Australasian Groundwater & Environmental Consultants

Report on

Groundwater Technical Report for Moolarben UG4 LW401 to LW408 Extraction Plan

Prepared for
Moolarben Coal Operations Pty Ltd

Project No. MOO1622F.20
November 2021

ageconsultants.com.au

ABN 64 080 238 642

Document details and history

Document details

Project number	MOO1622F.20
Document title	Groundwater Technical Report for Moolarben UG4 LW401 to LW408 Extraction Plan
Site address	12 Ulan-Wollar Road, Ulan NSW 2850
File name	MOO1622F.20 - Report on Moolarben UG4 Extraction Plan V1.06.docx

Document status and review

Edition	Comments	Author	Authorised by	Date
v01.01	Uncompleted Draft for internal feedback	MS/TD	AD	17/09/2021
v01.02	Uncompleted Draft for internal feedback	MS/TD	AD	13/10/2021
v01.03	Draft Report	MS/TD	AD	23/10/2021
v01.04	Draft Report	MS/TD	AD	2/11/2021
v01.05	Draft Report	MS/TD	AD	3/11/2021
v01.06	Final Report	MS/TD	AD	4/11/2021

Australasian Groundwater and Environmental Consultants Pty Ltd

Brisbane Head Office
Level 2/15 Mallon Street
Bowen Hills QLD 4006
t: (07) 3257 2055

Newcastle
4 Hudson Street
Hamilton NSW 2303
t: (02) 4962 2091

Townsville
1/60 Ingham Road
West End QLD 4810
t: (07) 4413 2020

brisbane@ageconsultants.com.au
ageconsultants.com.au

Table of contents

Table of contents

List of figures

Table of contents

List of tables

List of appendices

Groundwater Technical Report for Moolarben UG4 LW401 to LW408 Extraction Plan

1 Introduction

Moolarben Coal Operations Pty Limited (MCO) operates the Moolarben Coal Complex (MCC), which is located approximately 40 kilometres northeast of Mudgee in New South Wales (Figure 1.1). MCO has been granted approval to develop Stages 1 and 2 of the Moolarben Coal Project (MCP) under the Environmental Planning and Assessment Act 1979. Approval for Stage 1 of the MCP (05_0117) was granted by the Minister for Planning on 6 September 2007. Approval for Stage 2 of the MCP (08_0135) was granted on 30 January 2015.

Project Approval (05_0117) has been subject to fifteen approved modifications, with Modification 15 granted in June 2020. The Approved Layout extent is consistent with the Project Approval (05_0117), as modified, with an extraction height of 3.0 metres.

The MCC includes four approved open cut mines, known as Open Cut 1 mine (OC1), Open Cut 2 mine (OC2), Open Cut 3 mine (OC3) and Open Cut 4 mine (OC4). The MCC also includes three approved underground mines and associated infrastructure (Figure 1.2), known as Underground Area 1 (UG1), Underground Area 2 (UG2) and Underground Area 4 (UG4).

The MCO commenced open cut coal mining from OC1 in May 2010 and underground mining in UG1 in 2016. MCO are currently preparing for commencement of underground longwall mining operations in UG4, and are currently preparing an 'Extraction Plan' for the extraction of Longwalls 401 to 408 within UG4. The layout of Longwalls 401 to 408 that incorporates minor shortening of lengths of extraction is referred to as the Extraction Plan Layout in this report (Figure 1.3).

Since the Stage 1 Approval in 2007, extensive additional environmental monitoring and studies have been undertaken in the Ulan Coalfields, including MCO's Underground 1 and neighbouring mining operations. The additional studies and monitoring data associated with the inter-mine data sharing have improved the understanding of the underground mining impacts. This contemporary knowledge, supplemented with targeted site surveys, underpins this technical report and the refined impact predictions, performance indicators, management and monitoring measures for the UG4 LW401 to LW408 extraction plan.

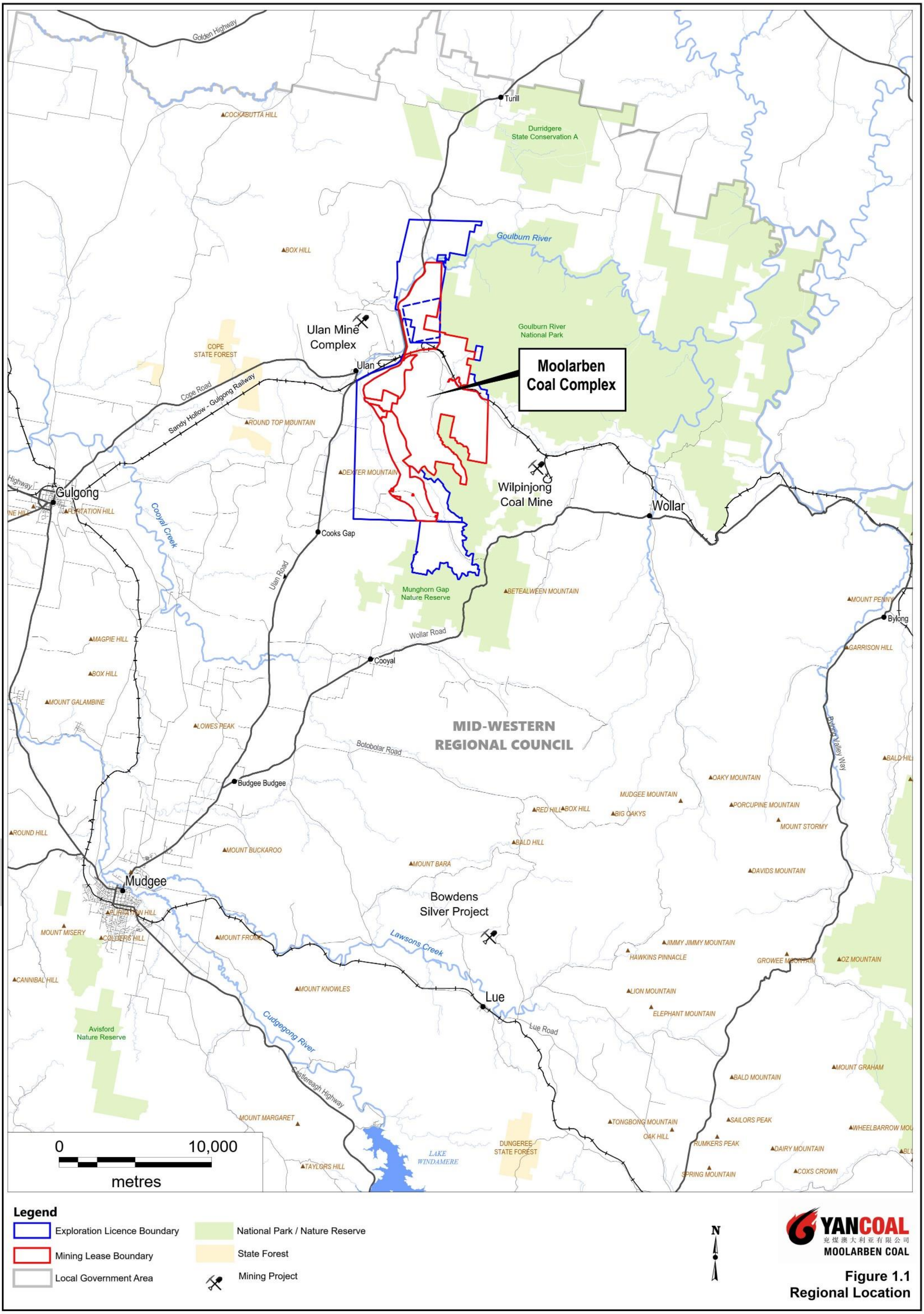
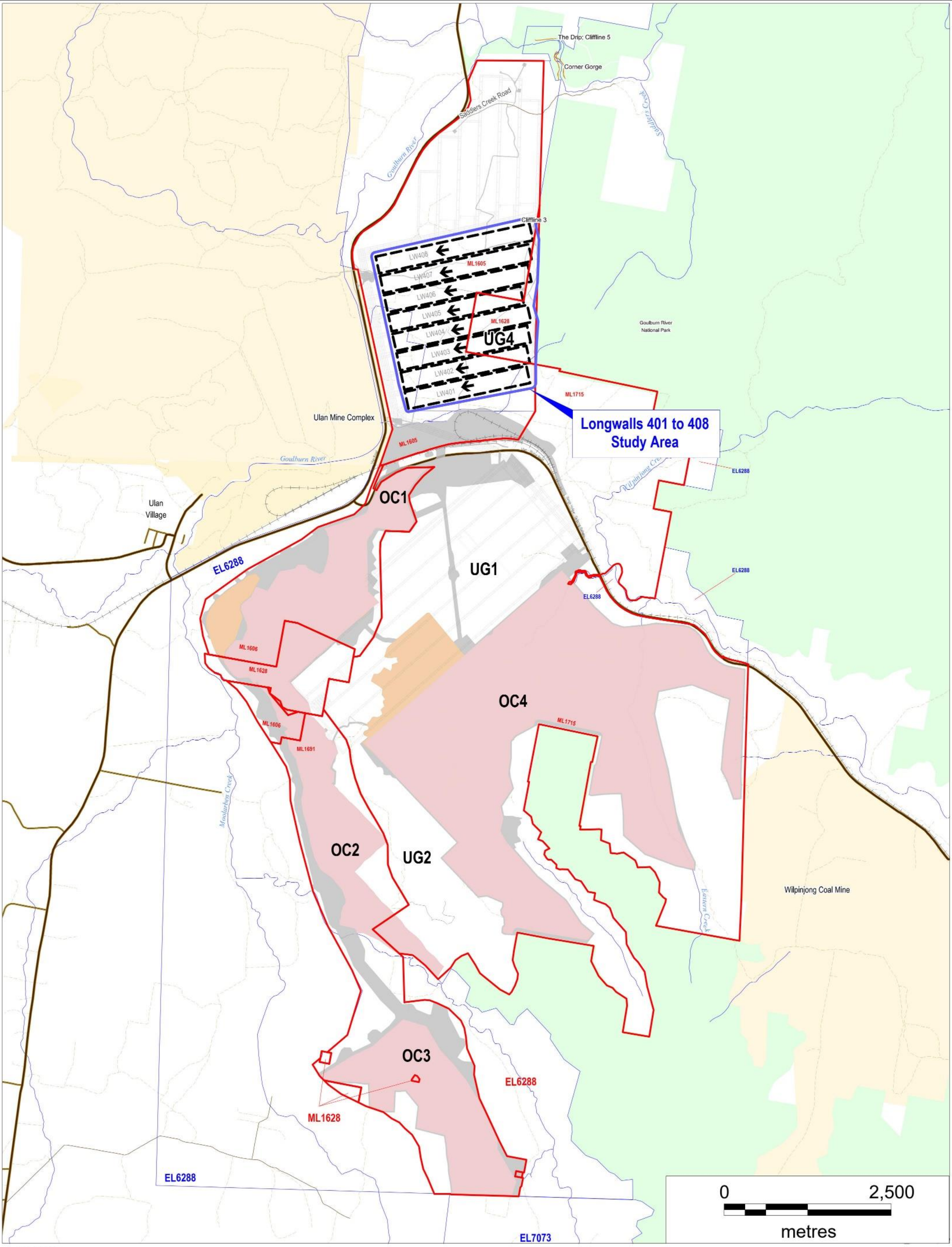


Figure 1.1
Regional Location



Legend

- Mining Lease Boundary
- Road
- Rail Line
- Watercourse
- National Park / State Conservation Area

Existing / Approved Development

- Open Cut Mining Area
- Underground Workings
- Surface Infrastructure
- Direction of Longwall Mining
- Out-of-Pit Emplacement

YANCOAL
MOOLARBEN COAL

Figure 1.2
Moolarben Coal Complex Layout

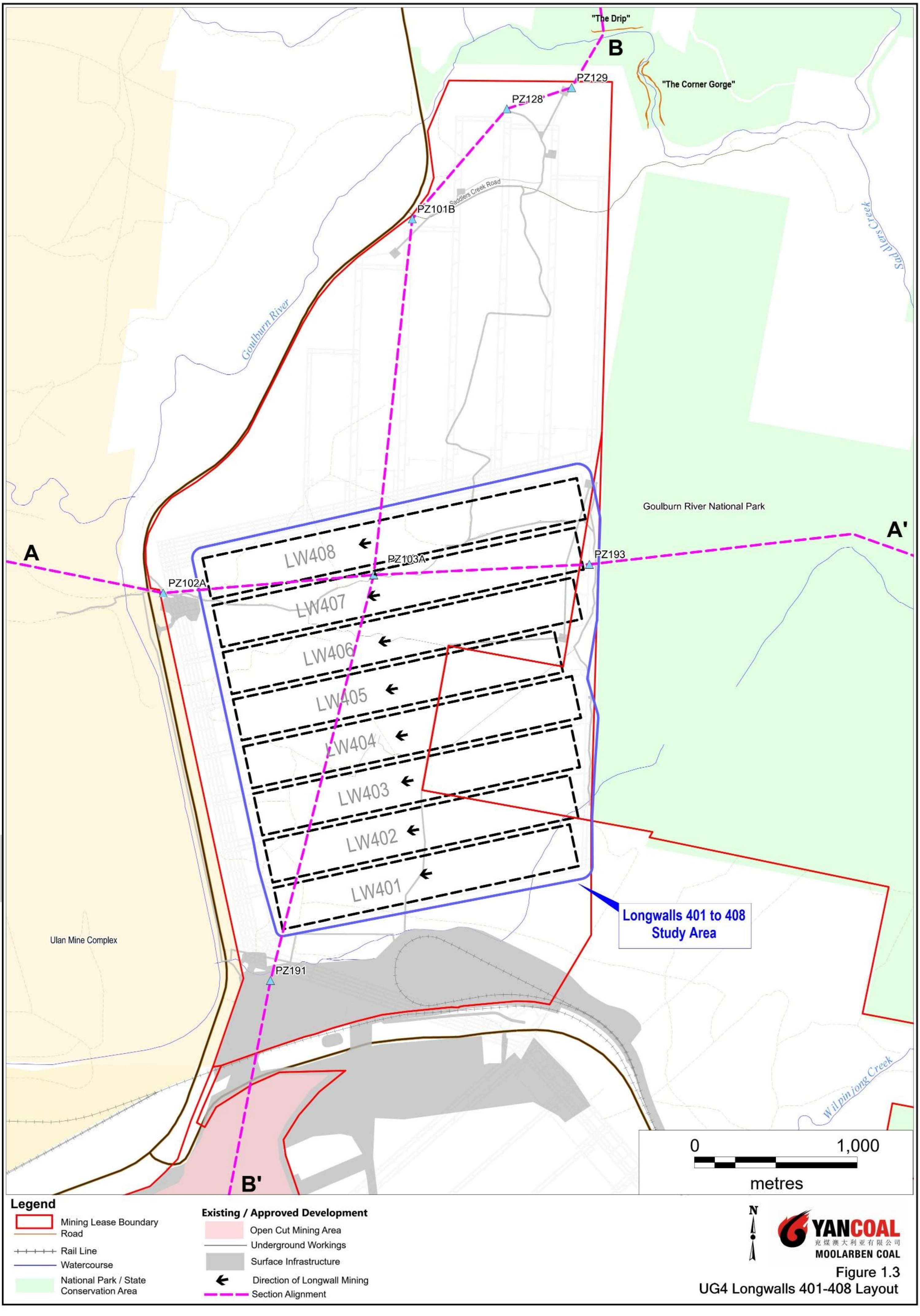


Figure 1.3
UG4 Longwalls 401-408 Layout

2 Objectives and scope of work

This report has been prepared to support the Extraction Plan for LW401 to LW408.

The report addresses the following:

- provides a summary of the groundwater regime in the vicinity of LW401 to 408, including the effects of historical mining activities;
- updated modelling of potential groundwater impacts from the approved mining of UG4 LWs 401 to 408 (including cumulatively with other operations at Moolarben, Ulan and Wilpinjong);
- identification of suitable monitoring and management measures, including Trigger Action Response Plans; and
- quantification of inflows for LW401 to LW408 and associated water licensing requirements.

3 Mining

3.1 Previous and Current Mining Activities

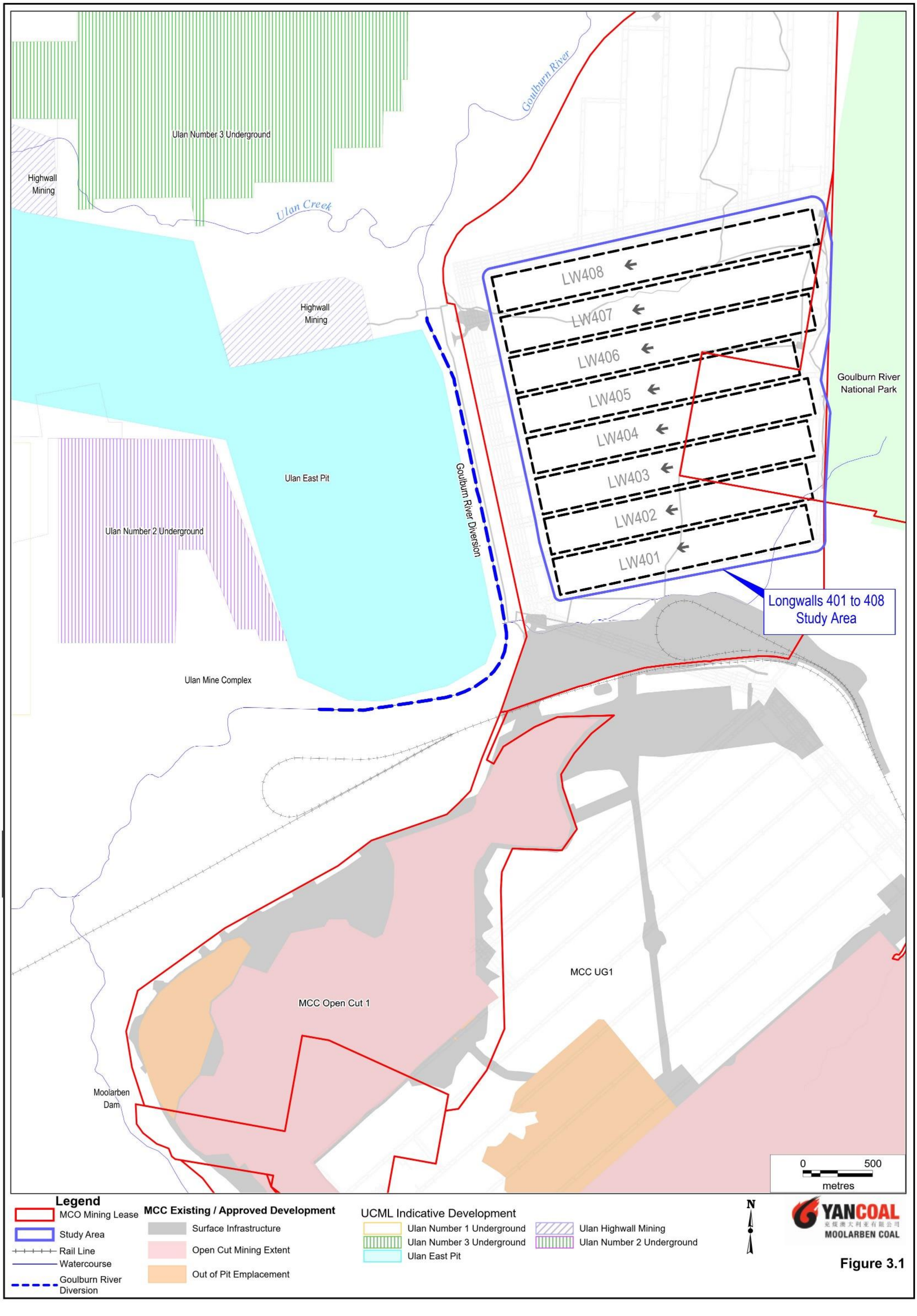
The MCC is located in a well-established mining precinct, comprising the existing MCC as well as the Ulan Mine Complex (UMC) and Wilpinjong Coal Mine. Mining in the area has been undertaken periodically since the Ulan No. 1 Colliery was established in the 1920's, with substantial expansion occurring in the 1980's with the development of the open cut and adoption of longwall mining at the Ulan Coal Complex (Umwelt Australia, 2009).

Key mining activities in the vicinity of UG4 include (Figure 3.1):

- MCC Open Cut 1 (OC1), which commenced in 2010 and has been mined to the base of the Ulan Seam;
- MCC UG1, which is located south of OC1 and also mines the Ulan Seam. First workings commenced in UG1 in April 2016 followed by secondary extraction commencing in October 2017;
- Ulan East Pit, which commenced in the 1980's and operated until 2008 (Figure 3.1). The Ulan East Pit was mined to the base of the Ulan Seam, partially backfilled and is now used as a tailings and mine water storage;
- Highwall mining north of the Ulan East Pit, which was undertaken in the 1990s in the Ulan Seam; and
- Longwall mining at Ulan No. 3, which commenced in 1986 and continues to extract the Ulan Seam.

In addition to these mining activities, the upper reaches of the Goulburn River (upstream of the Goulburn River National Park and adjacent to UG4), have been altered by historic development, including:

- construction of Moolarben Dam in 1957, which has significantly altered flows from Moolarben Creek into the Goulburn River;
- construction of the Goulburn River Diversion upstream of Ulan Creek, which has altered the original flow-path, size and geometry of the Goulburn River channel;
- discharges from the UMC downstream of Ulan Creek; and
- discharge from the MCC upstream of UG4, which commenced in 2020.



Goulburn River
Ulan Number 3 Underground
Highwall Mining
Ulan Creek
Highwall Mining
LW408
LW407
LW406
LW405
LW404
LW403
LW402
LW401
Goulburn River National Park
Ulan East Pit
Goulburn River Diversion
Ulan Number 2 Underground
Longwalls 401 to 408 Study Area
Ulan Mine Complex
MCC UG1
MCC Open Cut 1
Moolarben Dam
0
500
metres
Legend
MCO Mining Lease
Study Area
Rail Line
Watercourse
Goulburn River Diversion
MCC Existing / Approved Development
Surface Infrastructure
Open Cut Mining Extent
Out of Pit Emplacement
UCML Indicative Development
Ulan Number 1 Underground
Ulan Number 3 Underground
Ulan East Pit
Ulan Highwall Mining
Ulan Number 2 Underground
N
YANCOAL
MOOLARBEN COAL

Figure 3.1

3.2 Planned Mining at UG4

Longwall mining at UG4 would be undertaken in the Ulan Seam, which has been historically mined at MCC and UMC (Section 3.1).

The layout of Longwalls 401 to 408 is shown in Figure 1.3. Longwall lengths based on the Extraction Plan Layout are slightly shorter than those based on the Approved Layout. The lengths have been shortened from 10 m (LW401) to 85 m (LW405). With the exception of the shortened lengths, the longwall geometry for the Extraction Plan Layout is the same as that for the Approved Layout. A summary of the longwall dimensions is provided in Table 3.1.

Table 3.1 Geometry of Longwalls 401 to 408 based on the Extraction Plan Layout

Longwall	Overall Void Length Including Installation Heading (m)	Overall Void Width Including First Workings (m)	Overall Tailgate Chain Pillar Width (m)
LW401	1854	260	-
LW402	1912	260	35
LW403	1982	260	35
LW404	2046	260	35
LW405	2014	260	35
LW406	2196	260	35
LW407	2271	260	35
LW408	2348	260	35

The surface elevations directly above the proposed longwalls in the Extraction Plan Layout vary from a high point of 500 m above the Australian Height Datum (mAHD) above the commencing (eastern) end of Longwall 404, to a low point of 405 mAHD above the finishing end of Longwall 407. The depth of cover to the Ulan Seam above these longwalls varies between a minimum of 83 m at the finishing end of LW401 and LW407, to a maximum of 205 m at the commencing end of LW404.

The seam floor within the mining area generally dips from the southwest towards the northeast. The average dip of the seam within the extents of the proposed longwalls is around 1.6 %. The thickness of the Ulan Seam D-Working Section within the extents of the proposed longwalls varies between 2.8 m and 3.2 m. The proposed mining height for the longwalls is 3.0 m.

The seam floor contours, seam thickness contours and depth of cover contours for the Ulan Seam D-Working Section are shown in MSEC 2021.

The mining of East-West panels LW401 to LW408 will provide valuable site-specific information which will inform future decisions regarding Longwall panels LW409 to LW414. The mining of LW409 to LW414 will be the subject of future extraction plans.

4 Groundwater Regime

4.1 Groundwater Monitoring Network

Comprehensive groundwater monitoring is undertaken at MCC in accordance with the approved Groundwater Management Plan. The existing MCC groundwater monitoring program is detailed in Appendix A. Key existing groundwater monitoring sites in the vicinity of UG4 are shown on Figure 4.1 and summarised in Table 4.1. Additional UMC groundwater bores are also located in the vicinity of UG4.

Table 4.1 Baseline Groundwater Monitoring Network in the vicinity of UG4

Bore Name	Type	Unit Screened	Screened Interval (mbgl)	Ground Elevation (mAHD)
PZ 101B	Standpipe	Permian OB	54 – 60	403.28
PZ 101C	Standpipe	Lower Triassic	24 – 30	403.00
PZ 102A*	Standpipe	Marrangaroo Conglomerate	116 – 125	408.54
PZ 102B*	Standpipe	Ulan seam	80 – 86	408.23
PZ 103A*	Standpipe	Ulan seam	118 – 127	425.21
PZ 103B	Standpipe	Permian OB	81 – 87	425.00
PZ 103C	Standpipe	Lower Triassic	24 – 30	425.00
PZ 105A	Vibrating Wire Piezometer	Permian OB	28	388.93
		Permian OB	80	
		Ulan Seam	118	
PZ 105C	Standpipe	Lower Triassic	20 – 28	389.00
PZ 128	Vibrating Wire Piezometer	Triassic	20	409.52
		Permian OB	36	
		Permian OB	55	
PZ 129	Vibrating Wire Piezometer	Triassic	35	417.95
		Permian OB	53	
		Permian OB	74	
PZ 191*	Standpipe	Ulan seam	60 – 72	417.69
PZ 192	Vibrating Wire Piezometer	Triassic	68	453.70
		Ulan seam roof	166	
		Ulan seam base	178	
PZ 193	Vibrating Wire Piezometer	Permian OB	80	461.40
		Ulan seam roof	162	
		Ulan seam base	184	

Note: * To be decommissioned prior to extraction for safety of underground operations. Will continue to be monitored until decommissioned.

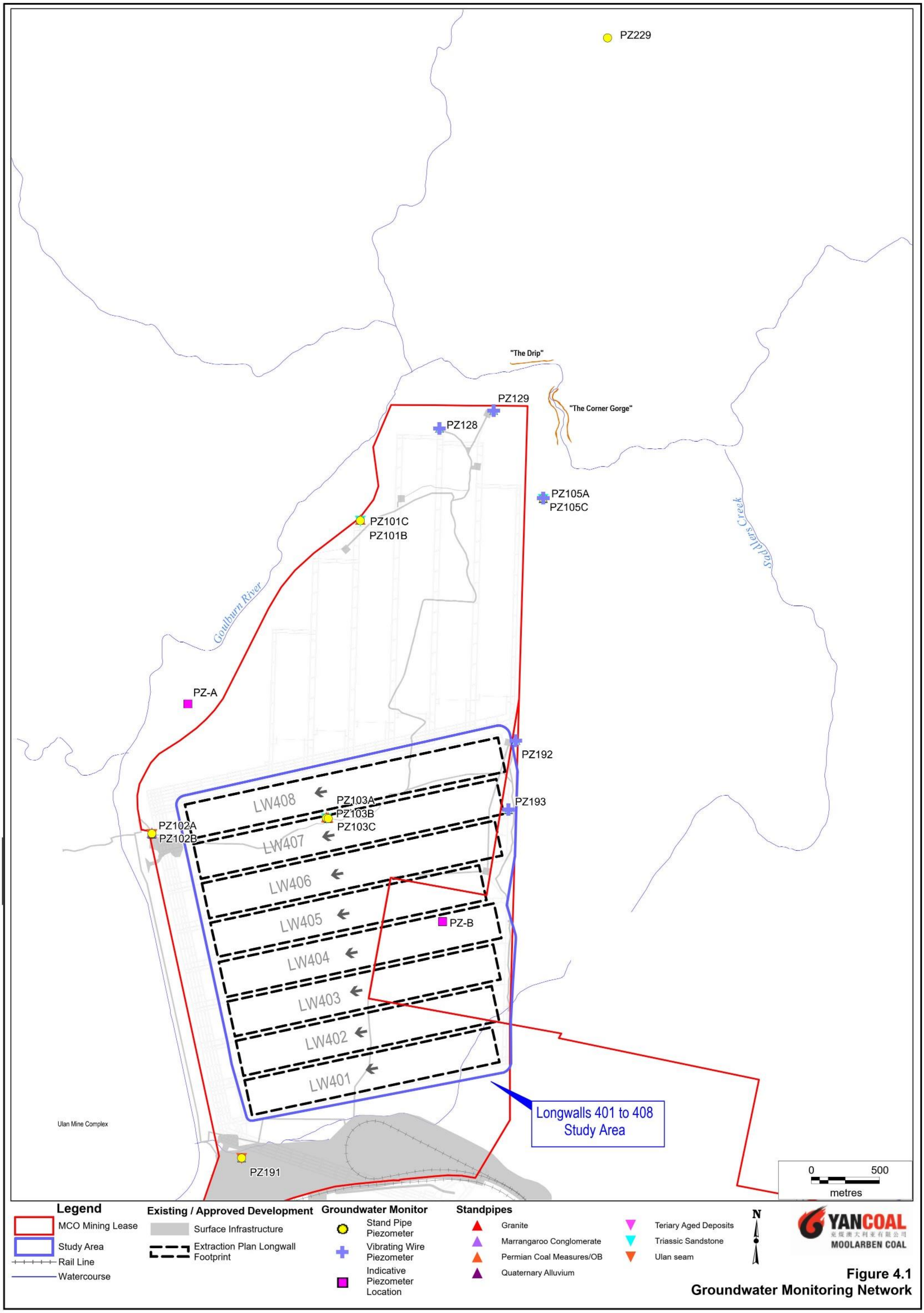


Figure 4.1
Groundwater Monitoring Network

4.2 Hydrogeology

Regional groundwater investigations were carried out for the Moolarben Coal Stage 1 and Stage 2 Projects. These investigations included:

- **Moolarben Coal Project – Groundwater Assessment** (Peter Dundon and Associates Pty Ltd, 2006);
- **Moolarben Stage 2 Groundwater Assessment** (Aquaterra Simulations Pty Ltd, 2008);
- **Moolarben Complex Stage 2 – Preferred Project Report – Groundwater Impact** Assessment (RPS Aquaterra, 2011);
- **Moolarben Coal Project Stage 1 Optimisation Modification Groundwater Assessment** (Australasian Groundwater & Environmental Consultants Pty Ltd, 2013);
- **Moolarben Coal Complex – UG1 Optimisation Modification – Groundwater Assessment** (Dundon Consulting Pty Ltd, 2015); and
- **Moolarben Coal Open Cut Optimisation Modification Groundwater Assessment** (HydroSimulations, 2017).

Various groundwater studies have also been completed for the UMC and Wilpinjong Coal Mine.

Since 2007, contemporary knowledge of the groundwater system has improved significantly, through further exploration drilling, geophysical surveying to map subsurface features, the construction of new groundwater monitoring infrastructure, ongoing monitoring, additional hydraulic testing, the analysis of groundwater trends in response to mining, and additional numerical groundwater modelling studies. Cumulatively, the completion of these studies has advanced the knowledge base of the groundwater system significantly and has informed the monitoring and management measures.

4.2.1 Hydrogeological units

The Moolarben Coal Complex area is located in the Western Coalfields on the north-western edge of the Sydney-Gunnedah Basin, which contains sedimentary rocks of Triassic and Permian age, including coal measures. The main hydrogeological units within and surrounding the Moolarben Coal Complex include:

- **Quaternary alluvium** associated with the present day drainage system;
- **Tertiary alluvium** associated with the identified palaeochannel that is not related to the present day drainage system;
- **Narrabeen Group** - Triassic sandstone consisting of Quartzose Triassic and Lithic Triassic sandstone;
- **Illawarra Coal Measures** - Permian coal measures, which includes the Ulan Seam near the base of the unit;
- **Marrangaroo Conglomerate** – Permian aged conglomerate; and
- **Basement** - Units that include Carboniferous volcanics and the Gulgong granite.

Quaternary Alluvium

Quaternary alluvial deposits in the vicinity of the Moolarben Coal Complex are associated with Lagoon Creek, the Goulburn River, Moolarben Creek and Wilpinjong Creek. The alluvium comprises fine to coarse grained sands and gravels within a silt/clay matrix.

Limited alluvial material is present in the Goulburn River Diversion, which was constructed in Permian bedrock and is now overlain by a layer of sediment. Alluvial sediments are more predominant downstream, where the Goulburn River has a coarse sandy base and developed sand bars are evident (Section 4.2.3). Notwithstanding, the presence of rocky outcrops in the Goulburn River channel indicates an expansive, highly productive alluvial aquifer is not present downstream of UG4.

Tertiary Sediments

Tertiary sediments associated with the defined palaeochannel are remnants of inactive river or stream channels that have been filled in or buried by younger sediment. The infill sediments consist of poorly-sorted semi-consolidated quartzose sands and gravels in a clayey matrix. The sediments are unsaturated across a large proportion of the footprint of the palaeochannel.

Tertiary Sediments are located within the palaeochannel to the south of UG4. The sediments vary in thickness with a maximum thickness of 50 – 60 metres, located to the south of Longwall 401. The presence of the palaeochannel sediments should result in less subsidence within these alluvial and unconsolidated sediment areas and reduced far-field movements within and beyond these channels (MSEC, 2021).

Triassic Narrabeen Group

The Triassic aged sandstones overly the Permian coal measures and are present over eastern portions of LW401 to LW408. Large extents of the Triassic strata are unsaturated, either naturally or from dewatering caused by previous mining activities. The Triassic aged sandstones provide some water supply potential, however the sandstone is generally low yielding. The Triassic sandstone supports a small number of stock and domestic bores on private properties to the north of the Moolarben Complex. Groundwater perching within the Triassic sandstones supports the local and culturally sensitive water feature on the Goulburn River known as The Drip.

Where saturated, the Triassic aged sandstones above LW401 to LW408 host the regional watertable. The depth to the watertable typically ranges from approximately 50 – 65 metres below ground (mbgl) at the eastern end of these panels, based on data collected from PZ 192. Data collected from the Triassic groundwater monitoring bore PZ 103C suggests that the shallowest depth to water in the LW401 to LW408 area occurs at approximately 25 mbgl, which at that location occurs near the very base of the Triassic sandstone.

Illawarra Coal Measures

The Permian aged Illawarra Coal Measures are present across the Moolarben Coal Complex. The coal measures conformably underlie the Triassic Narrabeen Group and comprise interbedded claystones, siltstones, sandstones (fine to coarse grained) and coal seams, including the Ulan Seam which will be mined at UG4.

Underlying the Ulan Seam is the Marrangaroo Conglomerate, which comprises weakly cemented conglomerates and medium to coarse grained sandstones.

Groundwater storage and movement occurs within the coal seam cleats and fissures, and to a lesser degree within fractures associated with faults intersecting the seams. Other sediments in the coal overburden and interburden sequence are relatively impermeable and behave as aquitards. Some Permian sandstones yield minor groundwater, although in the mined section of the coal measures, these are rare.

The Permian strata can be categorised into the following hydrogeological sub units:

- Very low permeability and very low yielding (to essentially dry) sandstone and siltstone, that comprises the majority of the Permian interburden / overburden; and
- Low to moderately permeable coal seams, which are the principal water bearing strata within the Illawarra coal measures.

The Permian coal measures are hydraulically confined to semi-confined within the region. However, the coal measures are depressurised locally due to historic and current mining activities.

Groundwater Productivity

The Aquifer Interference Policy (AIP) covers water licensing and assessment processes for aquifer interference activities within NSW (NOW, 212). Groundwater sources within the AIP have been divided into "highly productive" and "less productive" categories.

Highly productive groundwater is defined in the AIP as a groundwater source that is declared in the Regulations, and is to be based on the following criteria:

a) has total dissolved solids of less than 1,500 mg/L, and
b) contains water supply works that can yield water at a rate greater than 5 L/sec.

Given the AIP definition, none of the hydrogeological units surrounding the Moolarben Coal Complex are considered to be highly productive. A combination of low permeability and/or observed groundwater salinity effectively classifies the units as 'less productive'.

The main aquifers in the vicinity of the Moolarben Coal Complex are associated with the alluvium adjacent to the major drainages, and the Ulan Seam which occurs at the base of the Illawarra Coal Measures. Neither of these aquifers are considered to possess major water supply potential.

The Permian and overlying Triassic strata generally dip in a north-easterly direction away from the edge of the Sydney Basin which is located very close to the subcrop line of the Ulan Seam. There is limited potential to develop parts of the Permian coal measures (e.g. sandstones, siltstones, conglomerates and minor coal seams) for water supply purposes. Groundwater abstraction and observed yields has been low, likely due to a lack of interconnected fractures, and extremely low primary permeability within the rock mass matrix.

There has been extensive depressurisation of the hard rock aquifers surrounding UG4, as a result of previous and current mining operations (Section 3.1).

4.2.2 Recharge and discharge

Recharge to the groundwater system occurs by the direct infiltration of rainfall and downward percolation through the near surface weathered rock and alluvium where present. Recharge to the deeper units within the Permian coal measures occurs by downward seepage into the units where they subcrop beneath the alluvium or weathered rock cover.

Pre-mining groundwater conditions were significantly altered by the neighbouring Ulan Mine Complex to the west, which began operating well over 40 years before Moolarben Coal Operations. Earlier mining at Ulan Mine Complex has resulted in dewatering of the Ulan Seam and overlying hydrogeological units.

As part of this project, AGE has estimated that recharge to the groundwater system at the MCC is likely to be less than two percent of annual incident rainfall. This estimate aligns with the estimates completed by Mackie Environmental Research (2009) when assessing groundwater impacts to the adjacent Ulan Coal Operation.

Mackie (2009) reported that watertables and groundwater pressures in the saturated strata are sustained by rainfall infiltration to the regolith and to underlying hard rock layers with estimates of recharge to deep hard rock strata varying from close to zero, to no more than about 2% of annual rainfall.

4.2.3 Groundwater and Surface Water Interaction

The Goulburn River is the main watercourse in the vicinity of UG4 and has been heavily modified by the Goulburn River Diversion (Plate 1) adjacent to UG4 (Figure 3.1). The Goulburn River Diversion has been characterised by Advisian (2017) as follows:

- significantly altered flow regime due to the construction of Moolarben Dam and UCM/MCC discharges;
- has a channel bed formed in natural sandstone bedrock with a rocky base covered with a layer of sediment;
- is generally a uniform, well vegetated channel with trapezoidal channel dimensions, river bank heights varying from 4 m to 20 m, and channel bed widths varying from 30 m to 40 m; and
- has aquatic ecology diversity reflective of a disturbed environment that does not provide habitat for threatened aquatic ecology species.

Plate 1 Goulburn River Diversion West of LW401 (Advisian, 2017)

Further downstream, the Goulburn River is a broad, well vegetated channel formed in natural surface soils and has a coarse sandy base. The channel contains various sand bars, elongated permanent pools and rocky outcrops (Advisian, 2017; Plate 2).

Plate 2 Goulburn River (Natural) Downstream of UG4 (Advisian, 2017)

The Goulburn River is likely a losing stream along the full length of the Goulburn River Diversion. This is due in part to groundwater depressurisation and the lowering of the watertable from historical mining activities, as well as changes to the natural flow regime. A series of hydrogeological cross sections have been prepared, which traverse the Goulburn River, and are detailed in Section 4.4. Further inspection of the groundwater model along the diversion suggest that the diversion switches from a connected losing stream to a disconnected losing stream prior to the mining of LW401 to LW408 in many sections of the diversion.

Further downstream of the Goulburn River diversion, there is evidence to suggest that the regional groundwater system has a shallow gradient towards the natural Goulburn River course in some areas and a shallow gradient away from it elsewhere.

4.3 Groundwater receptors

4.3.1 Groundwater users

Groundwater usage in the area is primarily composed of mine dewatering for the Moolarben Coal Complex and the neighbouring Ulan Mine Complex and Wilpinjong Coal Mine.

There is one private bore in the vicinity of the Moolarben Coal Complex, located to the northeast of UG4. The bore is a relatively shallow bore (24 m) developed in Triassic strata and connected to the river alluvium. The location and baseline condition of this bore is summarised in Table 4.2.

Table 4.2 Baseline Condition of Privately Owned Bores

Work ID	Licence No.	Easting	Northing	Bore Type	Hydrogeological Unit	Water Level (m AHD)	EC (µS/cm)	pH
GW800279	80BL236762	765208	6431971	Domestic	Triassic Narrabeen Group	371	730	6.00

Notes: EC = electrical conductivity.
µS/cm = microSiemens per centimetre.
m AHD = metres Australian Height Datum.

4.3.2 Groundwater dependent ecosystem / assets

Groundwater Dependent Ecosystems (GDEs) are ecosystems that require access to groundwater to meet all or some of their water requirements on a permanent or intermittent basis for maintenance of the ecosystems (Richardson et al., 2011).

As identified in the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009*, the closest GDE to the Goulburn River is the Wappinguy Spring, which is located approximately 28 km north from the Goulburn River at its closest point.

Mapping from the Groundwater Dependent Ecosystems Atlas (BoM, 2021) identifies the Goulburn River as a low to moderate potential aquatic GDE as well as vegetation identified as low to high potential terrestrial GDEs in the vicinity of UG4. The significant depth to water (i.e. approximately 25 – 65 m) indicates that GDEs are not present within the UG4 area.

Springs and groundwater seeps in nearby creek valleys and localised pools and soaks along the creeks support riparian vegetation. None of these features constitute high priority Groundwater Dependent Ecosystems (GDEs) listed under the Water Sharing Plans relevant to the Moolarben Coal Complex.

4.3.2.1 The Drip

The Drip is a groundwater dependent ecosystem with local cultural and community significance. The Drip is a cliff face seepage feature located more than 2.5 km north of UG4 Longwall panel 408 and occurs directly adjacent to the northern side of the Goulburn River.

Groundwater discharges from The Drip are derived from the perching of groundwater in zones that are exposed in the cliff faces. The perching occurs in the Triassic Narrabeen Group sediments and is formed by accumulations of groundwater above less permeable horizons in the Triassic sequence to the north of the Goulburn River. Groundwater seepage from The Drip occurs at an elevation of approximately 387 to 388 mAHD. The bed of the Goulburn River at that location is approximately 380 mAHD.

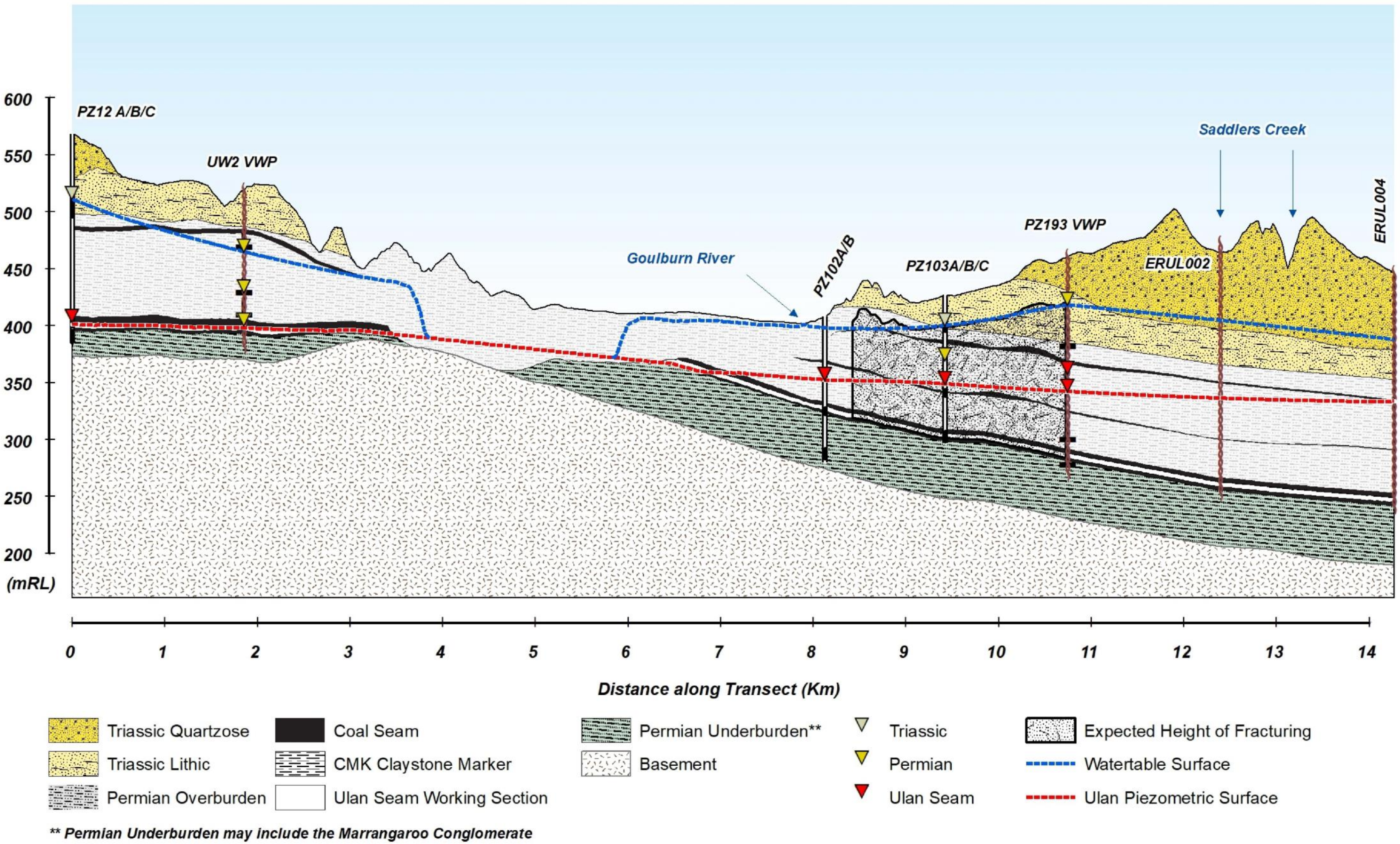
Previous groundwater impact assessments have concluded that The Drip will not be affected by the Moolarben Coal Complex. These assertions are reasonable because the Goulburn River forms a constant head boundary between The Drip and UG4. The main mechanisms for potential impacts to effect The Drip, would be through the enhancement of the vertical permeability of the Triassic sandstone (on the northern side of the Goulburn River), or through a reduction in groundwater recharge which supplies flow to The Drip. Neither of these mechanisms are possible from the underground mining of LW401 to LW408.

4.4 Conceptual Groundwater Model

AGE has constructed two hydrogeological cross sections for the purpose of illustrating the salient features of the groundwater system in proximity to UG4. The location of the cross section Transects A-A’ and B-B’ are shown on Figure 1.3 and are presented as Figure 4.2 through to Figure 4.3.

The following can be inferred from the two cross sections:

- there has been extensive depressurisation of hard rock aquifers surrounding UG4, as a result of previous and current mining operations;
- the Triassic outcrops in the vicinity of UG4 and does not exist over the western portions of the study area;
- large masses of the Triassic strata are unsaturated, either naturally or from depressurisation caused by previous mining activities;
- dewatering of the strata directly above LW401 to LW408 is predicted to occur due to the expected height of fracturing and interpolated watertable elevation. As a result, changes in the predicted height of fracturing would have limited effect on the predicted impacts of mining UG4 LW401 to LW408;
- the perching of groundwater within the Triassic sandstone associated with The Drip is effectively disconnected from the underling regional watertable. As a result, depressurisation caused by mining at LW401 to 408 will not impact the water supply to The Drip.

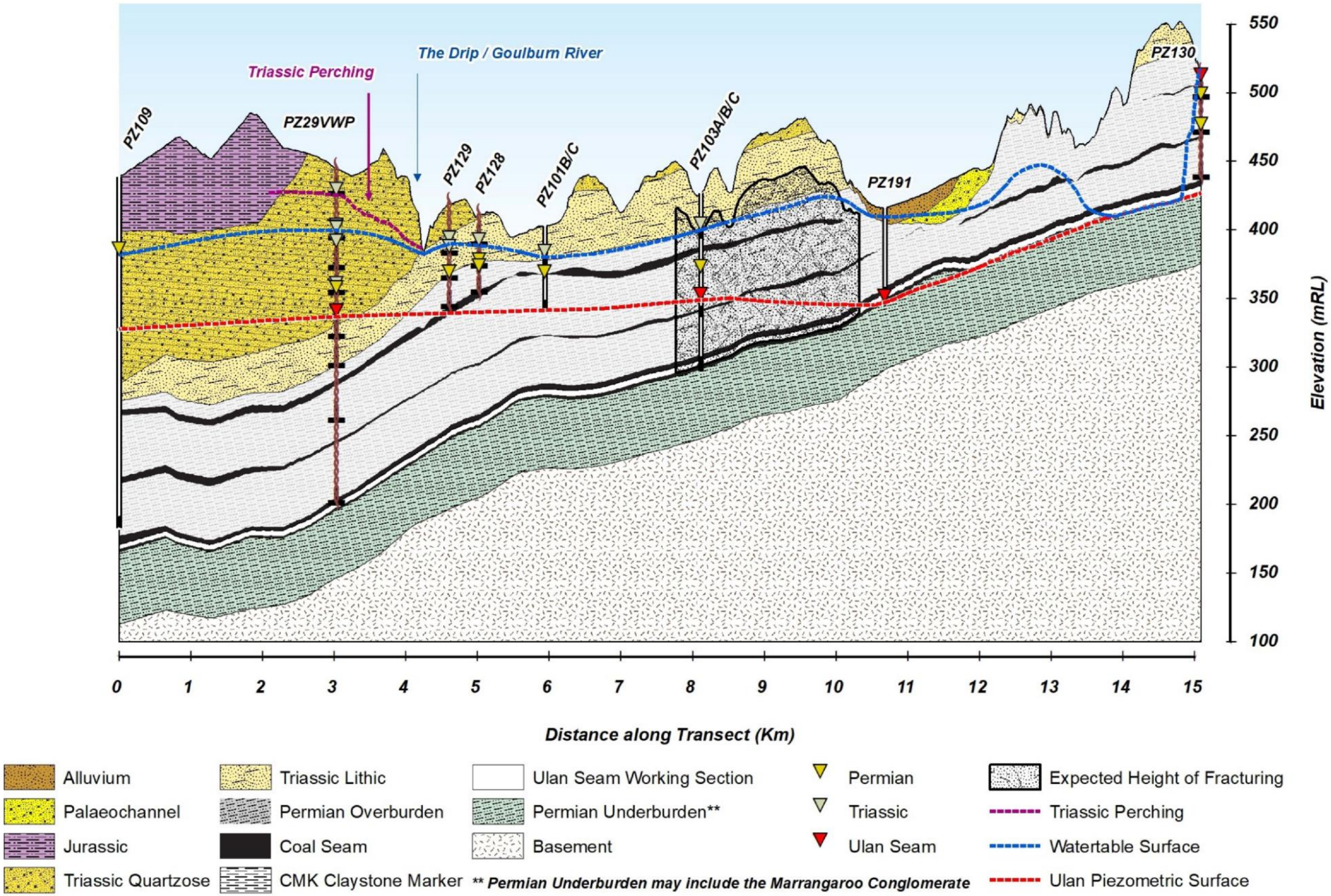


Hydrogeological Conceptual Section A-A'
Moolarben Groundwater Conceptualisation - Pre UG4 Groundwater Conditions
Moolarben Coal Operations - UG4 Extraction Plan (G1622F)

AGE

DATE 29/10/2021

FIGURE No: **4.2**



Hydrogeological Conceptual Section B-B'
Moolarben Groundwater Conceptualisation - Pre UG4 Groundwater Conditions
Moolarben Coal Operations - UG4 Extraction Plan (G1622F)

AGE

DATE 29/10/2021

FIGURE No: 4.3

5 Groundwater Predictions

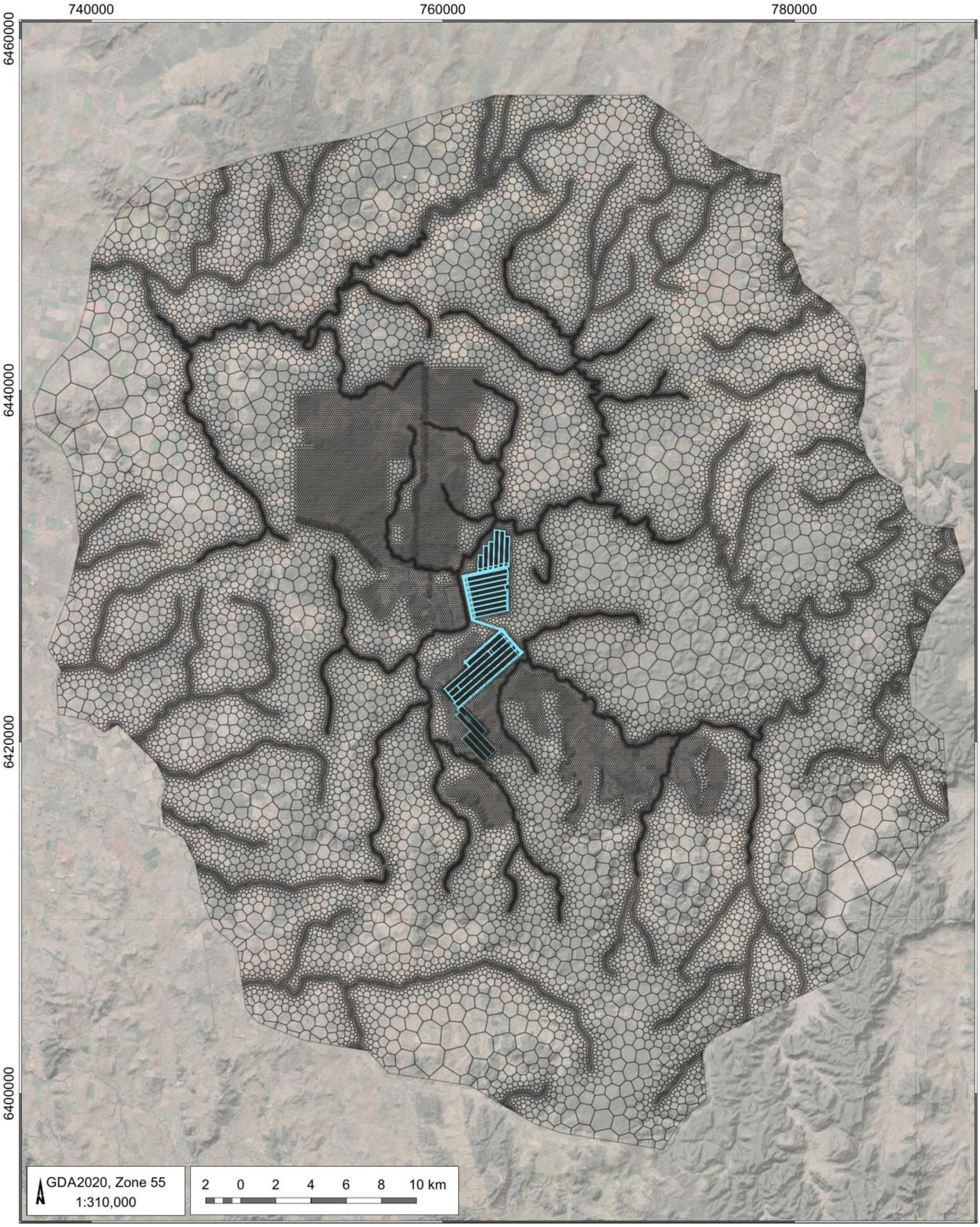
Groundwater predictions for UG4 LW401 to LW408 have been based on contemporary groundwater understanding, monitoring results and an updated groundwater numerical model.

5.1 Summary of model updates

The groundwater model update has included revisions to the model mesh and layering, recalibration and consideration of current subsidence predictions. These changes are outlined in the following sections.

5.1.1 Model mesh and extent

The extent of the model has remained unchanged in the recent model update (the model domain is approximately 60 km north south by 50 km west to east). The internal Voronoi mesh has been modified to reduce the number of model cells in areas where detail is not needed. The updated model mesh is presented in Figure 5.1 and Figure 5.2.



LEGEND

Moolarben underground

Model mesh

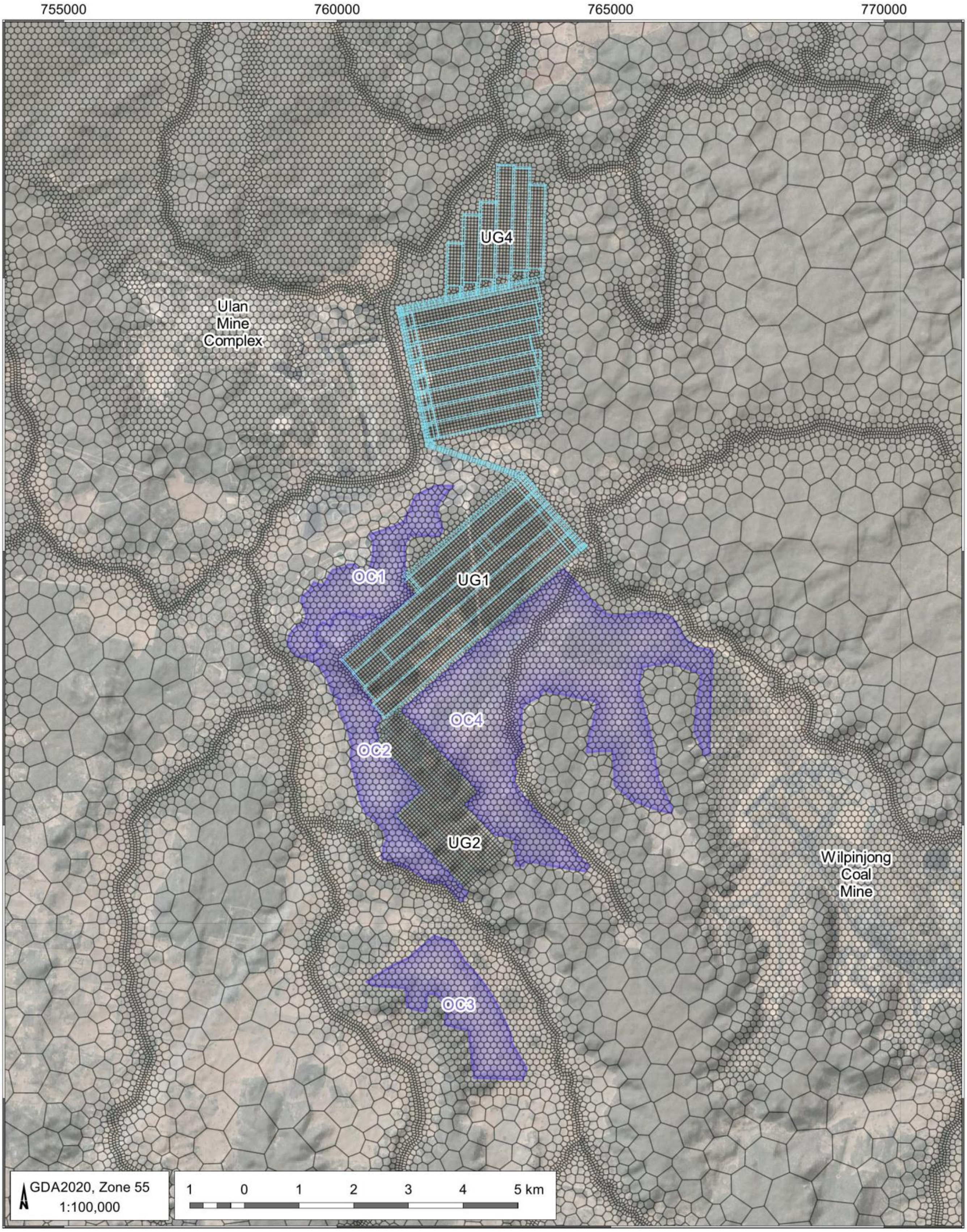
Moolarben (G1622F)

Model mesh (regional view)

DATE 17/09/2021

FIGURE No: **5.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1622F_Moolarben\3_GIS\Workspaces\001_Deliverable1\05.01_G1622F_Model mesh.qgs



LEGEND

Moolarben underground

Moolarben open cut

Model mesh

Moolarben (G1622F)

Model mesh (local view)

AGE

DATE 17/09/2021

FIGURE No: **5.2**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1622F_Moolarben\3_GIS\Workspaces\001_Deliverable1\05.01_G1622F_Model mesh.qgs

5.1.2 Model layering

The model layering has been updated in line with changes to the site based geological model. The CSIRO depth of regolith dataset (Wilford et al, 2015) was also used to guide the depth of alluvium and colluvium estimates in areas where regolith data was limited. The site based geological model was used as the primary source of layer elevations, and the previous groundwater model layer elevations were incorporated beyond the site geological model domain.

The updated numerical groundwater model includes additional vertical discretisation and now consists of 21 model layers representing the hydrostratigraphic units in the area. The uppermost layers represent the shallow Quaternary alluvium and colluvium sediments, with the lowest layers representing the deep Permian coal measures and the granitic basement. Intermediary layers (e.g. layer 7) were added to the model to increase the vertical resolution within the model. Table 5.1 details the hydrostratigraphic units represented by each model layer.

Table 5.1 Model layers

Model layer	Hydrostratigraphic description
1	Quaternary alluvium and colluvium
2	Paleochannel
3	Tertiary basalt
4	Jurassic Pilliga Formation
5	Jurassic Purlewaugh Formation
6	Triassic sandstone (quartzose)
7	Triassic sandstone (quartzose)
8	Triassic sandstone (quartzose)
9	Triassic sandstone (lithic)
10	Triassic sandstone (lithic)
11	Permian overburden
12	Permian coal (combined Middle River, Goulburn, and Turill Seams)
13	Permian overburden
14	Permian coal (combined Moolarben, Glen Davis, and Irondale Upper/Lower Seams)
15	Permian overburden
16	Permian coal (Ulan Seam – Working Section 1)
17	Permian clay interburden
18	Permian coal (Ulan Seam – Working Section 2)
19	Permian coal (Ulan Seam – below Working Section 2)
20	Permian Marrangaroo conglomerate underburden
21	Carboniferous Gulgong granite

5.1.3 Recalibration

Following the updates to the model structure (mesh and layering) the model was recalibrated to ensure it replicates observed water level (and flow) behaviour to satisfactory quantitative and qualitative standards.

A total of 638 monitoring points were available to calibrate the model, including data collected from groundwater bores and vibrating wire piezometers. Model performance was also gauged by history matching the inflows observed from workings at UG1 and first workings associated with UG4.

The water level match is summarised with a scatter diagram in Figure 5.3. One of the statistical measures recommended by the Australian groundwater modelling guidelines (Barnett et. al., 2012) to determine if a model is sufficiently calibrated is the Scaled Root Mean Squared Error (SRMS). The SRMS of the recalibrated model is 6.7%. A value of SRMS below 10% indicates that a model can generally be considered calibrated.

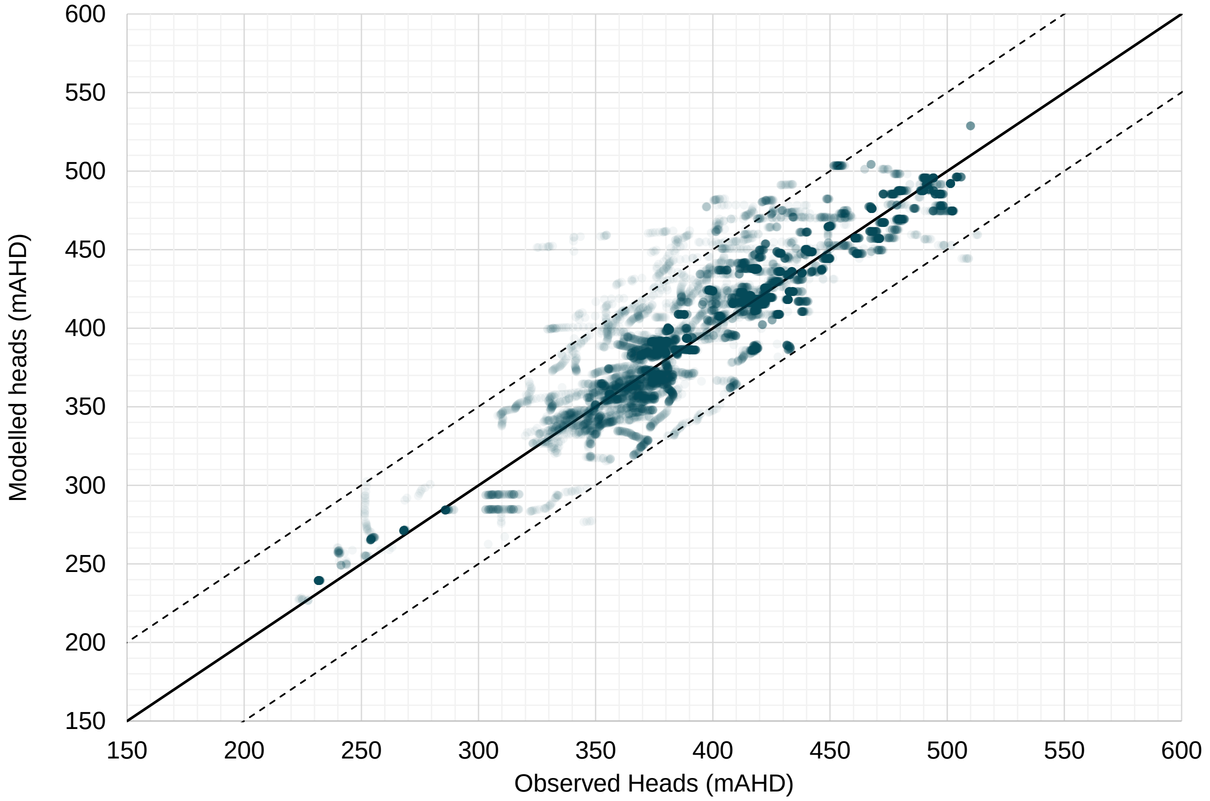


Figure 5.3 Modelled vs. observed water levels

Hydraulic properties and groundwater recharge rates were varied during the model recalibration. The calibrated hydraulic properties are presented in Table 5.2. Note that the K_h values and the ratio of K_v/K_h are varied spatially by pilot points to represent heterogeneity in the parameter values. Table 5.2 therefore presents the average values per layer.

Table 5.2 Calibrated hydraulic properties

Model layers	Description	K_h (m/day)	K_v/K_h	S_y	S_s (m^{-1})
1 (zone 1)	Alluvium	3.75E+01	1.03E-02	1.0E-01	1.3E-05
1 (zone 2)	Colluvium	4.82E-01	1.04E-02	8.0E-03	5.0E-06
2	Paleochannel	5.00E-02	1.00E-01	1.8E-02	5.0E-06
3	Tertiary basalt	1.06E-03	4.80E-02	2.0E-02	5.0E-06
4	Jurassic Pilliga Formation	1.31E-03	1.04E-02	1.0E-02	5.0E-06
5	Jurassic Purlewaugh Formation	1.03E-03	1.19E-02	1.0E-02	5.0E-06
6, 7, 8	Triassic sandstone (quartzose)	1.07E-02	1.17E-02	3.0E-02	1.0E-05
9, 10	Triassic sandstone (lithic)	5.05E-04	1.27E-02	1.0E-02	8.0E-06
11, 13, 15	Permian overburden	1.03E-05	1.18E-02	1.5E-02	1.0E-06
12, 14	Permian coal (combined seams)	1.06E-05	1.27E-02	2.0E-02	2.0E-06
16, 18, 19	Permian coal (Ulan Seam)	*	1.58E-01	2.0E-02	2.0E-06
17	Permian clay interburden	1.06E-04	1.13E-02	1.5E-02	1.0E-06
20	Permian Marrangaroo conglomerate underburden	9.98E-05	1.41E-02	5.0E-03	1.0E-06
21	Carboniferous Gulgong granite	9.97E-05	9.72E-01	1.0E-03	1.0E-06

Note: * Uses depth dependence equation.

Due to the effects of mechanical loading, the hydraulic conductivity of coal seams is known to reduce with depth due to the additional weight of overburden and resultant increase of compression upon coal cleats. AGE has adopted the following equation to account for the depth dependence relationship in coal seam hydraulic conductivity:

$$K_h = K_0 e^{sd}$$

where K_h is resultant horizontal hydraulic conductivity, K_0 is the seed hydraulic conductivity value (15 m/day), s is the slope (-0.005) and d is the depth (m). The maximum K_h value of the coal seams is limited to 0.8 m/day.

The overall recharge rate and evaporation to the revised model has reduced and is consistent with other local models and the conceptual hydrogeological model of AGE.

The water budget over the transient calibration period (1984 to 2021) is provided in Table 5.3, which shows the average water budget for the transient calibration.

Table 5.3 Modelled water budget

Parameter	In (ML/day)	Out (ML/day)	In - Out (ML/day)
Rivers	0.68	21.69	-21.01
Rainfall recharge	21.86	-	21.86
Evapotranspiration	-	1.94	-1.94
General head boundaries	28.41	23.74	4.67
Drains	-	27.10	-27.10
Total	50.95	74.47	-23.52

An objective of the model calibration has been to match (as closely as possible) the historic inflows to the underground mining at Moolarben.

Comparison between the site data and model results suggests that the long-term trend is matched sufficiently. Groundwater ingress commences in 2016 as mining progresses beneath the phreatic surface. This confirms that the initial groundwater model level distribution is adequate. From 2016 onwards, inflows generally increase (on average) year on year, and are commensurate with site based observations and the progression of mining down dip below the regional watertable.

The general agreement between modelled and observed inflows, significantly reduces issues with model non-uniqueness, given the model also achieves a satisfactory match in terms of head distribution, and other significant components (such as groundwater recharge and baseflow) with the conceptual hydrogeological model.

Further assessment of the calibration can be made from comparing predicted and observed water level behaviour in the form of hydrographs. Figure 5.4 to Figure 5.6 show the variability in observed trends and how the predicted model water levels compare.

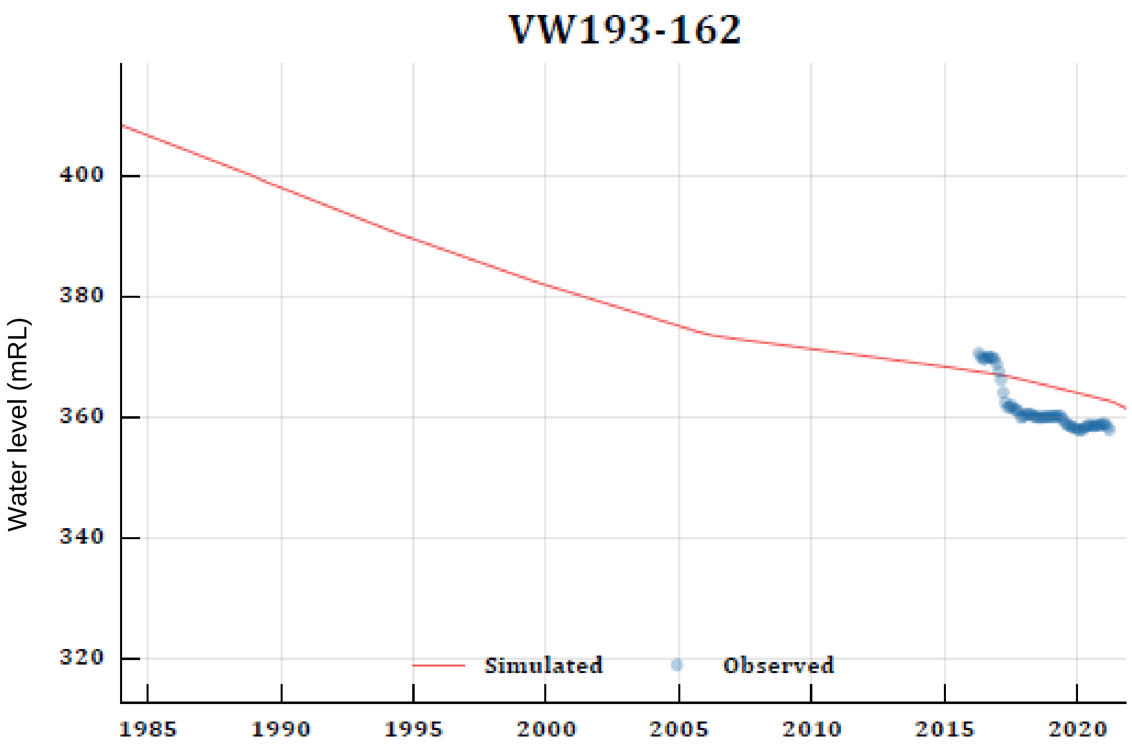


Figure 5.4 Calibration hydrograph for bore VW193-162

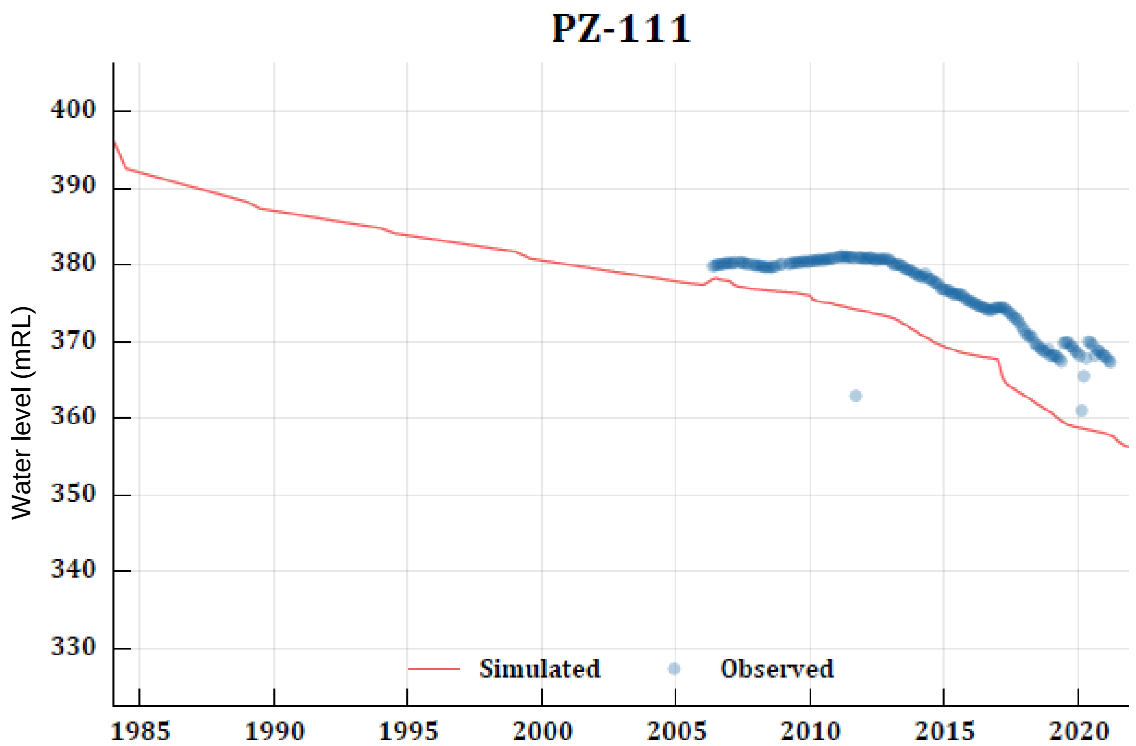


Figure 5.5 Calibration hydrograph for bore PZ111

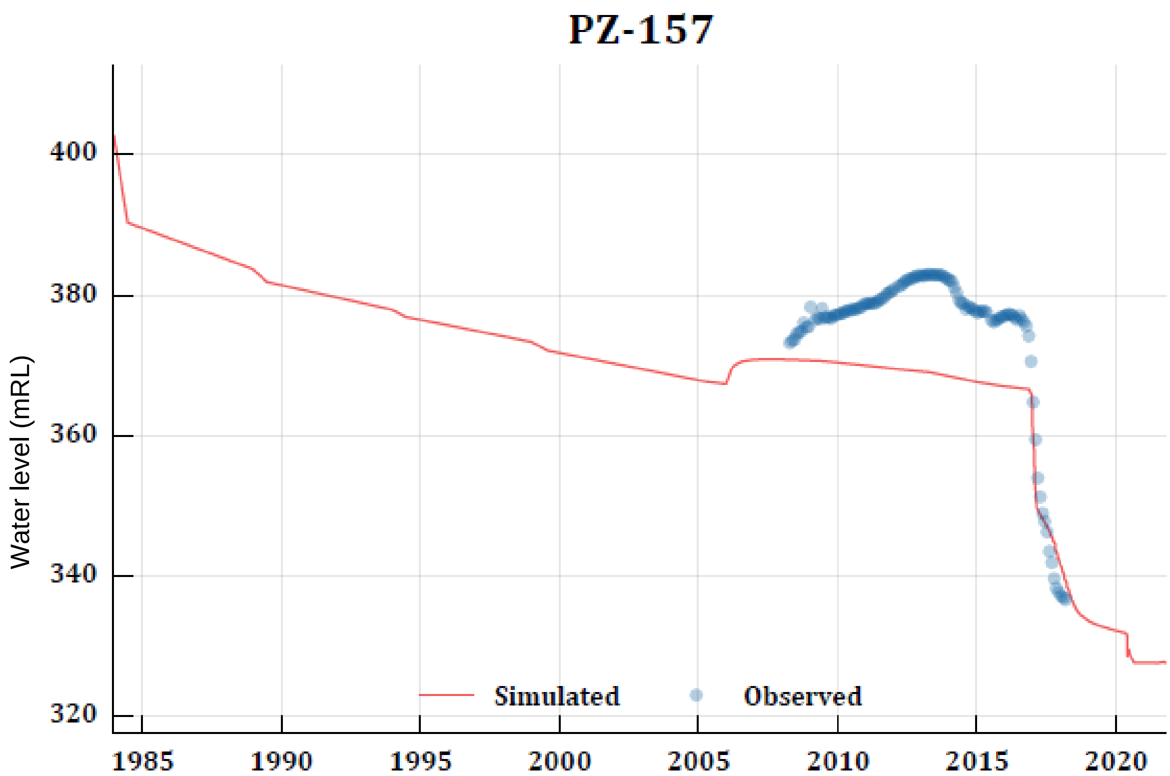


Figure 5.6 Calibration hydrograph for bore PZ-157

The calibration hydrographs confirm that a reasonable level of calibration has been achieved and that trends are generally followed. Observed water levels were available and utilised in the calibration from the neighbouring mines and a representative selection of bores is provided below for monitoring at Ulan (Figure 5.7 and Figure 5.8) and monitoring at Wilpinjong (Figure 5.9 and Figure 5.10). These hydrographs demonstrate that the impacts from the neighbouring mines are adequately captured in the model. This increases the confidence in the impacts predicted from the Moolarben Operations.

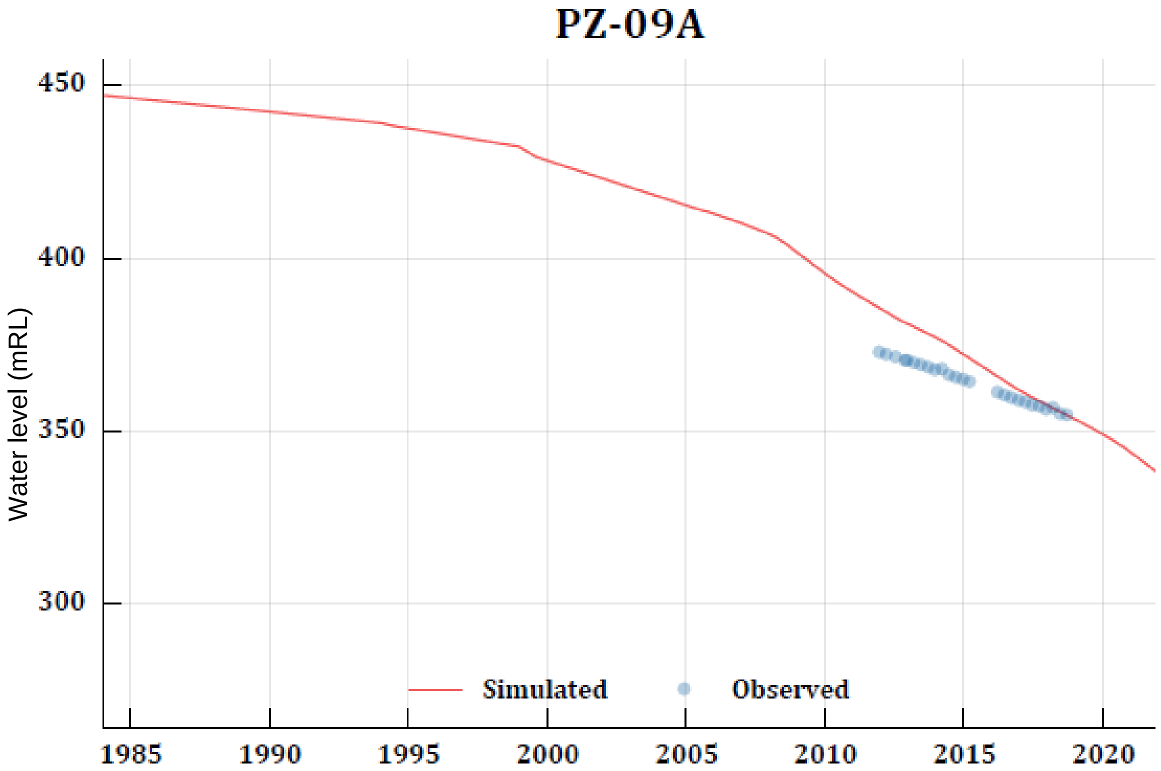


Figure 5.7 Representative calibration hydrograph for bore PZ-09A (Ulan)

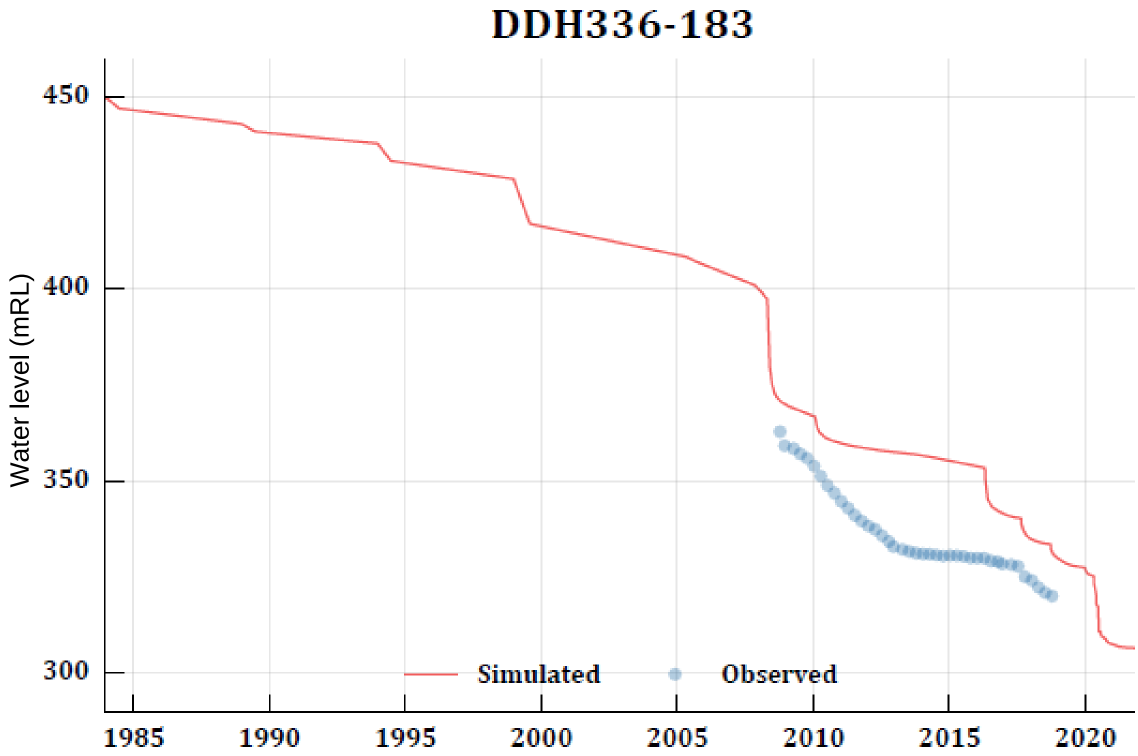


Figure 5.8 Representative calibration hydrograph for bore DDH336-183 (Ulan)

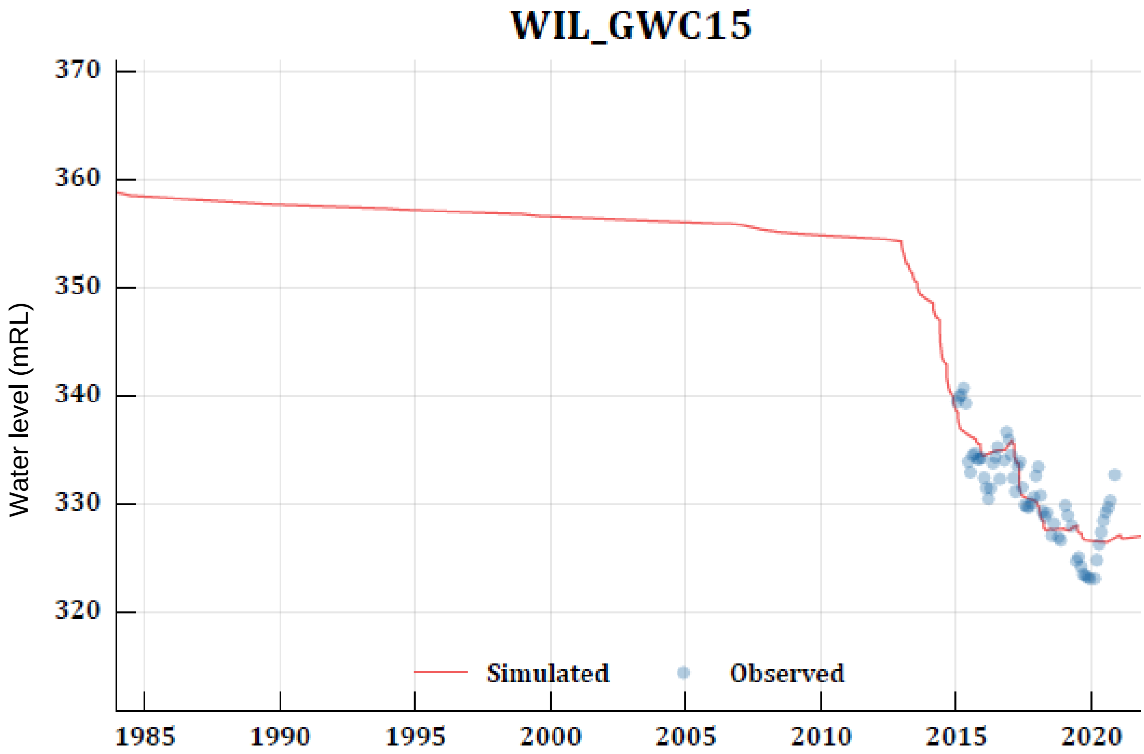


Figure 5.9 Representative calibration hydrograph for bore GWC15 (Wilpinjong)

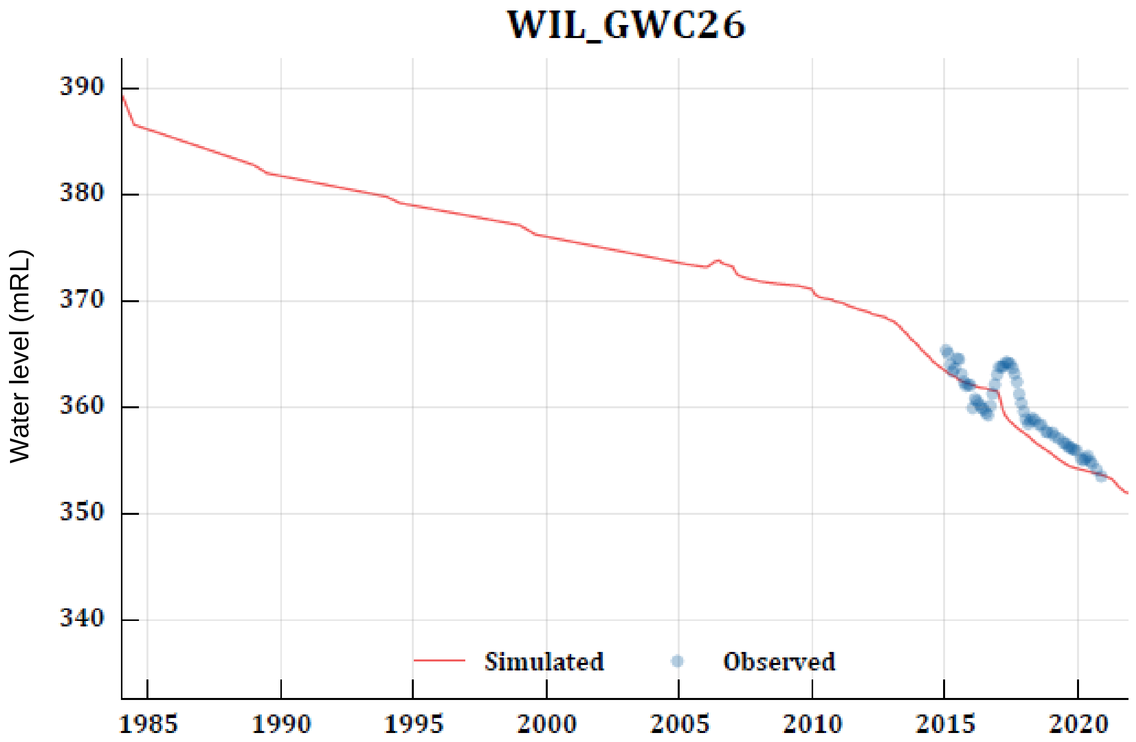


Figure 5.10 Representative calibration hydrograph for bore GWC26 (Wilpinjong)

5.2 Subsidence model updates

Potential subsidence impacts for the Approved Layout for the UG4 longwalls (Longwalls 401 to 408) were reviewed by MSEC (2021). A comparison of the maximum predicted subsidence parameters resulting from the extraction of Longwalls 401 to 408, based on the Extraction Plan Layout, with those based on the Approved Layout with a 3 m cutting height is provided in Table 5.4 (MSEC 2021).

Table 5.4 Maximum Predicted Conventional Subsidence Parameters based on Layout

Layout	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
Stage 1 EA Preferred Project Report (Strata Engineering 2006)	2440	96	> 3	> 3
Approved Layout	1900	60	> 3	> 3
Extraction Plan Layout	1900	60	> 3	> 3

Mine Subsidence Engineering Consultants Pty Ltd (MSEC) concluded the maximum predicted total subsidence parameters based on the Approved Layout are the same as those for the Extraction Plan Layout for Longwalls 401 to 408 and are less than the maximum predicted total subsidence parameters for Stage 1 EA project approval (Strata Engineering, 2006). Whilst the specific values of the maximum curvatures are not shown, due to these representing the localised irregular movements rather than the macro (i.e. overall) movements, these parameters do not change (MSEC 2021).

5.3 Fracturing and depressurisation

During longwall mining, the removal of coal causes the overburden to subside into the spent longwall void (goaf). The resultant strain imposed on the rock strata develops a fracture network of varying connectivity according to the height above the longwall panel. The thickness of the mined section, the effective width of the longwall panel, and the geological properties of the overburden all influence the degree of fracturing which results from the collapsing of the longwall panel (post mining).

Figure 5.11 shows a schematic of the fracture network and identified zones which are produced above a collapsed longwall panel.

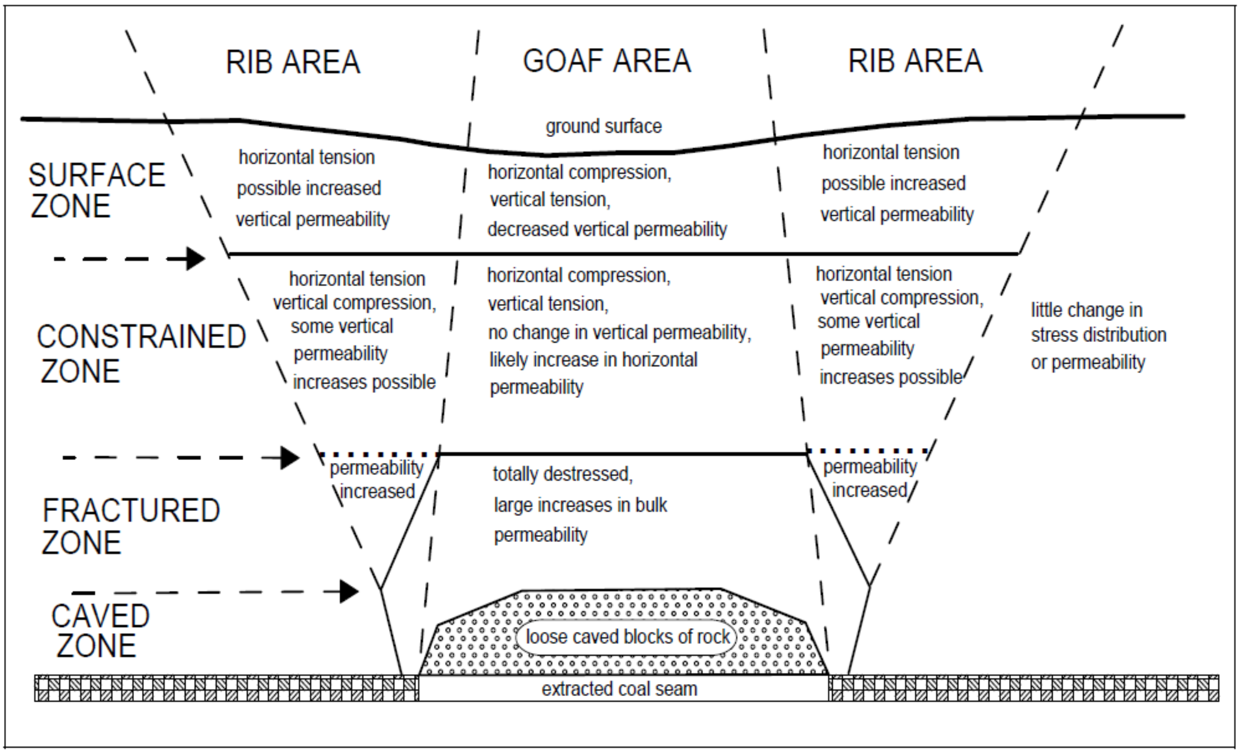
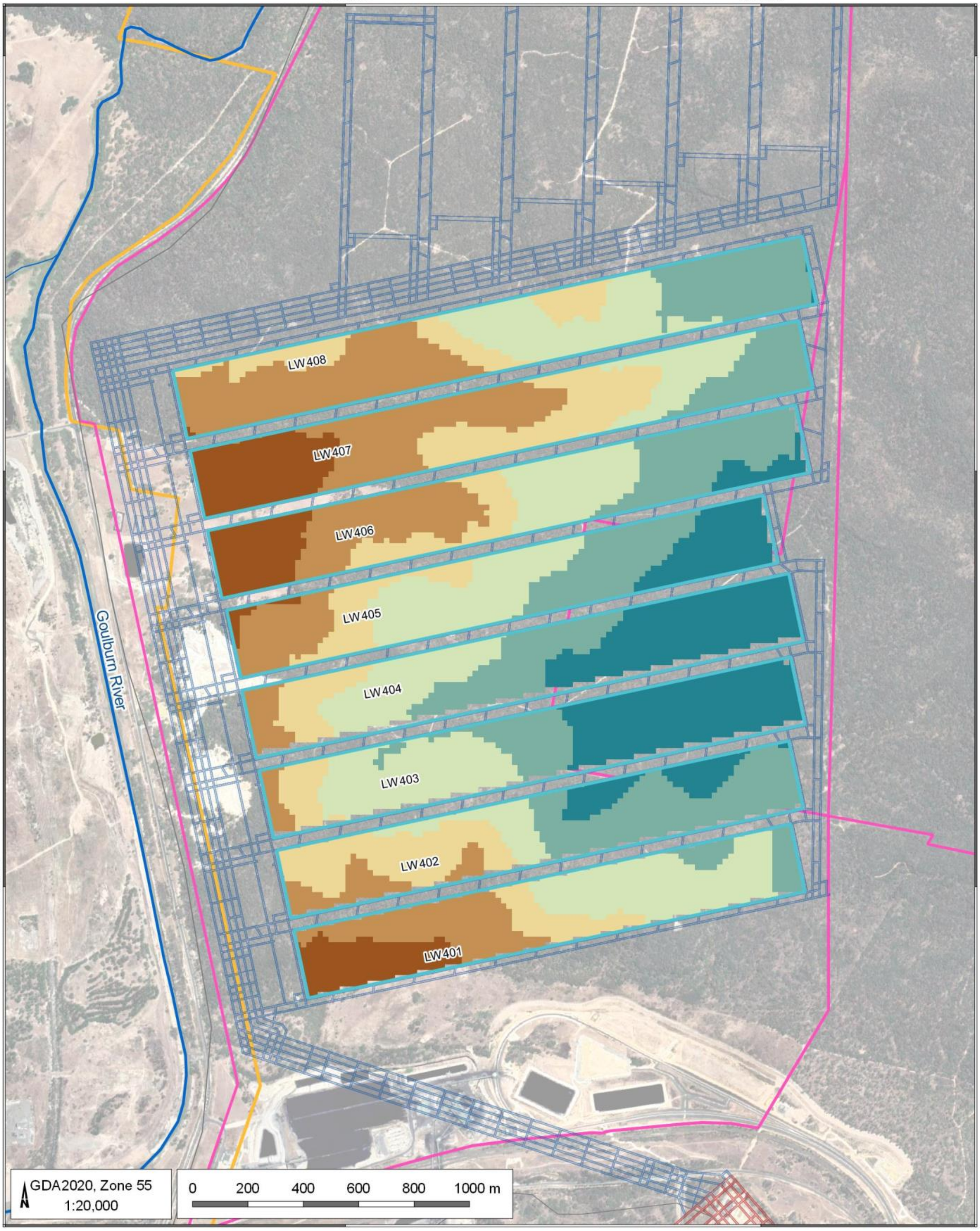


Figure 5.11 Processes which occur above a longwall panel (Forster and Enever, 1992)

In the Moolarben groundwater model the fractured zone is represented by adjustments of the hydraulic properties to reflect the changes which occur in the developed fractured zone. Dewatering is simulated in the coal seam layers through the application of the MODFLOW drain boundary condition. The model layers above the mined coal seam have their properties adjusted at the same time (that mining occurs) to replicate the fracturing which occurs in response to longwall mining.

The amount that hydraulic properties are altered depends on where in the zone of continuous fracturing the model cell is situated. Cells immediately above the mined coal seam are altered the greatest, with a reduction in change occurring with height, within the fracture zone.

Figure 5.12 shows the estimated fracture height taking into account the width of the longwall panel, the thickness of the mined seam and the amount of overburden material. Figure 5.13 presents the depth from the land surface to the top of the fracture zone. It indicates that continuous fracturing is not predicted to occur at the land surface with the zone of continuous fracturing being 16 m or more below the ground surface. The estimated height of fracturing is also shown on the hydrogeological cross sections (Figure 4.2 and Figure 4.3).



LEGEND

- Surface water drainage
- Longwall panel outline (LW401 - LW408)

Road

- Minor Road

Moolarben Underground

- UG1
- UG4

- Moolarben Mining Lease
- Ulan mine area
- Moolarben open cut

Fracture Height above the Ulan Seam (m)

- 65 - 80
- 80 - 100
- 100 - 110
- 110 - 120
- 120 - 130
- 130 - 145

Moolarben (MOO1622F.02)

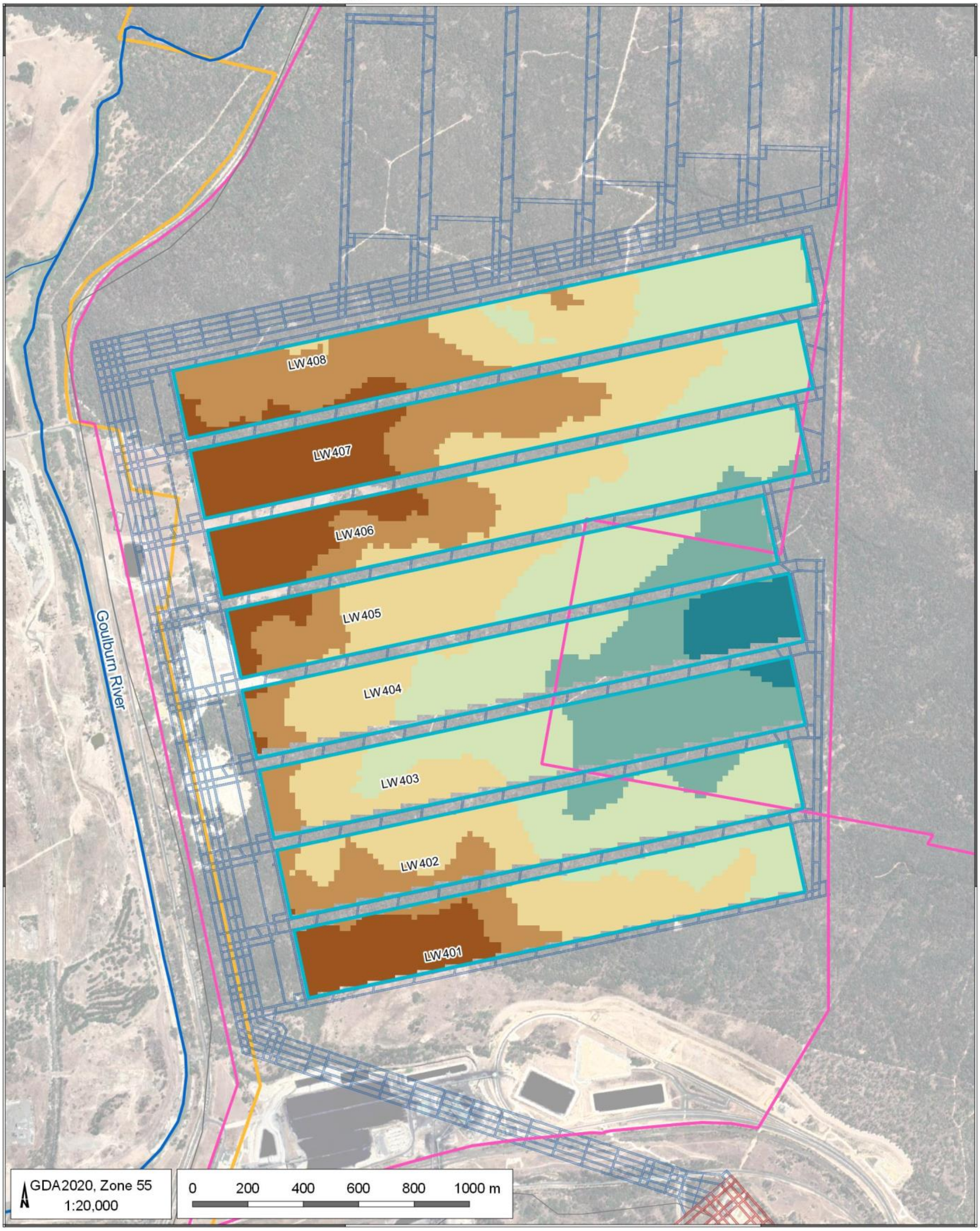
Fracture height above the Ulan Seam

AGE

DATE 02/11/2021

FIGURE No: **5.12**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1622F_Moolarben\3_GIS\Workspaces\001_Deliverable1\05.13_G1622F_Fracture height above the Ulan Seam.qgs



LEGEND

- Surface water drainage
- Longwall panel outline (LW401 - LW408)

Road

- Minor Road

Moolarben Underground

- UG1
- UG4

- Moolarben Mining Lease
- Ulan mine area
- Moolarben open cut

Depth to the Top of the Fracture Zone (m)

- 16 - 25
- 25 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 55

Moolarben (MOO1622F.02)

Depth to top of fracture zone

AGE

DATE 02/11/2021

FIGURE No: **5.13**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1622F_Moolarben\3_GIS\Workspaces\001_Deliverable1\05.14_G1622F_Depth to top of fracture zone.qgs

5.4 Predicted impacts – to end of LW408

5.4.1 Drawdown

Segregating the impacts due to LW401 to LW408 from other predicted impacts from mining at Moolarben was achieved by simulating a 'no UG4' model run and comparing that to the model scenario simulating the cumulative approved mining at Moolarben, Ulan, and Wilpinjong. The difference between these two simulations is the impact due to the extraction plan longwall panels.

Figure 5.14 to Figure 5.20 show the model predictions of groundwater drawdown for each of the key formations directly attributable to Moolarben UG4 (LW401 to LW408). The difference in predicted heads between the two models has been used to calculate the drawdown extent (per modelled layer / formation), as shown in the figures.

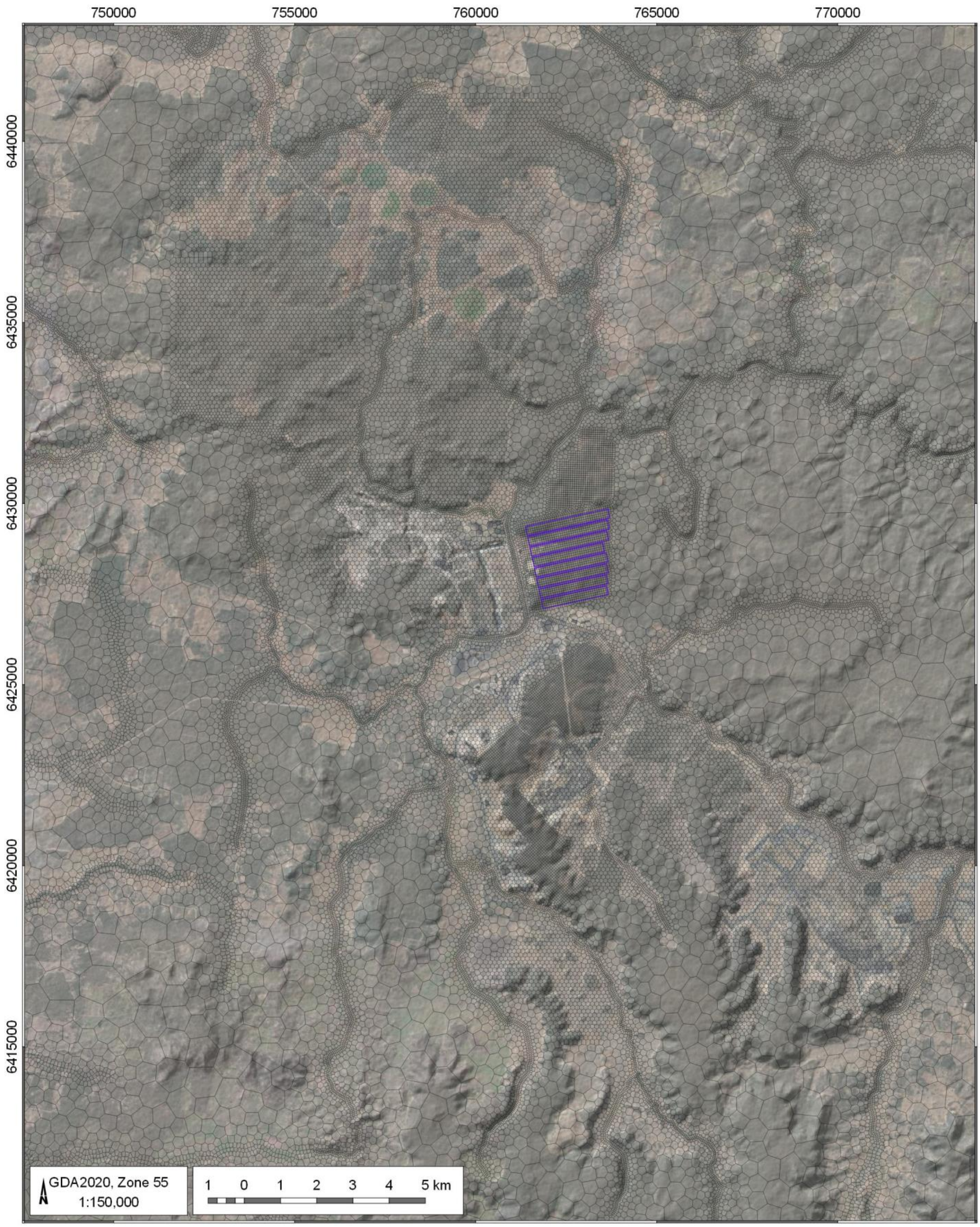
Above LW401 to LW408 the model predicts complete desaturation of the formations due to the subsidence induced fracturing. The Triassic drawdown extent to the west is limited by the level of saturation in the formation and as such does not cover the entire footprint of the longwall panels. The extent of drawdown diminishes as vertical distance from the coal seam increases.

Model predictions show that drawdown of more than 1 metre within the Triassic Quartzose (model layer 8) is expected to be generally limited to less than 250 to 300 m radial distance from LW401 to LW408, with a maximum radial distance occurring near LW 403.

Model simulations show that drawdown of more than 1 metre within the Triassic Lithic (model layer 10) is expected to be generally limited to less than 600 to 700 m radial distance from LW401 to LW408, with a maximum radial distance occurring near LW 405.

Negligible drawdown is predicted in the Alluvium/colluvium and Jurassic formations, while localised drawdown of the Tertiary sediment is predicted in the vicinity of the western end of LW401.

The deeper Permian coal measures and Ulan Seam are predicted to be completely dewatered above LW401 to LW408 with drawdown attributable to Moolarben UG4 (LW401 to LW408) primarily extending to the north and east. Drawdown (depressurisation) propagation in these confined formations occurs to greater distances than the watertable aquifer due to it being a confined (elastic) aquifer response.



LEGEND

- Drawdown contour (m)
- Model mesh
- Longwall panels 401 to 408

Drawdown (m)

- 0
- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500

Moolarben (G1622F)

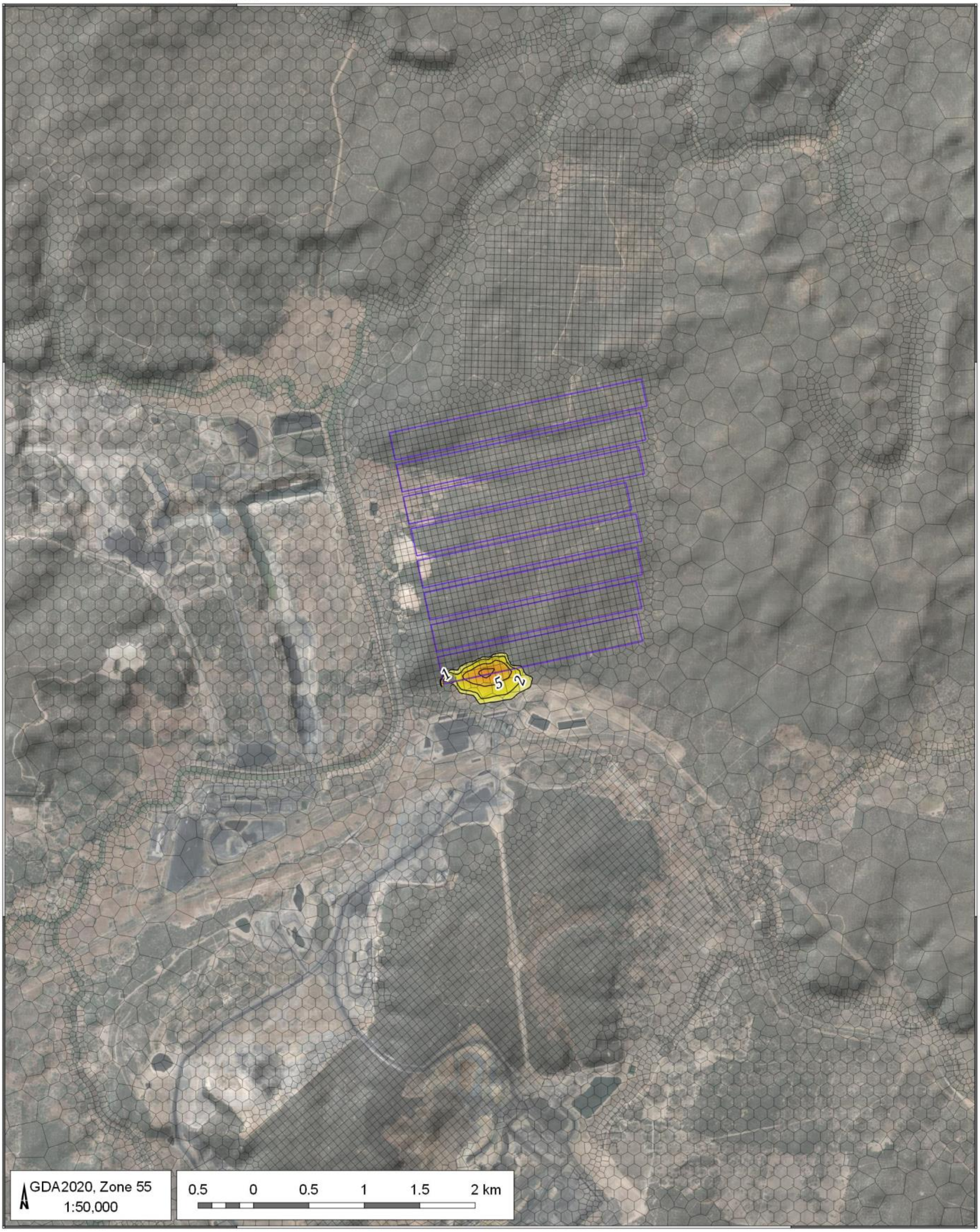
Drawdown in the alluvium/colluvium due to LW401-LW408 at completion of LW408

AGE

DATE 02/11/2021

FIGURE No: **5.14**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1622F_Moolarben\3_GIS\Workspaces\999_Working\drawdowns_UG4.qgs



LEGEND

- Drawdown contour (m)
- Model mesh
- Longwall panels 401 to 408

Drawdown (m)

- 0
- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500

Moolarben (G1622F)

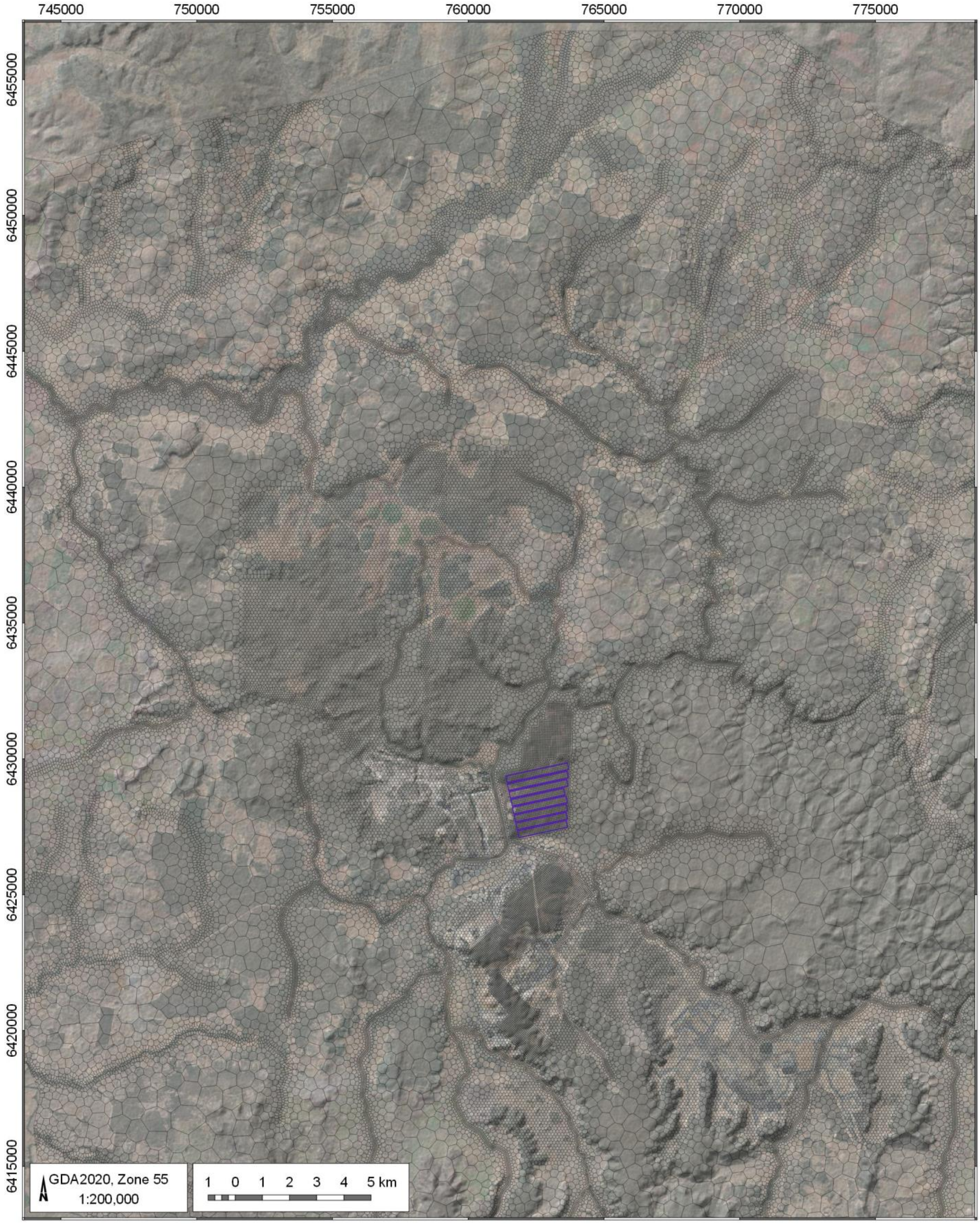
Drawdown in the paleochannel due to LW401-LW408 at completion of LW408

AGE

DATE 02/11/2021

FIGURE No: **5.15**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1622F_Moolarben\3_GIS\Workspaces\999_Working\drawdowns_UG4.qgs



LEGEND

- Drawdown contour (m)
- Model mesh
- Longwall panels 401 to 408

Drawdown (m)

- 0
- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500

Moolarben (G1622F)

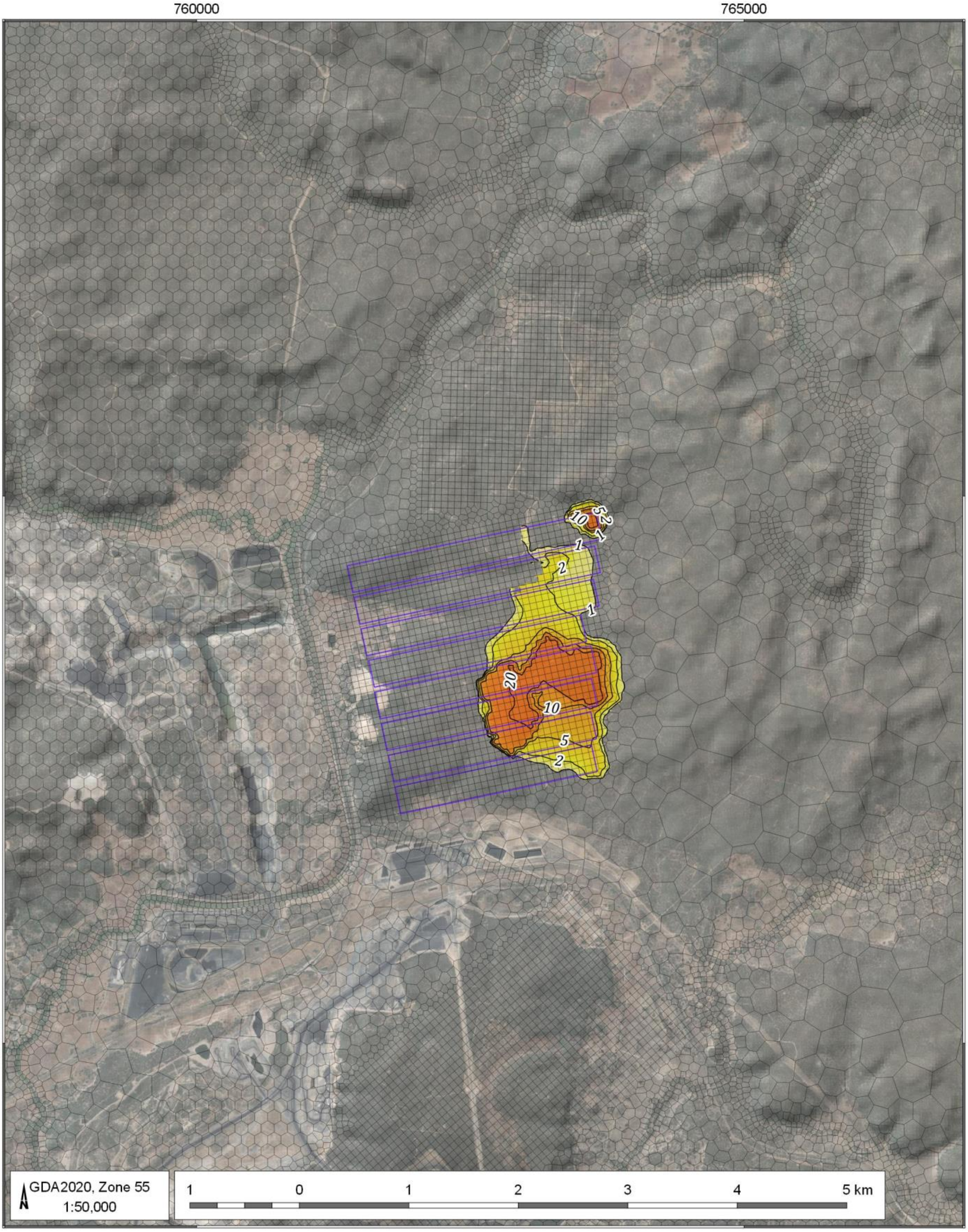
Drawdown in layer 5 (Jursasic Purlewaugh) due to LW401-LW408 at completion of LW408

AGE

DATE 02/11/2021

FIGURE No: **5.16**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1622F_Moolarben\3_GIS\Workspaces\999_Working\drawdowns_UG4.qgs



LEGEND

- Drawdown contour (m)
- Model mesh
- Longwall panels 401 to 408

Drawdown (m)

0
1
2
5
10
20
50
100
200
500

Moolarben (G1622F)

Drawdown in layer 8 (base of Triassic quartzose) due to LW401-LW408 at completion of LW408

AGE

DATE 02/11/2021

FIGURE No: **5.17**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1622F_Moolarben\3_GIS\Workspaces\999_Working\drawdowns_UG4.qgs

LEGEND

Drawdown contour (m)

Model mesh

Longwall panels 401 to 408

Drawdown (m)

- 0
- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500

Moolarben (G1622F)

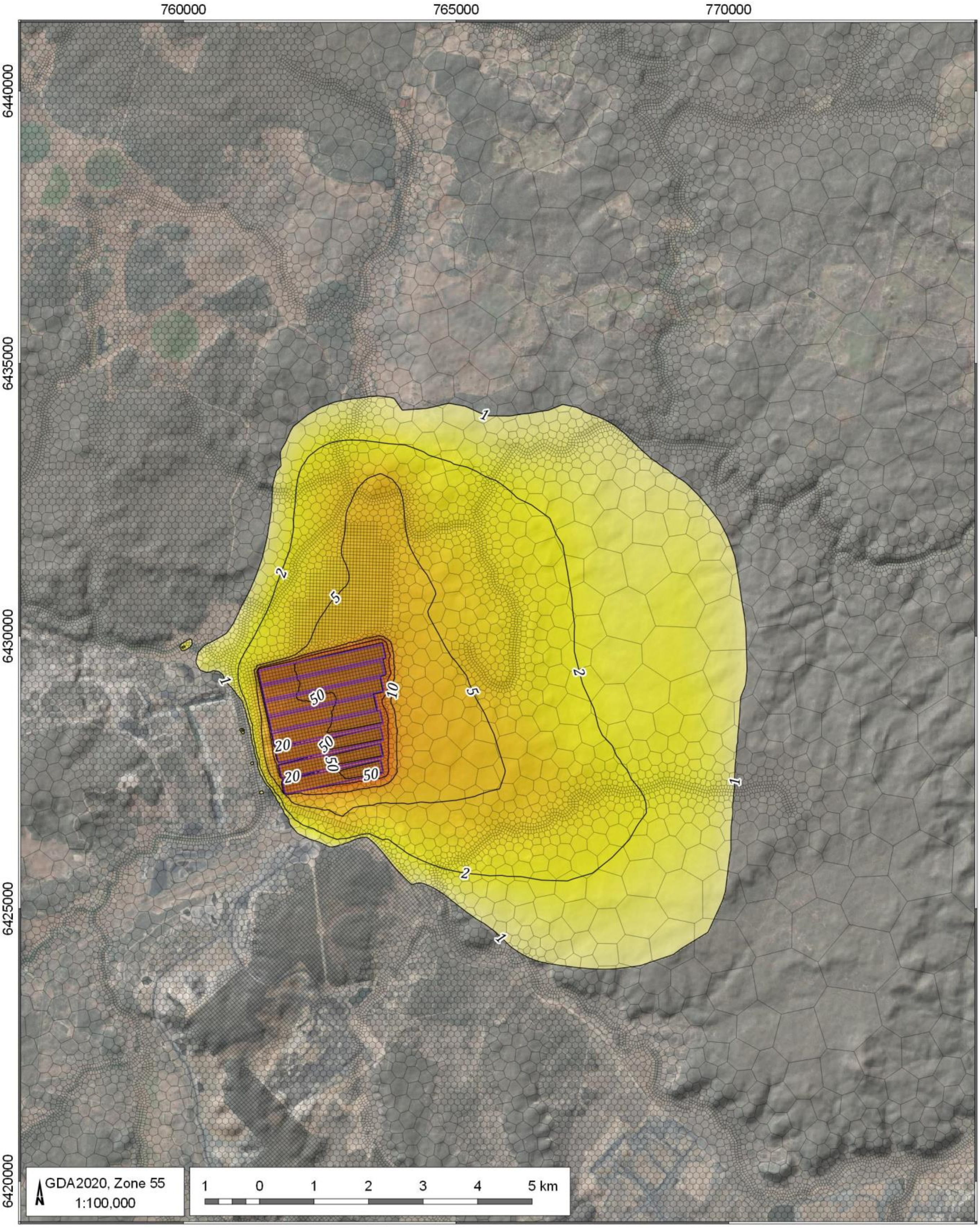
Drawdown in layer 10 (base of Triassic lithic) due to LW401-LW408 at completion of LW408

AGE

DATE 02/11/2021

FIGURE No: **5.18**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1622F_Moolarben\3_GIS\Workspaces\999_Working\drawdowns_UG4.qgs



LEGEND

- Drawdown contour (m)
- Model mesh
- Longwall panels 401 to 408

Drawdown (m)

- 0
- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500

Moolarben (G1622F)

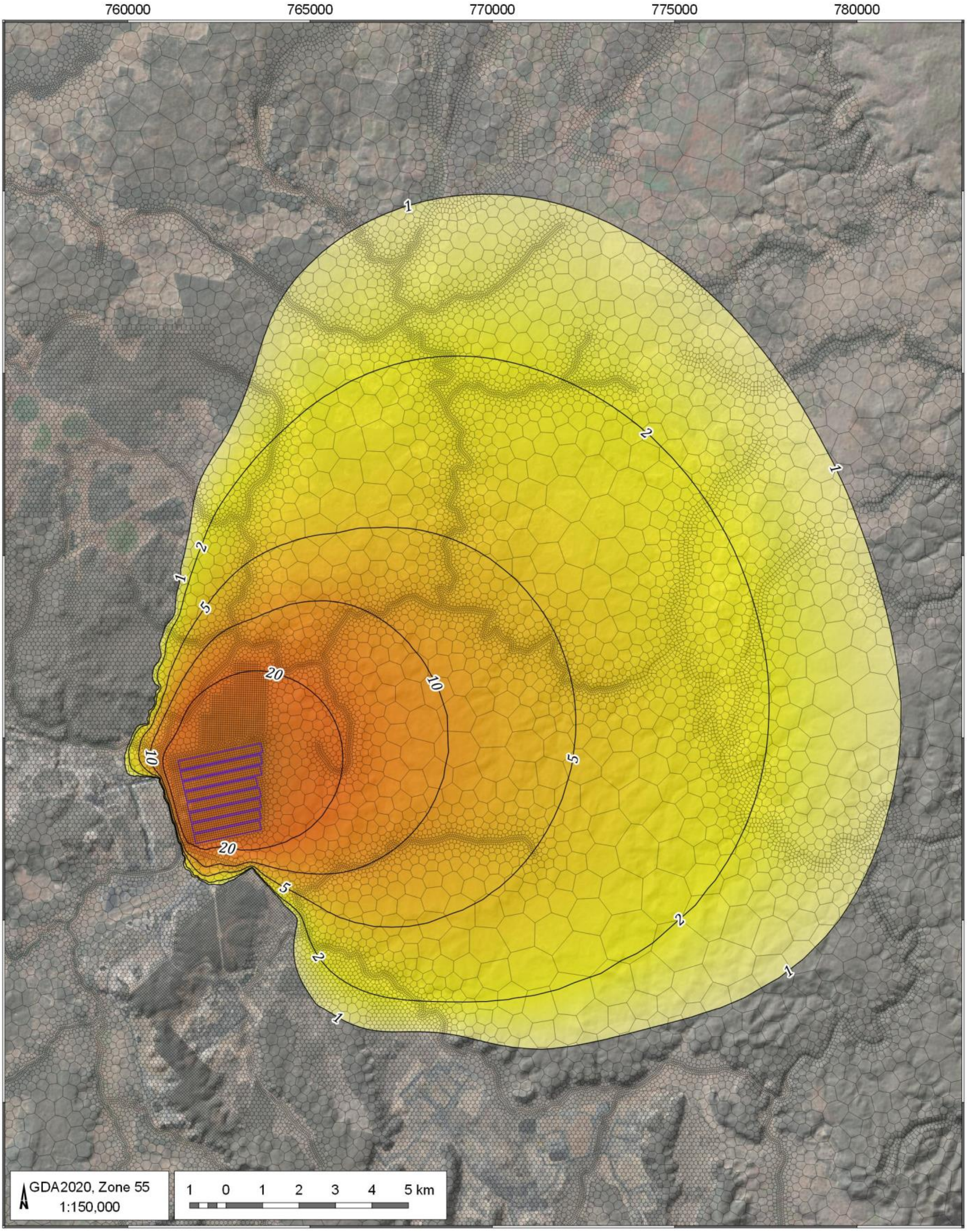
Drawdown in layer 15 (base of Permian overburden) due to LW401-LW408 at completion of LW408

AGE

DATE
02/11/2021

FIGURE No:
5.19

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1622F_Moolarben\3_GIS\Workspaces\999_Working\drawdowns_UG4.qgs



LEGEND

- Drawdown contour (m)
- Model mesh
- Longwall panels 401 to 408

Drawdown (m)

- 0
- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500

Moolarben (G1622F)

Drawdown in layer 18 (Ulan Seam WS2) due to LW401-LW408 at completion of LW408

AGE

DATE 02/11/2021

FIGURE No: **5.20**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1622F_Moolarben\3_GIS\Workspaces\999_Working\drawdowns_UG4.qgs

5.4.2 Private bores

There is one privately owned bore in the vicinity of the Moolarben Coal Complex (Section 4.3.1).

No private bores are predicted to experience greater than minimal impact (i.e. drawdown greater than 2 m, as defined in the *NSW Aquifer Interference Policy*) due to the Moolarben Coal Complex.

5.4.3 Inflows

The predicted inflow for LW401 to LW408 per water year is shown in Figure 5.21. This includes components of first workings associated with UG4.

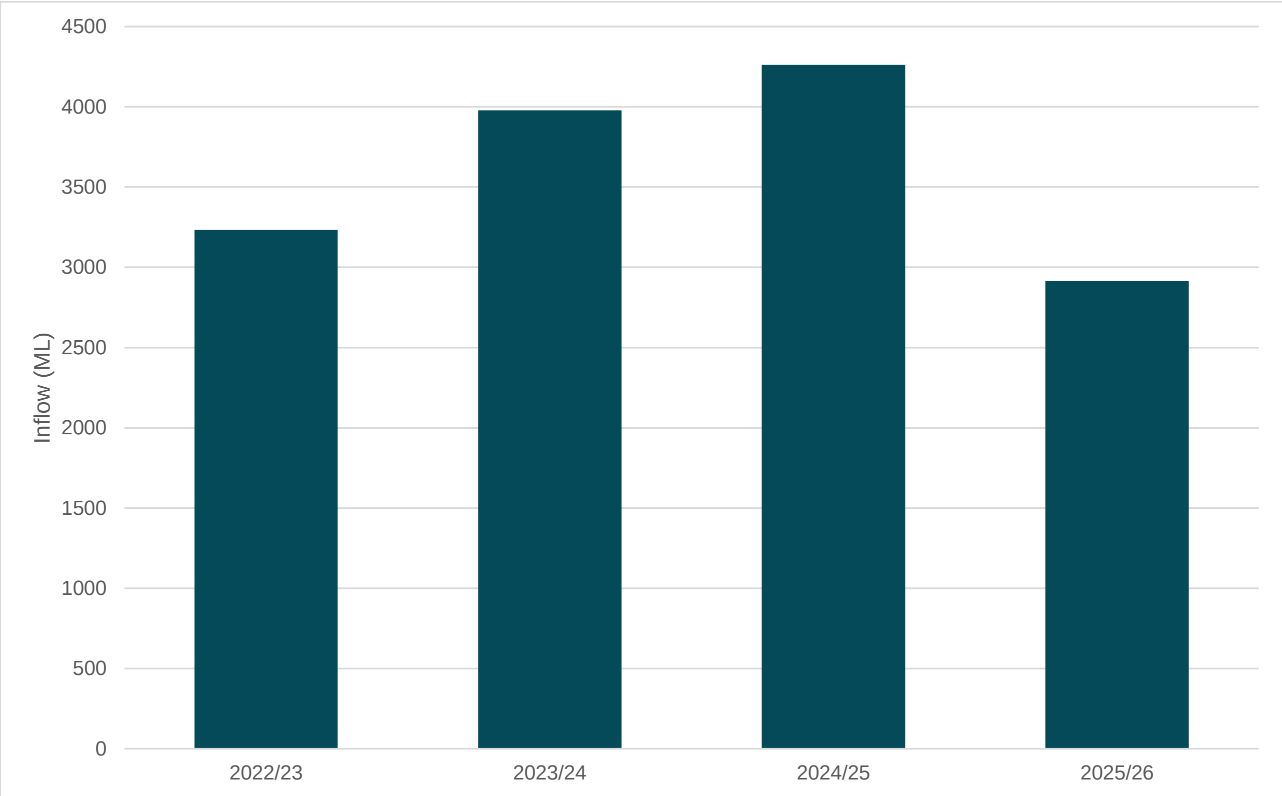


Figure 5.21 Predicted groundwater inflow to LW401 to LW408

5.4.4 Interception of baseflow

Underground mining and associated mine induced dewatering (and fracturing) will lower the watertable in and around the mine, reducing and sometimes reversing hydraulic gradients in the groundwater regime. This alteration could temporarily divert water that might have historically migrated to surface drainages and become baseflow.

Groundwater baseflow to the minor creeks, such as Bora Creek, is insignificant as the creek systems are highly ephemeral, and generally only flow in response to significant weather events.

Predicted baseflows were extracted from the approved mining and ‘no UG4’ simulations to estimate the predicted change in baseflow due to mining of LW401 to LW408. The results from this simulation and the baseflow changes are summarised below in Table 5.5, which shows that mining of LW401 to LW408 is expected to result in negligible change to baseflow in the Goulburn River.

Table 5.5 Net baseflow take

Water year	Net baseflow take in Upper Goulburn River water source (ML)	Net baseflow take in Wollar Creek Water Source (ML)
2022/23	0.5	0.0
2023/24	0.6	0.0
2024/25	0.8	0.0
2025/26	0.7	0.0

5.5 Potential impact to The Drip

There is no predicted change in the perched water levels associated with The Drip from LW401 to LW408. At their nearest point the longwalls are over 2 km south of The Drip.

6 Water Take and Water Sharing Plans

Mining of longwall panels LW401 to LW408 will result in a direct take of groundwater from the Sydney Basin-North Coast Groundwater Source, which is regulated under the *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016*.

The subsidence and fracturing associated with longwall mining will provide increased connection to overlying and underlying strata, and the hydraulic gradients will result in the flow of groundwater to the mine area. This flow results in indirect take from the surrounding strata.

The amount of incidental water take from surrounding groundwater sources has been determined by comparison of two model scenarios, one representing pre-mining conditions (the null model) and the other representing the mining activity. Using this process, a third model run removing the simulation of dewatering for longwalls LW401 to LW408 was undertaken to isolate the influence and contribution of those panels.

The estimated water take from the various Water Sources due to LW401 to LW408 are outlined in the following sections, which indicate:

- MCO holds sufficient water access licenses to account for its indirect take from the Upper Goulburn River and Wollar Creek Water Sources;
- MCO holds 2,850 units to account for direct take from the Sydney Basin-North Coast Groundwater Source, which is sufficient until 2024/2025;
- MCO requires some additional units in the Sydney Basin-North Coast Groundwater Source to account for take from 2025/2026 onwards when carry-over provisions are applied in accordance with subclause 38(3) of the *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016*; and
- Yancoal holds additional entitlements in the Sydney Basin-North Coast Groundwater Source that can be utilised to account for additional take.

6.1 Direct take

The predicted direct take from mining activities is presented for the entire Moolarben site and for LW401 to LW408 below in Table 6.1.

Table 6.1 Predicted direct take from the Sydney Basin-North Coast Groundwater Source

Water Year	Licence Entitlement (including carry-over)	Moolarben Take (ML)	LW401 to LW408 Take (ML)
2022/23	5,900	3,427.1	3,232.6
2023/24	5,422	4,150.9	3,977.8
2024/25	4,222	4,427.5	4,261.1
2025/26	2,950	3073.3	2914.1

6.2 Indirect take

Mine dewatering at Moolarben has indirect impact on two water sources that are regulated under the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009*. The peak impacts are presented below in Table 6.2.

Table 6.2 Peak water take from the Upper Goulburn River and Wollar Creek Water Sources

Water Source	Licence (units)	Moolarben Peak Take (ML/year)	LW401 to LW408 Peak (ML/year)
Upper Goulburn River Water Source	99	25.4	19.2
Wollar Creek Water Source	228	184.3	1.0

7 Groundwater Monitoring, Management and Triggers

7.1 Proposed Groundwater Monitoring

The existing baseline groundwater monitoring program in the vicinity of UG4 is discussed in Section 4.1.

A number of additional monitoring sites are proposed to be established as part of the UG4 Extraction Plan. These additional monitoring points are focused on measuring potential impacts on the Goulburn River downstream of UG4 LW401 to LW408 (i.e. the natural part of the Goulburn River downstream of the diversion, where some baseflow interaction is understood to occur). The following additional monitoring points are proposed (Figure 4.1):

- Additional Monitoring Site 1 (PZ-A): This site would target shallow groundwater monitoring;
- Additional Monitoring Site 2 (PZ-B): This site would be established above LW404 to assist the delineation of the height of continuous fracturing as longwall mining advances. This data would inform future extraction plans; and
- Additional Monitoring Site 3: A new VWP has been established (PZ229) with sensors in both the Triassic and Permian strata.

In addition to the new monitoring sites detailed, PZ102A and PZ103A would be re-purposed as VWPs to monitor water levels in the Triassic and Upper Permian. PZ102B intersects planned underground workings and PZ103B is currently blocked and will be decommissioned.

The additional and re-purposed monitoring points will be established prior to secondary extraction of LW405, to provide sufficient time to collect data and establish appropriate triggers for the mining of LW405 to LW408.

7.2 Trigger Action Response Plan

Condition 73, Schedule 3 of Project Approval (05_0117) outlines subsidence performance measures relevant to the preparation of Extraction Plans. These performance measures relate to direct subsidence impacts and have been addressed in MSEC (2021).

Condition 32, Schedule 3 of Project Approval (05_0117) outlines water management performance measures. Performance measures relevant to groundwater are summarised in Table 7.1.

Table 7.1 Water Management Performance Measures

Feature	Performance Measure
The Drip	Nil impact on the water supply to The Drip

In addition to the above, Condition 77(h)(iv) of Project Approval (05_0117) requires Extraction Plans include a program to predict, manage and monitor impacts on privately-owned groundwater bores.

7.2.1 The Drip

Groundwater discharge at The Drip is derived from a perching of groundwater within the Triassic Narrabeen Group sediments which is understood to be disconnected from the underlying regional watertable (Section 4.3.2). Updated groundwater modelling confirms that mining at UG4 LW401 to LW408 would not impact the water supply to The Drip, as any lowering of the underlying watertable would not affect the perching of groundwater that supplies The Drip (Section 5.5). The addition of new drillholes in close proximity of The Drip should be avoided due to the risk of creating preferential vertical pathways, which could assist to drain localised perching within the Narrabeen Group.

Photographic monitoring of The Drip is proposed to be undertaken every two months.

7.2.2 Private bores

No private bores are predicted to experience greater than minimal impact (i.e. drawdown greater than 2 m, as defined in the *NSW Aquifer Interference Policy*) due to the Moolarben Coal Complex (Section 5.4.2). Notwithstanding, Groundwater Level Investigation Triggers have been established at monitoring bores to provide an early indication of a potential exceedance of the AIP criteria at a private bore (i.e. these monitoring bores are located significantly closer to the UG4 LW401 to LW408 mine workings than any private bores and would therefore experience any mining-related impact well in advance of that impact occurring at a private bore).

Groundwater Level Investigation Triggers relevant to the extraction of LW401 to 408 have been developed based on the updated groundwater model predictions with the objective of identifying any non-natural or expected (approved) impacts from LW401 to LW408 and which may adversely affect local water supply work (as per Table 1: Less Productive Groundwater Sources of the *NSW Aquifer Interference Policy)*. Groundwater level investigation triggers are based on the greater of the predicted groundwater drawdown, or 2 m drawdown below the minimum observed water level and are presented in Table 7.2. Triggers would also be established at the additional monitoring locations PZ-A and PZ229 described in Section 7.1, once sufficient baseline data has been collected.

Table 7.2 Updated Groundwater Investigation Trigger Levels

Piezometer	Screened Unit	Monitored Interval (mbgl)	Recommended Trigger Level (mAHD)
PZ101C	Triassic	24 – 30	378.0
PZ105C	Triassic*	20 – 28	371.7
PZ129	Triassic	35 (VWP)	386.0

Note: * Screened interval for PZ105C also includes a small portion of underlying Permian.

In the event that two consecutive groundwater level monitoring results exceed the investigation trigger levels at the monitoring locations specified in Table 7.2, MCO would implement the actions outlined in the Groundwater Management Plan.

Groundwater quality triggers in the current approved Groundwater Management Plan should also continue to be applied.

The trigger levels for future extraction plans (ie LW409 to LW414) will need to be re-evaluated, due to the proximity of the proposed monitoring points to the UG4 longwall panels LW409 to LW414.

8 References

Advisian (2017). *Controlled Water Release Impact Assessment for the Goulburn River*.

Aquaterra Simulations Pty Ltd (2006). *Moolarben Coal Groundwater Model ('MC1 Model').* Prepared for Peter Dundon and Associates Pty Ltd. Included as Appendix F of Appendix 5 within the Stage 1 EA. Date September 2006.

Aquaterra Simulations Pty Ltd (2008). *Moolarben Stage 2 Groundwater Assessment.* Dated 24 November 2008.

Australasian Groundwater and Environmental Consultants Pty Ltd (2013). *Moolarben Coal Project – Stage 1 Optimisation Modification Groundwater Assessment.* Dated May 2013.

Barnett et al. (2012). *Australian groundwater modelling guidelines.* Waterlines report, National Water Commission, Canberra. June 2012.

Dundon Consulting Pty Ltd. (2015). *Re: Moolarben Coal Complex – UG1 Optimisation Modification – Groundwater Assessment*. Letter date 21 May 2015. Included within Appendix B of the Moolarben Coal Complex UG1 Optimisation Modification – Groundwater Assessment.

Dundon Consulting Pty Ltd. (2019). Moolarben – UG4 Modification – Review of Groundwater Effects. Letter date 28 September 2019. Included as Appendix H of the Moolarben Coal Complex UG4 Ancillary Works Modification – Groundwater Assessment.

Forster, I., and Enever, J. (1992). Hydrogeological response of overburden strata to underground mining, Central Coast, New South Wales, Sydney: Office of Energy. 1992.

HydroSimulations. (2015a). *Moolarben Coal Complex UG1 Optimisation Modification. Groundwater Modelling Assessment*. Prepared for Moolarben Coal Operations Pty Ltd. Included within Appendix B of the Moolarben Coal Complex UG1 Optimisation Modification – Groundwater Assessment. Date May 2015.

HydroSimulations Pty Ltd (2015b). *Wilpinjong Extension Project – Groundwater Assessment*.

HydroSimulations. (2017). *Moolarben Coal Open Cut Optimisation Modification. Groundwater Assessment*. Prepared for Moolarben Coal Operations Pty Ltd. Included as Appendix I of the Moolarben Coal Complex Open Cut Optimisation Modification – Groundwater Assessment. Date October 2017.

Mackie Environmental Research (2009). *Ulan Coal - Continued Operations – Groundwater Assessment*. July 2009.

Mine Subsidence Engineering Consultants Pty Ltd (2021). *Moolarben Coal Complex: Moolarben Project Stage 1 – Longwalls 401 to 408 Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Extraction Plan*.

Moolarben Coal Mines Pty Ltd (MCM). (2020). *Groundwater Management Plan*. Document MCO_ENV_PLN_0038. Date October 2020.

NSW Department of Primary Industries – Office of Water, (2012). *NSW Aquifer Interference Policy – NSW Government policy for the licensing and assessment of aquifer interference activities*. September 2012.

Peter Dundon and Associates Pty Ltd. (2006). *Moolarben Coal Project Groundwater Assessment*. Appendix 5 – Groundwater Assessment. Prepared for Moolarben Coal Mines Pty Limited. 05-0158-R01J. Date 8 September 2006.

Peter Dundon and Associates Pty Ltd. (2013). *Re: Email from NOW to DoPI* dated 19 April 2013, with attached internal NOW memo dated 9 April 2013. Letter date 7 June 2013.

Richardson, S., Irvine, E., Froend, R., Boon, P., Barber, S. and Bonneville, B. (2011) *Australian Groundwater-Dependent Ecosystems Toolbox*.

RPS Aquaterra. (2011). *Moolarben Coal Complex Stage 2 Preferred Project Report Groundwater Impact Assessment*. Appendix E – Groundwater Impact Assessment. Prepared for Hansen Bailey on behalf of Moolarben Coal. Date November 2011.

RPS Aquaterra. (2012). *Moolarben Stage 2 – Groundwater Accounting and Water Sharing Plan Summary*. Prepared for Hansen Bailey on behalf of Moolarben Coal. Date 13 June 2012.

SLR. (2020). *Moolarben Coal Complex. Extraction Plan Longwalls 104 to 105* - Technical Report. Prepared from Moolarben Coal Operations. Date March 2020.

Strata Engineering (2006). *Preferred Project Report for the Proposed Longwalls 1 to 14 in the No. 4 Underground Area, Moolarben (Stage 1)*. Report No. 06-002-WHT/1, 1st December 2006, Moolarben Coal Project Response to Submissions Appendix A8 Subsidence Response

Umwelt Australia (2009). *Ulan Coal – Continued Operations Environmental Assessment*.

University of Oslo (2015). BFI tool downloaded from www.geo.uio.no/edc/software/BFI/BFI.xls

Wilford, John; Searle, Ross; Thomas, Mark; Grundy, Mike (2015): Soil and Landscape Grid National Soil Attribute Maps - Depth of Regolith (3" resolution) - Release 2. v6. CSIRO. Data Collection. https://doi.org/10.4225/08/55C9472F05295

Appendix A

Moolarben Coal Complex Groundwater Monitoring Network

Table A-5: Groundwater Monitoring Program

Bore	Type	Depth (m)	Screened interval (m)	Lithology screened	Water Level Monitoring Frequency	Historic Water Level range (mbgl)	Water Quality Monitoring Frequency	Easting (m)	Northing (m)	RL (mAHD)
PZ003	Stand Pipe Piezometer	21	9-15	Ulan seam	Manual monthly	3.13-7.74	6-monthly	762714	6417964	474.92
PZ040B	Stand Pipe Piezometer	45	38-44	Permian OB	Manual monthly	6.06-14.93	6-monthly	763928	6423743	428.40
PZ044	Stand Pipe Piezometer	23	20-23	Ulan Granite	Manual monthly	7.84-12.61	6-monthly	759906	6417069	491.30
PZ055	Stand Pipe Piezometer	15	11-14	Marrangaroo Conglomerate	Manual monthly	3.33-7.63	6-monthly	758773	6423995	429.46
PZ58a	Stand Pipe Piezometer	12	8-11	Tertiary Aged Sediment	Manual monthly	10.79-11.38	6-monthly	761622	6418359	478.39
PZ101C	Stand Pipe Piezometer	30	24-30	Lower Triassic	Manual monthly	21.34-22.63	6-monthly	762646	6431445	403.00
PZ101B	Stand Pipe Piezometer	60	54-60	Permian OB	Manual monthly	27.29-39.8	6-monthly	762646	6431445	403.28
PZ102B*	Stand Pipe Piezometer	86	80-86	Ulan seam	Manual monthly	32.96-53.46	6-monthly	761117	6429147	408.23
PZ102A*	Stand Pipe Piezometer	125	116-125	Marrangaroo Conglomerate	Manual monthly	33.27-52.91	6-monthly	761118	6429150	408.54
PZ103C	Stand Pipe Piezometer	30	24-30	Lower Triassic	Manual monthly	22.70-27.78	6-monthly	762397	6429264	425.00
PZ103B	Stand Pipe Piezometer	87	81-87	Permian OB	Manual monthly	24.55-58.6	6-monthly	762397	6429264	425.00
PZ103A	Stand Pipe Piezometer	128	118-127	Ulan seam	Manual monthly	50.66-70.79	6-monthly	762410	6429261	425.21
PZ104	Stand Pipe Piezometer	160	151-160	Ulan seam	Manual monthly	50.22-63.77	6-monthly	766832	6426451	438.93
PZ105C	Stand Pipe Piezometer	28	20-28	Lower Triassic	Manual monthly	10.86-15.1	6-monthly	763987	6431607	389.00
PZ105A	Vibrating Wire Piezometer	133	28	Permian OB	Datalogger Recorded monthly	TBC	N/A	763988	6431610	388.93
	Vibrating Wire Piezometer		80	Permian OB	Datalogger Recorded monthly	TBC				
	Vibrating Wire Piezometer		118	Ulan Seam	Datalogger Recorded monthly	TBC				

Bore	Type	Depth (m)	Screened interval (m)	Lithology screened	Water Level Monitoring Frequency	Historic Water Level range (mbgl)	Water Quality Monitoring Frequency	Easting (m)	Northing (m)	RL (mAHD)
	Vibrating Wire Piezometer		130	Ulan Seam	Datalogger Recorded monthly	TBC				
PZ106A	Stand Pipe Piezometer	131.5	125-131	Permian OB	Manual monthly	58.89-87.08	6-monthly	765128	6418275	510.69
PZ109	Stand Pipe Piezometer	254	246-252	Permian OB	Manual monthly	52.68-57.7	6-monthly	766123	6435558	437.12
PZ111	Stand Pipe Piezometer	83	71-77	Ulan seam	Manual monthly	23.67-41.92	6-monthly	767082	6423096	404.78
PZ112B	Stand Pipe Piezometer	12	6-12	Permian OB	Manual monthly	3.71-6.51	6-monthly	766139	6419517	485.67
PZ127	Vibrating Wire Piezometer	152	43	Triassic	Datalogger Recorded monthly	Dry	N/A	762799	6424948	494.55
	Vibrating Wire Piezometer		68	Permian OB	Datalogger Recorded monthly	47.2-52.98	N/A			
PZ128	Vibrating Wire Piezometer	61	20	Triassic	Datalogger Recorded monthly	Dry	N/A	763227	6432120	409.52
	Vibrating Wire Piezometer		36	Permian OB	Datalogger Recorded monthly	28.6-34.55	N/A			
	Vibrating Wire Piezometer		55	Permian OB	Datalogger Recorded monthly	28.6-38.85	N/A			
PZ129	Vibrating Wire Piezometer	74	35	Triassic	Datalogger Recorded monthly	25.2-35.23	N/A	763624	6432251	417.95
	Vibrating Wire Piezometer		53	Permian OB	Datalogger Recorded monthly	27.1-41.2	N/A			
	Vibrating Wire Piezometer		74	Permian OB	Datalogger Recorded monthly	36.0-43.09	N/A			
PZ130	Vibrating Wire Piezometer	111	38.5	Permian OB	Datalogger Recorded monthly	37.7-40.4	N/A	760940	6422438	535.07
	Vibrating Wire Piezometer		64	Permian OB	Datalogger Recorded monthly	51.6-64.29	N/A			
PZ137	Stand Pipe Piezometer	23	20-23	Permian OB	Manual monthly	16.38-18.93	6-monthly	764002	6420285	479.01
PZ170*	Stand Pipe Piezometer	31	26-29	Permian OB	Manual monthly	14.68-17.39	6-monthly	763591	6424306	437.49

Bore	Type	Depth (m)	Screened interval (m)	Lithology screened	Water Level Monitoring Frequency	Historic Water Level range (mbgl)	Water Quality Monitoring Frequency	Easting (m)	Northing (m)	RL (mAHD)
PZ179	Vibrating Wire Piezometer	145	29	Triassic	Datalogger Recorded monthly	24.6-31.2	N/A	764688	6426599	444.75
	Vibrating Wire Piezometer		33	Permian OB	Datalogger Recorded monthly	25.8-33.5	N/A			
	Vibrating Wire Piezometer		145	Ulan seam	Datalogger Recorded monthly	28.9-107.4	N/A			
PZ184	Stand Pipe Piezometer	9	6-9	Tertiary paleochannel	Manual monthly	6.19-9.11	6-monthly	765410	6423142	419.40
PZ186	Vibrating Wire Piezometer	126	40	Upper Permian	Datalogger Recorded monthly	TBC	N/A	764788	6425865	418.76
	Vibrating Wire Piezometer		65	Middle Permian	Datalogger Recorded monthly	TBC	N/A			
	Vibrating Wire Piezometer		86	Lower Permian	Datalogger Recorded monthly	TBC	N/A			
	Vibrating Wire Piezometer		118	Ulan Seam	Datalogger Recorded monthly	TBC	N/A			
PZ186a	Vibrating Wire Piezometer	18	13.5	Tertiary paleochannel	Datalogger Recorded monthly	TBC	N/A	764788	6425865	418.76
PZ188	Stand Pipe Piezometer	18.5	12-18	Tertiary paleochannel	Manual monthly	6.01-9.97	6-monthly	764478	6426084	423.62
PZ189	Stand Pipe Piezometer	65	59-95	Permian OB	Manual monthly	10.41-22.7	6-monthly	764503	6426089	424.17
PZ191*	Stand Pipe Piezometer	72	60-72	Ulan seam	Manual monthly	30.96-54.93	6-,monthly	761776	6426772	417.69
PZ192	Vibrating Wire Piezometer	180	68	Triassic	Datalogger Recorded monthly	47.5-54.25	N/A	763787	6429831	453.70
	Vibrating Wire Piezometer		166	Ulan seam roof	Datalogger Recorded monthly	72.9-97.72	N/A			
	Vibrating Wire Piezometer		178	Ulan seam base	Datalogger Recorded monthly	80.9-115.7	N/A			
PZ193	Vibrating Wire Piezometer	186	80	Permian OB	Datalogger Recorded monthly	42.12-43.94	N/A	763733	6429326	461.40
	Vibrating Wire Piezometer		162	Ulan seam roof	Datalogger Recorded monthly	90.84-101.8	N/A			
	Vibrating Wire Piezometer		184	Ulan seam base	Datalogger Recorded monthly	96.2-110.9	N/A			

Bore	Type	Depth (m)	Screened interval (m)	Lithology screened	Water Level Monitoring Frequency	Historic Water Level range (mbgl)	Water Quality Monitoring Frequency	Easting (m)	Northing (m)	RL (mAHD)
PZ203	Stand Pipe Piezometer	21	14-20	Tertiary paleochannel	Manual monthly	5.6-9.0	6-monthly	766296	6423545	409.40
PZ211	Stand Pipe Piezometer	20	17-20	Tertiary paleochannel	Manual monthly	Dry	6-monthly	763442	6426146	453.05
PZ213	Stand Pipe Piezometer	22	20-22	Tertiary paleochannel	Manual monthly	12.45-14.9	6-monthly	764341	6425229	427.57
PZ214	Stand Pipe Piezometer	25	22-25	Tertiary paleochannel	Manual monthly	15.08-17.9	6-monthly	764135	6425720	430.69
PZ217	Stand Pipe Piezometer	18	7-13	Ulan Seam	Manual monthly	TBC	6-monthly	763874	6415749	495.30
PZ221	Stand Pipe Piezometer	66	49-58	Ulan Seam	Manual monthly	TBC	6-monthly	763771	6417730	499.76

*NB. To be decommissioned prior to extraction for safety of underground operations. Sites will continue to be monitored until decommissioned.