some time. Ellesmere and Falcon pits will behave as a groundwater sinks, owing to evaporation for the foreseeable future and control the migration of groundwater and potential contaminants leaching from flooded mine voids. Groundwater levels in the southern extension area were predicted by modelling to recover to < 2 m below pre mining groundwater levels.

The influence of mine water on surrounding groundwater quality was predicted to be low. Overall modelling showed little movement of mine void water out of the mine area after 100 years. An important consideration is that groundwater interaction with the mine will occur at significant depth (500 m bgl to 1100 m bgl) in the FRA. There is little vertical movement towards the shallower part of the FRA (remaining at depths deeper than 500 m bgl) and therefore no foreseeable risk the Campaspe River, Axe Creek and associated alluvium.

11.0 RECOMMENDATIONS

FGM currently maintain an extensive groundwater and surface water monitoring program to monitor the condition of groundwater and surface water resources and detect responses to current mining operations. FGM currently undertake routine reviews of their groundwater monitoring program to ensure it remains effective and to identify opportunities to install additional monitoring bores in key areas as mining operations advance. It is recommended that groundwater monitoring network continue to be extended as mining progresses southward, and ongoing reviews of groundwater monitoring data be undertaken to detect potential impacts and validate the groundwater model.

As mining progresses, additional installations of paired monitoring bores targeting the FRA and alluvial aquifers are recommended . The final monitoring bore locations will be subject to landholder access and consent. Where possible, stream gauging of water levels in the Axe Creek and Campaspe River should also be undertaken for comparison against groundwater levels in the alluvium and FRA. It is also recommended that groundwater levels in new monitoring bores and surface water levels be used to validate the current conceptual and numerical groundwater models.

Field investigation may be required to determine the presence of any high value riparian GDE’s in areas along watercourses where a reduction to saturated thickness may occur.

The results of the stygofauna desktop assessment showed the natural conditions in the FRA are considered unsuitable to the existence and maintenance of stygofauna, however further field sampling of the alluvial aquifer has been recommended.

To assess the available drawdown in private bores, the current pump installation depth and depth to water in these wells should be determined. Where water levels cannot be determined, FGM may consider installation of additional monitoring bores to detect groundwater level impacts to these wells during mining. This too will be subject to landholder access and consent.

The permeability of the faulted areas in the southern extension area may be investigated and compared to modelled values. Aquifer permeabilities, which are higher than modelled values, may lead to higher groundwater inflows than what has been predicted by the model.

A critical aspect of the proposed monitoring will be the verification of groundwater model predictions (within acceptable limits or errors). Monitoring is essential to reduce risk to potential groundwater related receptors, but also needed for verification against predicted (modelled) trends. Where this is not observed to be the case, recalibration of the groundwater model or investigations may be required to verify that the risk have not altered from model predictions. If necessary, further adjustment would be made to the groundwater model at that time, and new forward predictions of groundwater level impacts would be undertaken. Circumstance where recalibration of the model is needed include:

- Mine inflows are substantially higher than those predicted by the model, as this could suggest a groundwater impacts which is greater than predicted.
- There was significant deviation in observed in groundwater level response from the predicted response.

Where significant deviation is observed, recalibration of the model may be required to verify that the risk have not materially altered from model predictions described in this report. If necessary, further adjustment would be made to the model at that time, and revised forward predictions of groundwater quality and groundwater level impacts would be undertaken. The above monitoring and model validation should be incorporated into the annual groundwater monitoring review that is initiated by FGM.

12.0 IMPORTANT INFORMATION

Your attention is drawn to the document – "Important Information", which is included in Appendix A of this report. The statements presented in this document are intended to advise you of what your realistic expectations of this report should be. The document is not intended to reduce the level of responsibility accepted by Golder Associates, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

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Signature Page

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APPENDIX A

Important Information

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