INDEPENDENT ADVISORY PANEL FOR UNDERGROUND MINING

ADVICE RE:

MOOLARBEN COAL COMPLEX UG4

LONGWALLS 401-408

EXTRACTION PLAN

April 2022

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EXECUTIVE SUMMARY

The Moolarben Coal Complex (MCC) is an open cut and underground coal mine located approximately 40 kilometres (km) north of Mudgee. Moolarben Coal Pty Limited (the Applicant) has submitted an Extraction Plan for Longwalls 401 to 408 in the 'UG4' mining area. The UG4 area comprises a total of 14 longwall panels. Longwalls 401 to 408 are the first panels to be extracted in the UG4 area.

On 2 February 2022, the NSW Department of Planning and Environment (the Department) requested the Independent Advisory Panel for Underground Mining (the Panel) to provide advice in relation to the Extraction Plan (EP).

Specifically, the Department requested advice on the following:

- *the scale and likelihood of potential subsidence, water-related impacts and environmental consequences on key water features in the vicinity of the Extraction Plan area, including the Drip gorge, Corner Gorge and the Goulburn River;*
- *the scale and likelihood of potential subsidence impacts to Aboriginal Heritage sites within the Extraction Plan area, including S1MC280; and*
- *whether the proposed monitoring program and Trigger Action Response Plans are adequate to satisfactorily identify subsidence impacts and related environmental consequences on significant water features and whether the monitoring program is suitable to inform monitoring and assessment of the extraction of the future longwall panels in the UG4 area.*

The Panel reviewed a range of documents in preparing its advice, met on multiple occasions via videoconference and requested supplementary information from the Applicant. The Panel also undertook a site inspection of the MCC and relevant surrounding significant features.

The Panel's findings include twenty recommendations relating to the Extraction Plan's subsidence, groundwater and surface water assessments. Key recommendations include:

- installation of an array of surface satellite monitoring stations between the subject longwalls and the Drip and Corner Gorge, in order to detect surface horizontal movements and potential adverse valley closure;
- identification and design of a suitable "early warning" subsidence monitoring site above the 402/403 row of chain pillars, to monitor the subsidence effects and impacts ahead of reaching Site S1MC280;
- a comprehensive mitigation plan, monitoring program and Trigger Action Response Plan for Site S1MC280, to cover all actions to prevent any significant cracking or instability of the site due to subsidence, tilt or strain;
- a geological structural analysis to be submitted by 30 June 2022 to determine whether there are any natural defects in the geology that could enhance or restrict groundwater migration and flow, and necessitate expanded monitoring and/or updated modelling;
- updating the numerical groundwater model predictions relating to leakage between the Triassic sandstones and the Permian ICM (overburden), surface water – groundwater connectivity, aquifer drawdowns and water budget estimates, predicted groundwater take;

- an independent peer review of the current and updated groundwater model within 12 months;
- a hold point at the completion of LW403 (anticipated to be August 2023) to allow the Panel to provide further advice to the Department as to whether any additional EP conditions are required, prior to the commencement of LW404;
- installation of additional groundwater monitoring bores at six sites, including two to be installed prior to the commencement of LW401;
- recommendations relating to groundwater performance indicators and investigation trigger levels; and
- increased monitoring of the Goulburn River and Drainage Lines 1 and 2 and an extended set of performance indicators and TARPs for these features.

1.0 SCOPE OF WORKS

The Moolarben Coal Complex (MCC) is an open cut and underground coal mine located approximately 40 kilometres (km) north of Mudgee. The complex lies directly between two other mining operations, the Ulan Coal Complex (UCC) to the north-west and Wilpinjong Mine to the south-east.

MCC operates under two integrated development consents known as 'Stage 1' (05_0117) and 'Stage 2' (08_0135). Stage 1 was approved in 2007 by the then Minister for Planning and allows for the development of three open cut pits (named OC1, OC2 and OC3) and an underground mining operation (named UG4). It also allows for a range of surface infrastructure to support mining operations. Stage 2 was approved by the Planning Assessment Commission in 2015 and allows for the development of another open cut pit (named OC4) and two underground mining areas (named UG 1 and UG2).

Condition 77 of Schedule 3 of the Stage 1 consent requires the preparation of an Extraction Plan prior to the commencement of second workings. The Extraction Plan must demonstrate that mining operations do not cause exceedances of performance measures identified in Conditions 73 and 75 of Schedule 3 of the consent.

Moolarben Coal Pty Limited (the Applicant) has submitted an Extraction Plan for Longwalls 401 to 408 in the UG4 mining area. The UG4 area comprises a total of 14 longwall panels. Longwalls 401 to 408 are the first panels to be extracted in the UG4 area. The UG4 mining area is located to the south of significant water features of the Goulburn River State Conservation Area and National Park, including the Drip, Corner Gorge and the Goulburn River.

On 2 February 2022, the Director – Resource Assessments, NSW Department of Planning and Environment (the Department) (Mr Steve O'Donoghue) requested the Independent Advisory Panel for Underground Mining (the Panel) to provide advice in relation to the Extraction Plan (EP) for Longwalls LW401 - LW408 (identified as LW 1 to 8 in the Moolarben Coal Stage 1 approval) in area UG4 at the Moolarben Coal Complex.

Specifically, the Department requested advice on the following:

- *the scale and likelihood of potential subsidence, water-related impacts and environmental consequences on key water features in the vicinity of the Extraction Plan area, including the Drip gorge, Corner Gorge and the Goulburn River;*
- *the scale and likelihood of potential subsidence impacts to Aboriginal Heritage sites within the Extraction Plan area, including S1MC280; and*
- *whether the proposed monitoring program and Trigger Action Response Plans are adequate to satisfactorily identify subsidence impacts and related environmental consequences on significant water features and whether the monitoring program is suitable to inform monitoring and assessment of the extraction of the future longwall panels in the UG4 area.*

The Chair of the Panel (Em. Professor Jim Galvin) nominated the following members of the Panel to prepare the advice:

- Em. Professor Bruce Hebblewhite – Panel Convenor – Subsidence and mining
- Professor Neil McIntyre – Surface water
- John Ross - Groundwater

2.0 METHOD OF OPERATION

The Panel convened by videoconference throughout the preparation of its advice and was administratively supported by Secretariat staff provided by the Department's Major Projects and Resource Assessments teams. The Panel also undertook a site inspection on 11 March 2022.

A wide range of documents was reviewed by the Panel in preparing this review, the principal ones are summarised in Table 1.

Table 1: Key documents reviewed by the Panel

Document Reference	Document Name
Extraction Plan	Extraction Plan – Moolarben Coal Complex – UG4 Longwalls 401 to 408 - Dec 2021 including the following addendums/volumes: • Appendix A – Water Management Plan • Appendix D – Heritage Management Plan • Appendix G – Subsidence Monitoring Program • Technical Report 1 – Subsidence Report • Technical Report 2 – Groundwater Technical Report • Technical Report 3 – Surface Water Technical Report • Technical Report 5 – Aboriginal Cultural Heritage Technical Report
Briefing Paper	Briefing Paper – Dr Julia Imrie (14 Aug 2020)
Agency Advice	• Biodiversity, Conservation and Science Directorate – 2 February 2022 • Biodiversity, Conservation and Science Directorate – 5 April 2022 • Department of Planning and Environment: Water – 7 March 2022 • Environment Protection Authority – 3 February 2022 • Heritage NSW – 30 January 2022 • Department of Planning and Environment – Crown Lands – 1 February 2022 • Resources Regulator – 18 February 2022
Applicant Response to Agency Advice	Moolarben Coal's Response to Agency Comments – 18 March 2022

2.1. SITE VISIT, SUBSEQUENT INFORMATION AND MEETINGS

Site Visit

On 11 March 2022, the Panel undertook a site inspection. The inspection involved a briefing at the MCC by the Applicant followed by inspection of key features including the Drip, Goulburn River, S1MC280 and the Goulburn River Licensed Discharge Point.

The Panel was accompanied by the Applicant and its relevant consultants, Department representatives, and representatives from National Parks and Wildlife Service (NPWS) during its inspection of the Drip and Goulburn River.

Subsequent Information

The Panel sourced additional reports from the Department and submitted two sets of questions for the Applicant that were addressed by way of written responses, an additional report and additional documentation. Additional information provided to the Panel included:

- *MCO EP 401-408 Request for Information (22 March 22)* – responding to questions relating to regional geology, incremental subsidence predictions, monitoring data and locations.
- Email correspondence titled *IAPUM Additional Information Request update* dated 11 April 2022 – responding to questions relating to tilt predictions, groundwater monitoring and cumulative groundwater modelling.

Meetings

The Panel convened several times over the course of preparing its advice. The Department's Resource Assessments team was invited to several of these meetings to provide technical briefings and updates to the Panel as needed. Table 2 summarises the schedule of meetings held in chronological order.

Table 2: Schedule of meetings held

Meeting Date	Meeting Information
10 February 2022	Panel Meeting - initial briefing
1 March 2022	Panel Meeting – overview of EP key issues, site inspection and report structure.
11 March 2022	Site Inspection - visit to MCC, the Drip and Goulburn River
16 March 2022	Panel meeting - with Dr Julia Imrie
5 April 2022	Panel Meeting - discussion regarding draft report
20 April 2022	Panel Meeting - discussion regarding draft report

3.0 PRIMARY FOCUS OF THIS ADVICE

In reviewing the Moolarben Extraction Plan for UG4 Longwalls 401 to 408 *("the Extraction Plan")* the Panel had a particular focus on the potential subsidence impacts and associated water-related impacts and consequences associated with The Drip, the Corner Gorge, the Goulburn River and the various overlying aboriginal heritage sites, in particular, the rock shelter, S1MC280.

It is important to recognise that the advice provided by the Panel is specific to the current proposed Extraction Plan for LW401 to LW408. Whilst the advice makes reference to important collection of baseline data for application in consideration and management of possible future extraction plans for the area of the mining lease to the north of these current longwall panels, the current Panel advice should not be interpreted as offering any opinion or recommendation with respect to any extraction beyond LW408 in the current Extraction Plan.

Condition 73, Schedule 3 of the Moolarben Stage 1 Project Approval requires the Applicant (Moolarben Coal) to *"ensure that the project does not cause any exceedances of the performance measures in Table 14, to the satisfaction of the Secretary."*

Table 14 lists the following relevant features and performance measures:

Table 14: Subsidence Impact Performance Measures	
Special Features	
The Drip and Goulburn River Gorge (see Appendix 7)	Nil impact or environmental consequences
Water Resources	
Goulburn River and the bed of the Goulburn River (see Appendix 7)	Negligible impact or environmental consequences. Remain outside the zone of recorded subsidence damage for longwall mining.
Land	
Cliff Line 3	Minimise subsidence damage
Heritage Sites	
Aboriginal heritage sites 264, 282, 283, 286 and 287 (see Appendix 7) Aboriginal heritage site 280 (see Appendix 7)	Reduce the likelihood of subsidence damage to low. Reduce the likelihood of subsidence damage to moderate.
Historic heritage sites	No greater subsidence impact or environmental consequences than predicted in the EA
Mine Workings	
First workings under an approved Extraction Plan beneath any feature where performance measures in this table require negligible impact, negligible consequence or negligible loss	To remain long-term stable and non-subsiding
Second workings	To be carried out only within the longwall mining domains, in accordance with an approved Extraction Plan

One point of concern is raised by the Panel in relation to the above performance measures, and in particular, those related to the aboriginal heritage sites, especially site 280. The performance measure specified is *"reduce the likelihood of subsidence damage to moderate"*. Whilst this measure may well be achievable, in terms of likelihood of damage, the performance measure fails to make any statement or impose any requirement on the Applicant with respect to consequence of the impact. As it currently stands, the heritage site could suffer serious damage as an impact of subsidence, albeit due to a reduced likelihood, but the Applicant would still be fully compliant with this performance measure.

The Panel believes that this performance measure should be reviewed by the Department and should incorporate a parameter associated with impact, rather than simply likelihood. The level of acceptable impact should be set to ensure that any form of collapse of the rock shelter at site 280 would be deemed unacceptable.

Further to the above Conditions, the Stage 1 Approval, Condition 78A of Schedule 3, requires the Applicant to gather and analyse *"the subsidence, surface water and groundwater impacts of the cumulative progress of longwall mining for the project, including consideration of data collected from the previously mined panels up to and including commencement in longwall LW11"*.

Whilst the Approval notes that the application of this Condition is beyond the current Extraction Plan, nevertheless, the need to gather essential baseline and subsequent cumulative data is considered to be a requirement to be addressed, from the start of LW401, through to LW408 and potentially beyond.

4.0 SUBSIDENCE ASSESSMENT

4.1. SUBSIDENCE PREDICTION AND MANAGEMENT

The Extraction Plan and supporting documentation provided makes predictions of subsidence effects and impacts on the surface as a result of the mining of LW401 to LW408. The Panel notes the methodology used for such prediction by the Applicant's consultants, MSEC, and accepts that the prediction methodology, and hence the initial results are acceptable. However, it is noted by the Panel that the predictions should be reviewed on a panel-by-panel basis, and recalibrated as required, as subsidence monitoring data is collected and analysed.

In relation to the surface impacts of extraction in the current block of eight longwall panels, it is noted that the proposed maximum extraction height has been reduced to 3.0m (from earlier planning proposals that used an extraction height of up to 4.2m) in order to reduce any adverse subsidence impacts. This reduction is noted and accepted as being an important control measure that must be adhered to during the operational stage of the project.

The depth of cover over the proposed longwall panels ranges from as low as 80m to approximately 200m, averaging between 100m and 150m. At this range of depths, with 250m wide longwall faces, the surface subsidence effects will be in the super-critical range, meaning the development of the maximum vertical subsidence magnitude across the centre of each panel, with reduced subsidence over the lines of chain pillars between the panels. It is also likely that at the shallower range of depths, the extent of fracturing and deformation of the overburden above the panels will result in the height of depressurisation due to mining (with respect to any contained groundwater) extending towards the near-surface fracture zone, with the absence of any significant constrained zone to prevent groundwater migration.

The proximity of The Drip and Corner Gorge features within the Goulburn River are 2.7km and 2.2km from the closest point of extraction in LW408. The MSEC predictions indicate negligible subsidence impact on these features at this separation distance. The Panel accepts this prediction as being reasonable, on the basis of the available evidence. However, the following recommendations are considered to be an appropriate immediate response to this issue – both in relation to the current Extraction Plan, and also to provide baseline data to inform future mine planning, to assist in understanding the extent of development of any far-field horizontal movements or valley closure and ensuring avoidance of any potential adverse impacts at The Drip or the Corner Gorge.

4.1.1. Recommendations

a) It is recommended that the Applicant immediately install an array of surface satellite monitoring stations (GNSS) that are capable of detecting surface horizontal movements down to $\pm$10mm or better accuracy, on a 24/7 continuous basis, prior to the commencement of extraction of LW401. These devices are now used quite widely in subsidence management with a high degree of reliability and accuracy. A line of GNSS stations should be positioned from the edge of LW401, at an appropriate regular spacing, extending from LW401 towards the Drip and also the Corner Gorge.

b) This monitoring system should also include a GNSS station on either side of each of these surface features, in order to detect any potential adverse valley closure, either now, or as a result of any future miníng.

4.2. POTENTIAL IMPACTS ON HERITAGE SITES

The most significant aboriginal heritage site above the proposed extraction zone is site S1MC280. This is located above the chain pillar located between LW402 and LW403. The Panel inspected the rock shelter at this site during the site visit on 11 March 2022. Figures 1 and 2 show the shelter, in the context of the surrounding hillside (Fig. 1) and the close-up view (Fig. 2) looking under the substantial shelter overhang.

Figure 1: Overall view of Site S1MC280

Figure 2: Looking into rock shelter

It is understood that the orientation of the shelter is such that LW402 will pass behind the shelter (up-hill), whilst LW403 will pass in front of the shelter. This configuration is indicated in Figure 3 below, taken from recent advice provided by the Applicant (22 March 2022).

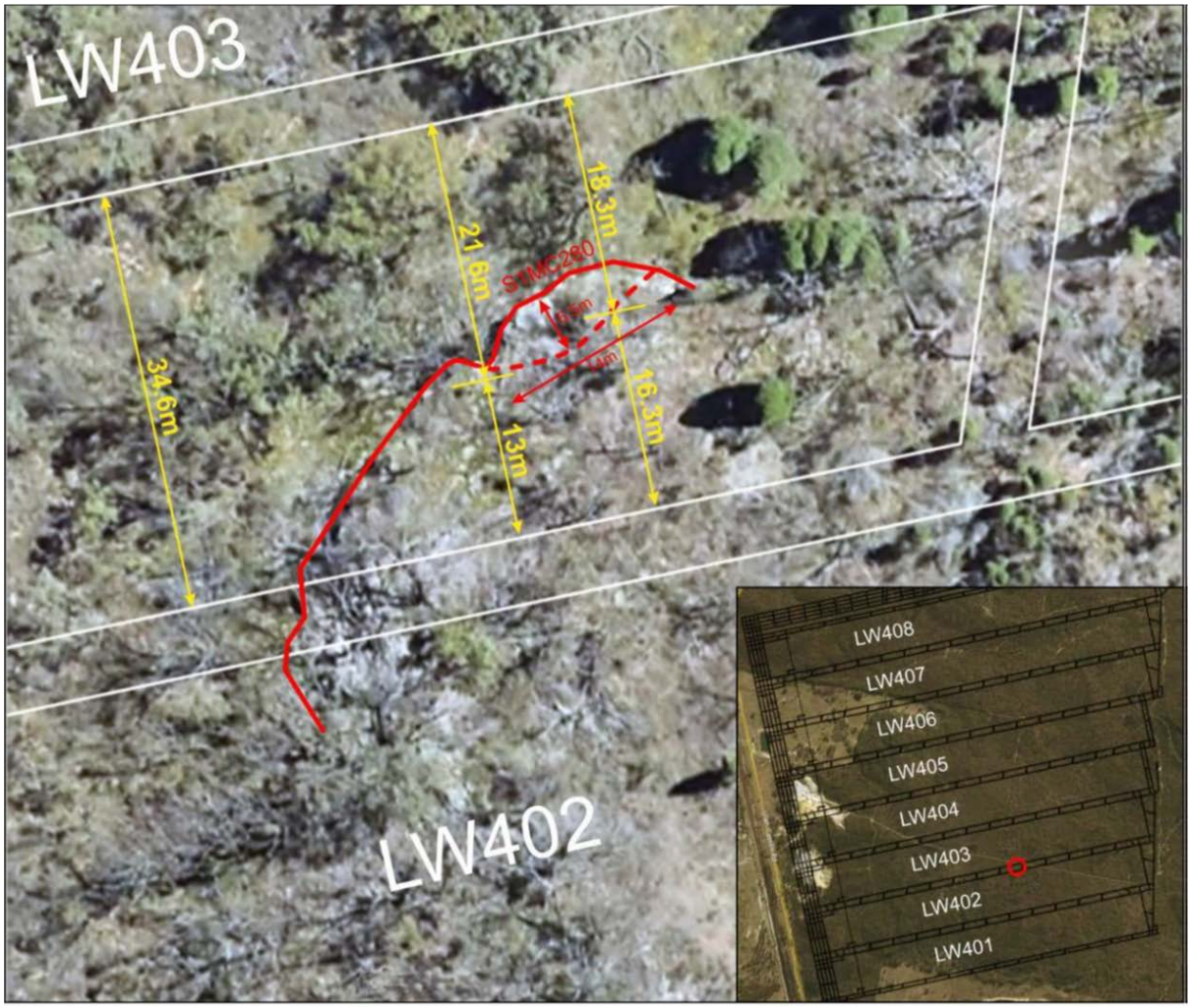

Figure 3: Site S1MC280 position, relative to longwalls 402 and 403 (direction of longwall retreat is from right to left)

It is understood that the floor and internal surfaces of the shelter contain numerous aboriginal artefacts which have been surveyed and recorded. These include a number of grinding grooves located on slabs of sandstone on the floor of the shelter.

The MSEC subsidence prediction for this site is for a maximum vertical subsidence magnitude of 150mm, a total tilt of 4.0mm/m and a maximum tensile strain of 2mm/m. The Heritage Management Plan notes the following, in relation to these predictions:

> *"Tensile strains of greater than approximately 0.5 mm/m are considered to be sufficient to result in tensile cracking of sandstone. The rock shelter is an isolated site within a small area of steep slopes at a topographical high point. The risk of subsidence impacts to Site 280 is low to moderate consistent with the approved impacts, and includes tensile cracks and instabilities. Large scale failure of the rock shelter is not expected to occur and the likelihood of tensile cracks coinciding with the location of the grinding grooves is considered to be low".*

The Heritage Plan makes the following further comments, under the heading of Monitoring (section 6.2.2).

> *"For the purpose of determining what constitutes a significant subsidence impact on Aboriginal heritage sites, a site is considered to be "affected by significant subsidence impacts" if it exhibits one or more of the following consequences that cannot be attributed to natural weathering or deterioration:*
> - *overhang collapse;*
> - *cracking of sandstone that coincides with the feature(s) of the site that make it significant; and*
> - *rock fall that damages the feature(s) of the site that make it significant".*

The Panel recognises the significance of this particular heritage site and the importance of ensuring that it is not adversely impacted by mining, to any significant extent – as per the above description of unacceptable significant impacts.

Given the size of the rock shelter and the overall shape and configuration, including the extent of the overhang, the Panel is concerned, and considers that there is a possibility that any of the above significant impacts could occur, without some degree of further mitigation.

During the site visit, the Panel requested a copy of the Applicant's conceptual mitigation plan for cutting of deep stress-relief slots surrounding the shelter, in order to isolate it from the impacts of any adverse mining-induced strains. A sketch and description of the proposed stress-relief slotting program has subsequently been provided by the Applicant (22 March 2022). It is accepted that, subject to the ability to install such a slot to an adequate depth and width surrounding the rock shelter, such an approach may prevent damage due to strains. However there remains a serious concern that it will not assist with any adverse tilt impacts, especially on the stability of the overhang when LW403 passes in front of it. (As a temporary measure, prior to the approach of LW402, it may be prudent to consider some form of temporary standing support beneath the overhang during mining, but this will not offer long-term stability once such support is removed).

Further incremental subsidence prediction data was requested from the Applicant to specify the progressive development and changes to tilt at the rock shelter location, as each of the longwall panels (402 and 403) passed the site. (The 4mm/m tilt prediction already provided is only a final tilt and does not indicate the incremental effects as each of LW402 and LW403 pass the location).

The response to this request (22 March 2022) indicates a tilt of 5.0mm/m (presumably towards LW402, or into the hillside behind the rock shelter), as 402 passes. The resultant tilt after 403 then passes the site is then predicted to be 4mm/m (presumably in the opposite direction, or down-slope towards 403). The sense of these tilt values is yet to be confirmed by the Applicant/MSEC, but if this interpretation is correct, it would suggest an incremental rotation of the rock shelter of up to 9mm/m towards the down-slope direction, between the passing of 402, and when 403 has passed. Based on a plan provided by the Applicant (11.04.22), the maximum depth of the rock shelter overhang is approaching 6m+. This would result in a net incremental rotation of up to 54mm.

The Panel has serious concerns about the ability of the rock shelter overhang to withstand these levels of incremental tilt, especially when combined with some degree of potential cracking and/or shearing. The Panel therefore recommends that the Applicant should develop a mining plan, as part of the overall mitigation strategy for the site, to create a reduction in the panel

width of LW403 in the region where it passes Site S1MC280, to avoid any adverse tilt or strain impacts (beyond restoring the shelter to its original tilt configuration) as this panel passes in front of the shelter.

4.2.1. Recommendations

a) The Applicant should identify and design a suitable "early warning" subsidence monitoring site above the 402/403 row of chain pillars, at least several pillars inbye of Site S1MC280, to monitor the subsidence effects and impacts of both LW402 and 403, ahead of reaching Site S1MC280, to determine the actual subsidence, tilt and strain figures, by comparison to the predicted values.

b) Establish a comprehensive TARP for both the "early warning" site listed in (a) above, and for monitoring at the rock shelter.

c) Provide a comprehensive mitigation plan for the site, to cover all actions to prevent any significant cracking or instability of the shelter due to subsidence, tilt or strain. This should include the planned stress-relief slotting design; consideration of temporary support of the overhang; and design of a LW403 Panel face shortening, to leave some additional coal in the vicinity of the site. This mitigation plan should also be linked to the above TARPs.

d) Full details of this mitigation strategy and associated monitoring program and TARPs should be submitted to the Department for endorsement and approval, prior to the commencement of LW402.

4.3. POTENTIAL IMPACTS ON GROUNDWATER

The Extraction Plan and supporting documents provide a reasonable appreciation of the likely groundwater impacts associated with the underground mining of LW401 to 408 in the southern portion of the UG4 area. Additional technical studies were reviewed to appreciate previous modelling predictions and to evaluate current monitoring programs and trends.

4.3.1. Background

The documentation describes the geology and primary groundwater systems underlying and adjacent to UG4 (and in particular LW401 to 408) as:

- Quaternary alluvium associated with the present day drainage system (downstream of the Goulburn River diversion).
- Tertiary alluvium associated with the palaeochannel immediately south of LW401 that is not related to the present day drainage system.
- Triassic Narrabeen Group sandstones consisting of upper quartzose and lower lithic units.
- Permian Illawarra Coal Measures (ICM) comprising minor claystone, sandstone and multiple coal seams, including the Ulan Seam near the base of the sequence.

The surficial extent of these geologies is shown on Figure 4. While the mapped geology is well known there is minimal detail regarding structural features (such faults, fractures, and lineaments) across the UG4 area and adjacent areas. The only mapped and identified feature to date is an inferred fault extending from the south-western portion of LW406 through to the

central portion of LW408 and trending in a north-easterly direction (see Figure 4). Such features can enhance or restrict groundwater migration and flow.

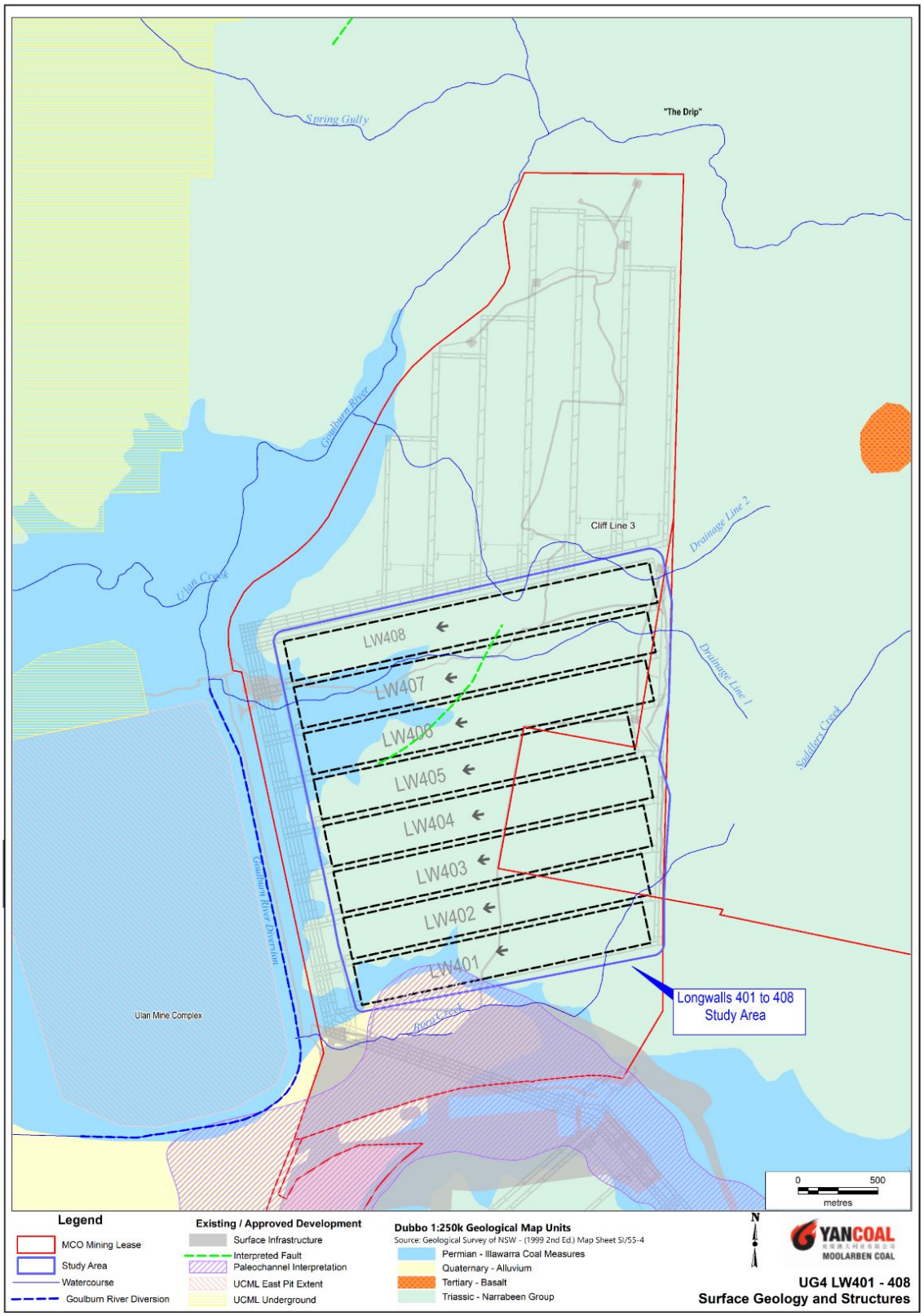

Figure 4: Surface geology and known structures

The aquifer units are (i) the alluvium, (ii) the Triassic sandstone, and (iii) the coal seams and sandstones within the Permian ICM. The connectivity between individual groundwater systems and connectivity with surface water in the Goulburn River is complex.

The Panel's focus is on potential changes to groundwater flow and water quality in the Triassic sandstone and Permian ICM coal groundwater systems, and the maintenance of shallow groundwater flow/supply to environmental receptors and water bore users.

The conceptual groundwater flow model is not well articulated in the Extraction Plan, the supporting groundwater technical/modelling report (AGE 2021) or previous groundwater studies. To summarise the current understanding:

- All groundwater systems (where exposed at surface) are recharged by rainfall.
- Water tables respond slowly to seasonal conditions – rainfall recharge events generate small and lagged groundwater level responses at some (not all) monitoring sites.
- The regional water table is mostly within the Triassic sandstone except where this geology is thin or not present near the Goulburn River diversion.
- The Triassic sandstone is only partially saturated (ie. within the eastern portion of the UG4 area extending into the Goulburn River National Park).
- Saturated thickness of the sandstone increases to the east from about 5m in the vicinity of PZ103C to approximately 20 to 30m in the vicinity of PZ192 and PZ193 (for locations see Figure 5).
- There is vertical seepage of groundwater from the Triassic sandstone (and upstream alluvium where present) to the underlying ICM.
- Groundwater discharge from the Triassic sandstone is via (minor) evapo-transpiration, seepage/springs, drainage to the ICM, and baseflow discharges to the Goulburn River.
- Within the ICM there is seepage of groundwater from upper units to the Ulan Seam.
- Groundwater discharge from the ICM is to mine workings, and potentially to the Goulburn River (via the Triassic sandstones and alluvium) in far downstream areas.
- In the vicinity the Goulburn River diversion near LW401 to LW408, the river is disconnected losing to the ICM groundwater system but changes to connected gaining within 2-3km once the bedrock in the river becomes Triassic sandstone.

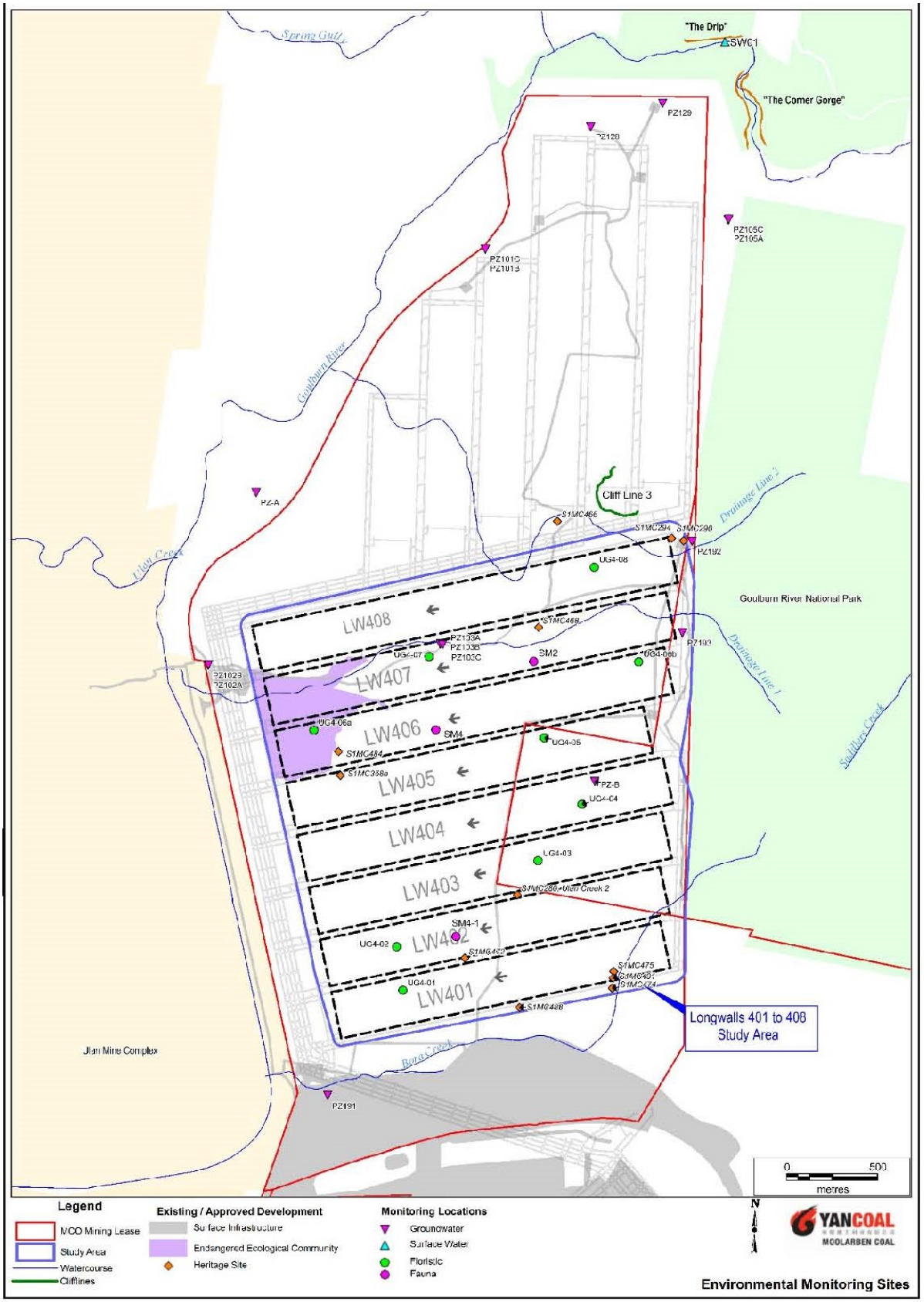

Figure 5: Existing and proposed environmental monitoring locations (from Yancoal, 2022)

There is a lack of data in the vicinity of LW401 to 408 to properly define the saturated extent of Triassic sandstone and the current groundwater flow contours. Based on limited 2011 site data, Figure 6 (reproduced from RPS Aquaterra 2011) shows the extent of saturated Triassic strata and the groundwater level contours for the sandstone aquifer at that time.

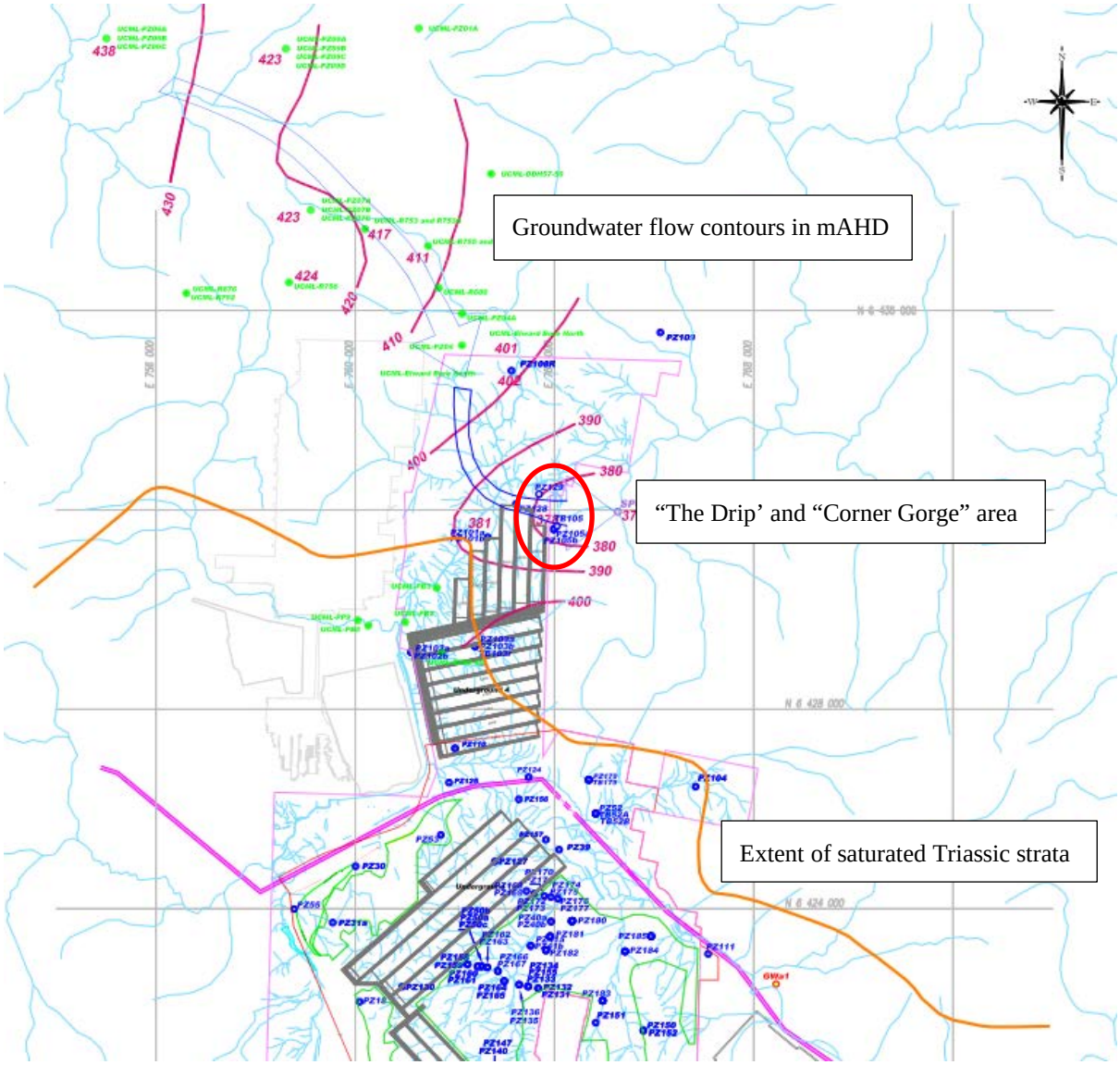

Figure 6: Triassic sandstone saturated extent and groundwater contours (2011)

"The Drip" and "Corner Gorge" locations are clearly within the groundwater discharge area of the Triassic sandstones to the Goulburn River. Groundwater sustaining the "The Drip" on the northern cliff face above the Goulburn River (as shown in Figure 7) is from groundwater migrating from the upper Triassic sandstone aquifers north to south. There are different discharge horizons evident in the cliff face however there is no regional evidence to confirm the Triassic sandstone aquifers are perched in relation to the underlying Permian ICM groundwater system.

The Panel's assessment is that the current Extraction Plan for LW401 to 408 is extremely unlikely to impact the water supply at "The Drip". However it is also the Panel's opinion that there is no current evidence to support the statement (AGE 2021) that:

"the perching of groundwater within the Triassic sandstone associated with The Drip is effectively disconnected from the underling regional watertable."

Figure 7: Groundwater discharge from upper Triassic sandstone aquifers at "The Drip" (March 2021)

Groundwater from the sandstone aquifers is also discharging to the Goulburn River and providing baseflow. This groundwater is discharging from the lower sandstone aquifers located both to the north and south of the river. Volumes are probably small in comparison to average mine discharges but have not been quantified or model calibrated.

Based on the hydrographs presented in the 2020 AEMR (Yancoal 2021c) (see Figure 8), mostly seasonal variations in water levels are evident in the Triassic sandstone aquifers in the vicinity of LW401 to 408 and towards "The Drip". The small declines in Triassic sandstone water levels at PZ192 and PZ193 in 2017 are the result of dewatering trials when 50ML of groundwater was pumped from MPB103.

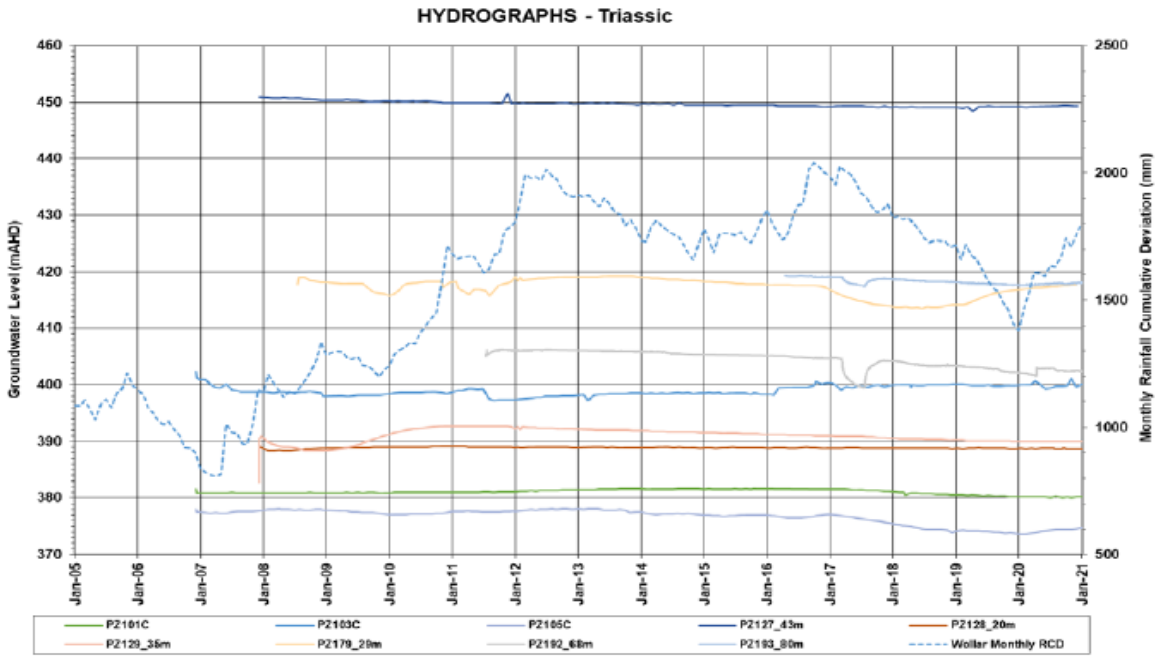

Figure 8: Triassic sandstone aquifer water levels to January 2021

There is also insufficient site data to produce Permian overburden and Permian Ulan Seam water level contours for the UG4 area and to confirm flow directions and connectivity with the overlying Triassic sandstone aquifer. The recently supplied hydrograph (from Yancoal 2022) showing 15-20m declines in water levels in the deep Permian aquifers during 2021 at the PZ102 and PZ103 sites (Figure 9) is concerning. These two sites are located above and adjacent to LW407 and LW408 and emphasise the need for additional nested monitoring sites prior to the commencement of mining in the UG4 area. It is unclear whether these recent trends are Moolarben Coal Complex (MCC) or Ulan Coal Complex (UCC) related.

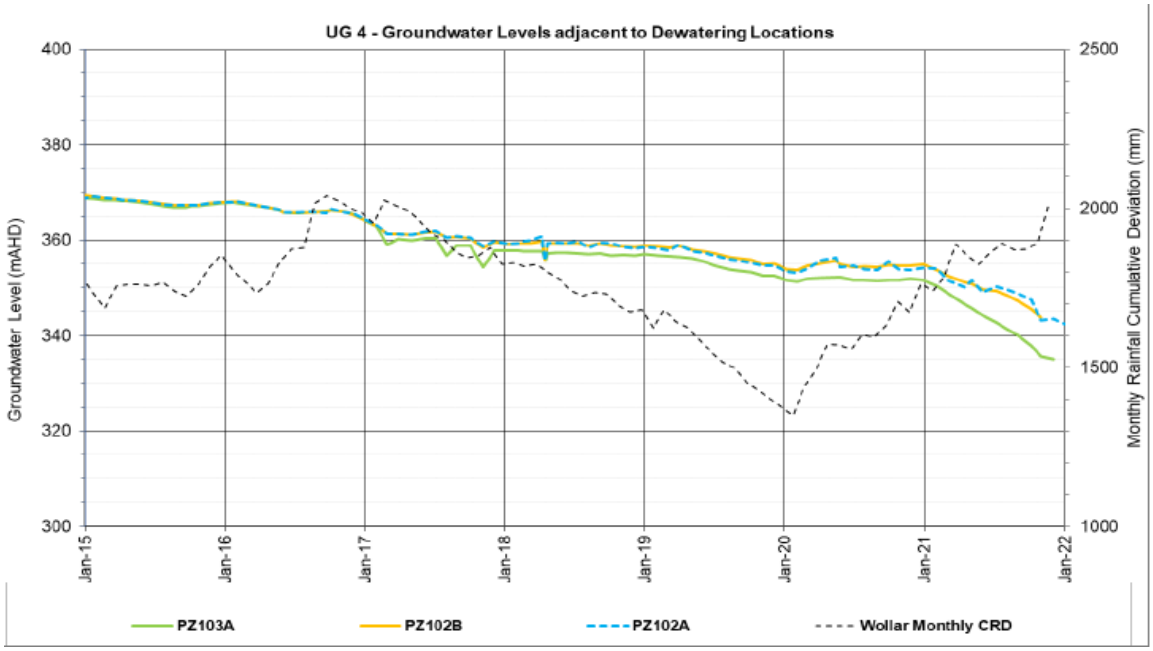

Figure 9: Permian aquifer water levels at selected sites to January 2022

The Panel accepts that the coal measures are depressurised across the MCC due to historic and current mining activities resulting in regional water level declines in the ICM groundwater system. As a result of hydraulic connection and the height of fracturing above the proposed longwalls, groundwater will also drain vertically from the overlying Triassic sandstone aquifer (AGE 2021).

To better understand baseline groundwater conditions (pre-mining of LW401 to 408) and to monitor impacts as mining progresses additional technical studies and monitoring bores are required. The Panel recommends:

- A geological structural analysis be completed as soon as practicable to determine whether there are any natural defects in the geology that could enhance or restrict groundwater migration and flow, and necessitate expanded monitoring and/or updated modelling
- An interim report on the geological structure and potential implications for groundwater impacts be supplied to the Department no later than 30 June 2022. Based on this report the Panel may provide further advice on additional groundwater monitoring or the siting of proposed monitoring bores (see Section 4.3.3)
- Additional groundwater monitoring locations be installed to:
    - Confirm the conceptual groundwater flow model
    - Confirm groundwater flow directions
    - Determine the extent and thickness of saturated Triassic sandstone strata
    - Monitor the dewatering of the Triassic sandstone and ICM overburden aquifers as mining progresses
    - Provide data on the connectivity of the Triassic sandstone aquifers with the underlying ICM groundwater system and the Goulburn River
    - Improve the conceptualisation of the Goulburn River particularly where it transitions from disconnected losing to connected losing and (most importantly) to connected gaining
- The expanded monitoring network should be installed prior to the completion of LW401 (ie within the next 6 months) with the two monitoring sites located at the start of LW401 and LW403 completed prior to the commencement of LW401 (see Section 4.3.3)

The outcomes of these studies are important to improve and validate the groundwater model and to ensure that water bore users and environmental receptors are not impacted by these first eight longwall panels in UG4. While mining of these panels is extremely unlikely to impact the groundwater discharge at “The Drip” and the private water supply bore (located 2.5km to the north-east of the start of LW408), groundwater baseflows to the Goulburn River could be impacted that cause a more than negligible impact to river flows.

4.3.2. Modelling

Groundwater model predictions for the Extraction Plan are presented by segregating the impacts due to LW401 to 408 from all other predicted mining impacts at Moolarben (AGE 2021). This 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 predicted impact due to the extraction of the LW401 to 408 panels.

This is a reasonable approach but for the benefit of the Panel and others, the full modelling output simulating the cumulative impact of all approved mining was not provided. These modelling predictions would have provided context and helped the Panel understand the current Goulburn River baseflow impacts from mining. However this lack of detail is unlikely to change the Panel's advice as appropriate conditions can be attached to the Extraction Plan if approved, and the performance measures and the existing/new TARPs (see Section 4.3.4) are sufficiently rigorous to trigger investigations and to identify potential remedial actions.

Of particular interest are the predicted drawdowns contours at the completion of LW408 for:

- Layer 8 (upper Triassic quartzose sandstone unit)
- Layer 10 (lower Triassic lithic sandstone unit)
- Layer 15 (Permian overburden unit)

According to the Extraction Plan (Yancoal 2021a), the Triassic sandstone units overlying LW401 to 408 range in total thickness from 14m to 70m (with an average of 60m across the area). Given the deep water levels of 50-65 metres below ground level (mbgl) in these units, the saturated sandstone thickness ranges from 5m in the centre of the UG4 area to around 20-30m on the eastern boundary of UG4.

The model conceptualisation of the Triassic sandstone units appears flawed as the predicted drawdowns at the end of mining LW408 suggest drawdown across the whole of the Triassic sandstone unit in excess of 20m for the upper sandstone unit and in excess of 50m for the lower sandstone unit. This cannot be possible when pre-mining conditions suggest that only the eastern portion of the units is saturated and the maximum saturated thickness is 30m. The results effectively mean that the whole of the Triassic sandstone is likely to be dewatered across the entire area overlying LW401 to 408. This is acknowledged in the report as it is stated:

> *"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."*

Nonetheless the model results place doubt on the validity of the drawdown contours extending to the north (towards the Goulburn River) and to the east (into the Goulburn River National Park).

In addition the modelling report predicts local dewatering of the ICM groundwater system (although this is not obvious from the drawdown contours at the completion of LW408):

> *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.*

At a minimum the impact of dewatering the Triassic sandstone and deeper Permian ICM aquifers to the north and east will be shallower hydraulic gradients towards the Goulburn River and a potential loss of baseflow to the Goulburn River. The predicted groundwater inflow

volumes to the mine from these eight longwalls are high for the next four years. Model predictions are from 3233 ML/yr in 2022/23 (8.9 ML/d) to a high of 4261 ML/yr in 2024/25 (11.7 ML/d) to 2914 ML/yr (8.0 ML/d) in 2025/26 (AGE 2021).

The Panel also queries the model's water balance prediction that "*mining of LW401 to LW408 is expected to result in negligible change to baseflow in the Goulburn River"*. The transient model calibration for the period 1984 to 2021 (i.e. the 'baseline period' prior to the commencement of LW401 to 408) quotes the discharge volume to rivers as 21.69 ML/d. This is assumed to capture both licensed discharges and groundwater baseflow contributions. The individual components have not been quantified in any of the reviewed reports. The modelling report (AGE 2021) predicts net baseflow takes of between 0.5 and 0.8 ML/d for the Upper Goulburn water source which could be interpreted to mean that the whole of the upper Goulburn River becomes a losing stream and that all groundwater that would have otherwise discharged as baseflow is retained in groundwater storage or discharges to the underground workings to be disposed of later via licensed discharge.

Another associated query is whether the Applicant has sufficient water licence entitlement to cater for the additional groundwater inflows expected over the next 4 years (Table 6.1 of AGE 2021). The predicted 'Moolarben Take' annual volume supposedly includes the additional inflow volumes from LW401 to 408. This would mean predicted inflows of only 200 ML/yr for the remainder of the MCC site for each of these 4 years. However the Applicant reported 2411 ML/yr of groundwater inflows in their 2020 site water balance (Yancoal 2021c) and predicted groundwater inflows of 2396 ML/yr, 3830 ML/yr and 5010 ML/yr for 2019, 2020 and 2021 respectively in an earlier site water balance (Yancoal 2020a). Updated modelling is required to confirm that the Applicant has sufficient licensed volume to account for all mine inflows from 2022/23 onwards.

The Panel recommends that once additional site data is available on the extent of the saturated Triassic sandstones, extra water levels in both Triassic sandstone and Permian overburden aquifers are available, and gaining sections of the Goulburn River are identified that:

- The model conceptualisation for the leakage between the Triassic sandstones and the Permian ICM (overburden) be revisited
- The model conceptualisation of surface water – groundwater connectivity be revisited
- The numerical model be updated and rerun to reassess aquifer drawdowns and revised water budget estimates particularly mine water inflow volumes and groundwater baseflow losses to the Goulburn River
- The predicted groundwater take should also be reassessed (both for the whole MCC site and these 8 longwall panels) to determine whether additional water licences are required for MCC operations
- The existing and updated (recalibrated) model be peer reviewed by an independent expert groundwater modeller
- The updated model and peer review are priorities. Reports should be completed and submitted to the Department within 12 months of this report (i.e. by end April 2023)
- A hold point at the completion of LW403 (anticipated to be August 2023) to allow the Panel to provide further advice to the Department as to whether any additional EP conditions are required, prior to the commencement of LW404

Notwithstanding the apparent shortcomings in the current numerical model and the drawdown and baseflow predictions, the Panel recommends that the Department proceed with their determination of the Extraction Plan with appropriate conditions including updating the numerical model within 12 months.

4.3.3. Adequacy of Proposed Groundwater Monitoring Program

The following expanded groundwater monitoring program is proposed (AGE 2021):

> *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)* (Figure 5 in this Panel report)*:*
>
> - *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*

The Panel supports additional groundwater monitoring locations and recommends extra nested sites in addition to those proposed in the Extraction Plan. The Panel's comments on the nominated sites are:

- Site PZ-A should be a standpipe that targets the shallowest aquifer in the Permian ICM overburden plus this location should include a shallow alluvial standpipe close to or within the Goulburn River if sandy alluvium is present. This new installation should be installed within the next 6 months.
- Site PZ-B should be dual standpipes that target the lower Triassic sandstone and the Permian ICM overburden. This new installation should be installed within the next 6 months (potentially in a centre panel position).
- The location of new VWP PZ229 is about 3km north of "The Drip" in an area unaffected by mining. This is a useful control site for monitoring natural water level variations in both the Triassic and Permian strata.
- The Applicant should confirm that when PZ102A and PZ103A are repurposed as VWPs that:

- PZ102 has sensors against Ulan Seam, Permian ICM overburden and Triassic sandstone (if required). Note that the Triassic sandstones should be thin and dry at this location
- PZ103 has sensors against Ulan Seam, Permian ICM overburden, and Triassic sandstone and standpipe PZ103C remains functional
- PZ103B is decommissioned once replaced by a VWP sensor monitoring the same interval.

The Panel's recommendations for additional monitoring sites are:

- Nested dual standpipes (two sites) (each monitoring lower Triassic sandstone and Permian ICM overburden) along the eastern boundary of UG4, ideally at the start of LW401 and LW403 (subject to site access)
- Nested triple standpipes (one site) (monitoring lower Triassic sandstone, Permian ICM overburden, and Permian Ulan Seam) at least 500m north of LW408 towards location PZ101 (subject to site access)
- Nested triple standpipes or VWP (one site) (monitoring Triassic sandstone, Permian ICM overburden, and Permian Ulan Seam) located on the eastern boundary of UG4 between PZ192 and PZ105 locations (subject to site access)
- Nested triple standpipes close to the Goulburn River (two sites) (monitoring alluvium if present, Triassic sandstone, and Permian ICM overburden) north of PZ101 and west of PZ128 in the vicinity of SW02, and at a second location near SW01 (subject to suitable site access and appropriate approvals from National Parks)

All the nominated sites and recommended new sites should be installed as a priority within the next 6 months with the two monitoring sites located at the start of LW401 and LW403 completed prior to the commencement of LW401.

4.3.4. Adequacy of Proposed TARPs

The Panel endorses the following performance measures and recommended trigger levels described in AGE 2021 and Yancoal 2021d:

<u>Performance measures</u>

- Nil (mining related) impact on the water supply to "The Drip". Photographic monitoring of "The Drip" every 2 months from the same locations is useful but unlikely to be diagnostic of any mining impacts given the natural seasonal variability of groundwater discharges.
- Negligible impact or environmental consequences on the Goulburn River and the bed of the Goulburn River. It is important that Triassic sandstone water levels be maintained near the Goulburn River by ensuring that the hydraulic gradient towards the Goulburn River is not reversed and groundwater baseflow contributions to the Goulburn River are maintained.

<u>Performance indicators</u>

- Groundwater investigation trigger levels (two consecutive (monthly) water level monitoring results that are lower than the recommended trigger levels):

- PZ101C (Triassic: 24-30mbgl) 378 mAHD
- PZ105C (Triassic 20-28 mbgl) 371.7 mAHD
- PZ129 (Triassic VWP-35m) 386 mAHD
- PZ-A once 12 months of baseline data is collected
- At least two other new sites monitoring Triassic sandstone located in the area north of LW408 once 12 months of baseline data is collected

- Groundwater salinity and pH investigation trigger levels (undefined but recommended as two consecutive quarterly events exceeding the following trigger levels):
  - PZ101C (Triassic: 24-30mbgl) EC – 810 µS/cm and pH 6.1-7.7
  - PZ103C (Triassic 24-30 mbgl) EC – 448 µS/cm and pH 5.2-6.8
  - PZ105C (Triassic 20-28 mbgl) EC – 319 µS/cm and pH 5.3-7.4

The performance indicators and updated TARPS are likely to trigger investigations while mining panels LW401 to 408. If investigations are triggered, then a report on the investigations and potential remediation options should be submitted to the Department for independent review within 3 months.

4.4. POTENTIAL IMPACTS ON SURFACE WATER

4.4.1. Background

The hydrological context of LW401-408 is summarised in Section 3 of the Surface Water Management Plan (Yancoal 2020c) and Section 2 of the Surface Water Technical Report (WRM 2021).

Figure 10 below shows the UG4 mining area, drainage lines and surface water monitoring sites. The identified low-order watercourses affected by LWs 401-408 are Bora Creek and Drainage Lines 1 and 2 (Figure 10). The regionally significant affected watercourse is the Goulburn River.

The upper Goulburn River is diverted around the south and east side of Ulan mine, with the diversion lying between 425 m and 500 m from the west (finishing) end of Longwalls 401-408. The Goulburn River enters the Goulburn River State Conservation Area north-west of the UG4 area, approximately 2 km from the north end of the Longwalls 401-408. Within this Conservation Area, The Drip and Corner Gorge are approximately 2.2 and 2.7 km from the north end of the Longwalls 401-408. A few hundred metres downstream of Corner Gorge, the Goulburn River enters the Goulburn River National Park.

The upper Goulburn River has been heavily modified, including the river diversion, mine water and sediment discharges from the mines, reductions in and modifications to the catchment due to the mines, and loss of baseflow due to mine dewatering.

The salinity of the river is spatially variable due to contrasting salinities of source hydrogeological units. Discharge to the river from the Permian units are highly saline (electrical conductivity, EC, of 2500 - 7500 µS/cm), whereas discharges from the Triassic units are fresher (~150 µS/cm) (Imrie 2019). EC values in non-mine impacted creeks upstream of the mines are reported as ranging between 1,632 and 4,210 µS/cm (20 and 80% percentiles)

(Yancoal 2021c). The impact of the Ulan and Moolarben mines on river salinity is managed by treating much of the mine-affected water using reverse osmosis. EC limits for major discharge points at the Ulan and Moolarben mines are 900 μS/cm and 685 μS/cm. The EC of the actual discharge from Moolarben mine in 2020 was in the range 200-300 μS/cm (Yancoal 2021c).

The mine discharges generally maintain river flows (total discharge from Moolarben of 1,426ML in the 2020 reporting period, or average 3.9 ML/day), although the Moolarben mine discharges are not continuous through the year, with periods of weeks in 2020 without discharge (Figure 11 of Yancoal 2021c). 2020 was a dry year, and the value of 3.9 ML/day and continuity of discharge is likely to be higher in wet years. 15 ML/day discharge plus additional for wet periods is licensed for UG4.

The performance measure related to the Goulburn River is "Negligible impact or environmental consequences" (negligible defined as "small and unimportant, such as to be not worth considering"). This is a potentially challenging requirement because it requires avoidance of cumulative impacts except those that are unimportant, in the context of The Drip and Corner Gorge features, the State Conservation Area, the National Park, and significant numbers of visitors to these areas.

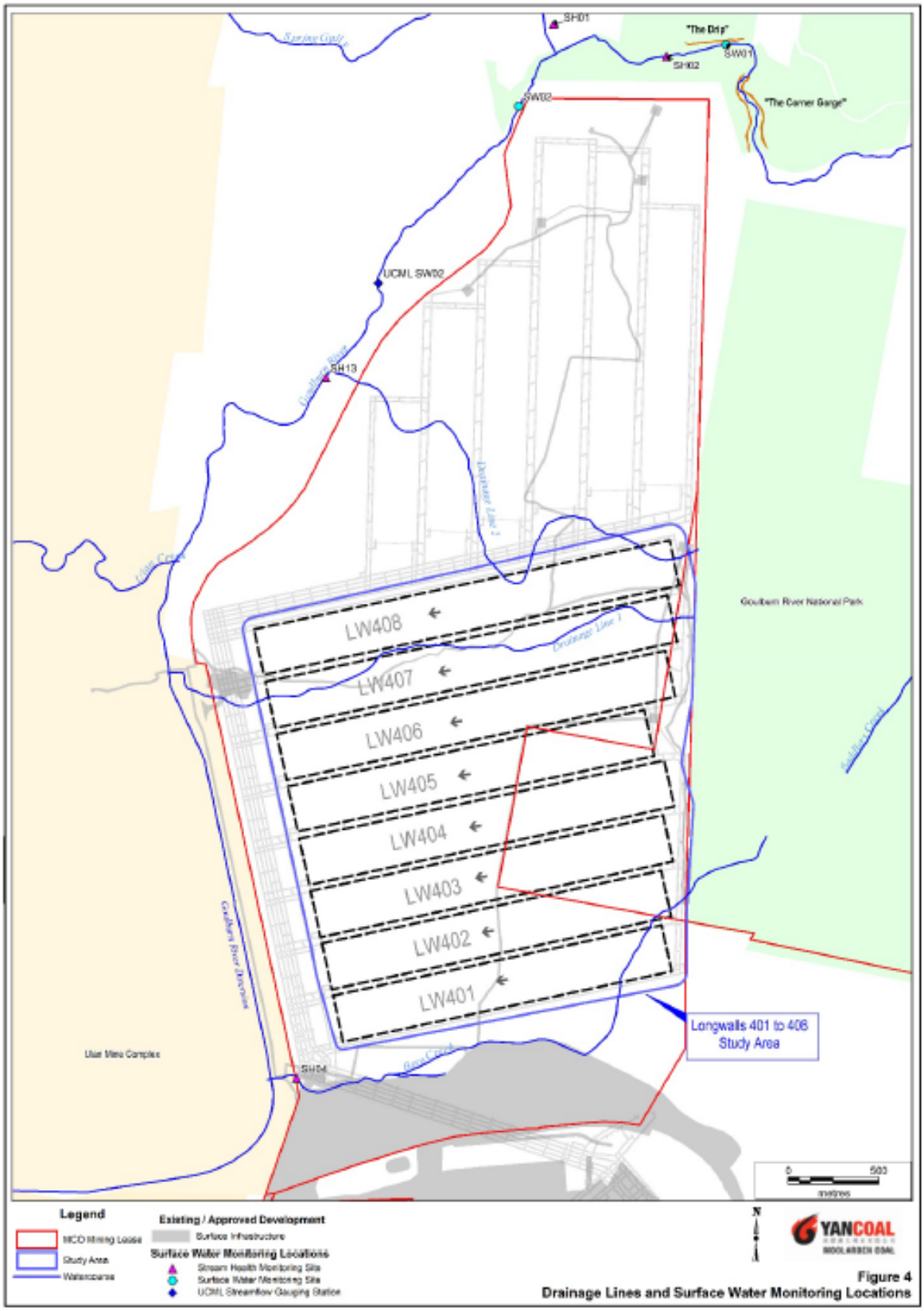

Figure 10:. Drainage lines, surface water monitoring locations and layout of proposed longwalls in UG4 (Figure 4 of Yancoal 2021d)

4.4.2. Assessment of Potential Impacts

The lower order watercourses that will be impacted by LW401-408 are Bora Creek and Drainage Lines 1 and 2. Water diversions from these lower order watercourses are expected during mining due to subsidence-induced surface fracturing. These diversions may include both localised diversions that would not significantly impact flow volumes discharging into the Goulburn River, and also flow diversions into the mine void through surface fractures that are connected to the height of depressurisation. Additional potential impacts on flows in these drainage lines are localised ponding and erosion due to changes in channel slopes.

The Extraction Plan (Yancoal 2021d) concludes "*In times of heavy rainfall, the majority of the surface water runoff would be expected to flow over the surface cracking in the beds and only a small proportion of the flow would be diverted into the fractured and dilated strata below. In times of low flow, however, a larger proportion of the surface water flow could be diverted into the strata below the beds and this could affect the quality and quantity of this water flowing through the cracked strata beds. Nevertheless, during high flow or low flow times, this small quantity is expected to have little impact on the overall quality of water flowing out of the drainage lines*". This is a reasonable expectation. However, there is uncertainty in the degree and duration of reductions in flow and water quality, and to what extent they may impact on the Goulburn River water quality. Water quality impacts can be gauged by suitable monitoring of the water quality of discharge from the drainage lines to Goulburn River including a baseline period.

Despite a likelihood of flow diversion and water quality changes, there is no evidence that these drainage lines themselves hold any particular ecological value or any highly significant natural features that would warrant protection, relative to the highly significant features of the downstream Goulburn River. Therefore, the Panel does not consider impacts to the drainage lines to be an issue of major environmental concern in relation to the performance measures, except in relation to potential downstream impacts on the Goulburn River. The Panel notes the presence of Aboriginal Artefacts and Isolated Finds in the Drainage Lines that have been classed as Low to Moderate scientific significance and have no associated performance measure (Figure 4 and Table 8 of Yancoal 2021d).

Potential risks to the Goulburn River downstream of the river diversion due to mining of LW401 to 408 are:

- Loss of flow due to fractures in the river bed. Although fracturing of the river bed in the length of the river adjacent to LW401-408 is possible, this is predicted to be minimal and not expected to result in any significant loss of flow. The Panel agrees. Fracturing of the river bed downstream of the diversion during mining of LW401-408 is not a significant risk due to the distances from the longwall footprint.
- Loss of baseflow due to groundwater depressurisation in the Triassic units (see section 4.3 of this report). The net baseflow take from the Upper Goulburn Water Source due to LW401-408 during the mining period is predicted by the groundwater model to be a maximum of 0.8 ML (AGE 2021, Table 5.5) and the peak incidental water take from that source due to LW401-408 is estimated to be 19.2 ML/year and due to Moolarben mine, 25.4 ML/year. These annual predicted losses of flow volume will be more than offset during mining by the average volume of discharged mine water (15 ML/day discharge license). However, as observed in 2020 (Yancoal 2021c), there may be periods when this is not the case due to the variability of discharge. Also, pumped discharges will end when mining ends, whereas baseflow losses and incidental take

may continue many years beyond mining. Time-series of surface water take predictions that include the impacts of LW 401-408 are not available at time of writing.

- Changes in river water quality due to reduced volumes of discharge of fresh water from the Triassic units. Because these discharges moderate the naturally high salinity from the Permian discharges, there is concern that any significant loss of baseflow discharge will impact river salinity (Imrie 2019). Predicting these potential impacts has not been attempted for the Extraction Plan, presumably due to the very low predicted impacts on baseflow. The significance of any predicted changes would be complicated to assess due to the dominant effects on salinity of the upstream mine water discharges.
- Increased volumes of mine water discharges and associated contaminants including licensed and unlicensed discharges. The mine has discharge compliance limits defined by Table 21 of Yancoal (2020c), which cover basic water quality variables. These are achieved by treating high-salinity water using a reverse osmosis plant. In 2020, which was a dry year, all of the discharge was treated in the mines reverse osmosis plant (Yancoal 2021c). Untreated discharges from sediment dams are permitted during wet weather (p59 of Yancoal 2020c) with no water quality compliance limits. Available data from discharges of this type raise no concern about their water quality.
- Changes to the flow and water quality due to subsidence impacts on the drainage lines overlying the mining area. If there are observable impacts in the Goulburn River due to impacts on these drainage lines, they are likely to be loss of low flows and changes in water quality. Changes in water quality due to a potential increase in erosion have been assessed as medium risk (WRM 2021), which the Panel agrees with.
- Changes to aquatic and riparian ecology related to changes in flow and water quality. The biodiversity management plan (Yancoal, 2020d) notes "*Literature reviews and aquatic ecology studies undertaken at the Moolarben Coal Complex indicate that there are no threatened aquatic plants, fish or macroinvertebrate species or populations (as listed under EPBC Act or under the NSW Fisheries Management Act 1994) listed or found in the upper Goulburn River*" referencing the ecological impact study of Ecovision (2008). The Panel has not reviewed the ecological impact study. Prior to determination of the Extraction Plan, the Applicant should explain the apparent reliance on Ecovision (2008) for the purpose of assessing potential aquatic ecology impacts in the Goulburn River, including commenting on whether the baseline and impact analysis are adequately up to date and extensive. If their adequacy remains questionable, then the Department should seek further advice on whether a new or updated study is necessary. This is not an urgent matter for determining the Extraction Plan, but if a new or updated study is deemed necessary then it should be addressed in the next 12 months.

4.4.3. Monitoring

Monitoring of surface water relevant to the Extraction Plan is described in Section 6 of Yancoal (2020c) and Section 6 of Yancoal (2021d), Table 3 summarises the Panel's understanding of that monitoring and the proposed surface water performance indicators and triggers.

Table 3: Summary of proposed surface water performance indicators and triggers

	Monitoring sites	Variables	Frequency	Triggers	Baseline for trigger	Performance indicator
Basic water quality	SW01, SW02, various sites upstream of LW401-408	pH, EC, TSS, TDS, temperature, turbidity (T13, 6.2, Yancoal 2020c)	Monthly and after rainfall events. Ulan Coal report continuous monitoring of EC and pH at UCML SW02[6].	Two consecutive monthly surface water quality monitoring results (pH, EC, NTU) exceed triggers. At SW01 (and SW05, SW16 upstream of LW410-408). [3]	Based on measurements at SW01, SW02 and other sites since 2005. Based on a combination of ANZECC default triggers, site-specific triggers and for SW01 the Ulan discharge concentration limits	None for Goulburn River
Other water quality parameters	SW01, SW02, various sites upstream of LW401-408	Al, Cu, Pb, Zn, Ni, Fe, Mn, As, Se, Cd, Cr, Li, Ba, Sr, DO, Total P and Total N (T13, 6.2, Yancoal 2020c)	6-monthly. Zn and Fe also after rainfall events.	None	-	None for Goulburn River
Stream health	SH01, SH02, SH13, SH04 and others upstream of LW401-408	AusRivAS, fish observation, water quality and other habitat indicators	6-monthly	None[5]	-	None
Flow	SW04 (Wilpinjong), SW15 (Wilpinjong), UCML SW02[6]	Flow rate	Continuous	No flow rate trigger for Goulburn River, although flow is partially represented by "Notable change in	There does not appear to be a baseline for pool levels.	None for flow rate in Goulburn River, although flow is partially represented by the pool

	Monitoring sites	Variables	Frequency	Triggers	Baseline for trigger	Performance indicator
	(Goulbourn River)			existing pools identified during monitoring inspections"[2]		performance indicator [1]
Channel stability (Goulburn River)	Many sites; none yet specified on Goulburn River downstream of LW401-408 (see Figure 5 of Yancoal (2020c))	List of features – see p20 of Yancoal 2020c [4]; and Table 12 of Yancoal (2021d)	6 monthly until 1 year after completion of Longwall 408 extraction	Visible cracking of bed or banks, or notable change in erosion[2]	There is a proposal to "Undertake a baseline inspection at access points along Goulburn River adjacent to LW401 - 408, noting the condition of vegetation in the channel and any areas of active erosion, sediment deposition, water ponding or streambed cracking. Collect photographic record of channel condition" (Table 12 of Yancoal 2021d). Neither Yancoal 2020c nor 2021d specify a baseline for the Goulburn River downstream of LW401-408.	Unpredicted impacts (cracking and noticeable changes in erosion) based on visual inspections [1]
Channel stability (Bora Creek)	Many sites (see Figure 5 of Yancoal (2020c))	List of features – see p20 of Yancoal (2020c) [4]; and Table 12 of Yancoal (2021d)	6 monthly until 1 year after completion of Longwall 408 extraction	Noticeable new areas of erosion or expansion of existing erosion, initiation of headcut or noticeable upstream advance of existing headcut or development of	Table 12 of Yancoal (2021d): Baseline to be collected in LW401-408 area prior to undermining of Bora Creek	Change in visible bed or bank erosion; Development of or change in headcut erosion; Change in vegetation; Extent and duration of water ponding; Appearance of

	Monitoring sites	Variables	Frequency	Triggers	Baseline for trigger	Performance indicator
				new pools or drainage of existing pools		unsealed surface cracking across the bed of Bora Creek
Channel stability (Drainage lines 1 and 2)	Visual inspection and photographic record of subsidence impacts. No specific sites have been proposed.	List of features – see p20 of Yancoal (2020c) [4]; and Table 12 of Yancoal (2021d)	6 monthly until 1 year after completion of Longwall 408 extraction	None	Table 12 of Yancoal (2021d) specifies baseline subsidence monitoring for drainage lines 1 and 2 "*Prior to undermining of drainage line DL1 & DL2 above LW407 and LW408*".	None

[1] The Surface Water performance indicator for the Goulburn River is "Unpredicted impacts on Goulburn River (cracking and or noticeable changes in erosion or pools)"

[2] Trigger event for the Goulburn river is "Visible cracking of bed or banks, or notable change in erosion or existing pools identified during monitoring inspections"

[3] Trigger event for surface water quality is "Two consecutive monthly surface water quality monitoring results exceed (or below in event of a trigger of the lower pH limit) investigation triggers at trigger monitoring location."

[4] "Documenting locations and dimensions of significant erosive or depositional features so that any subsequent changes can be evaluated; Establishing photographic points at representative locations, so that photos can be taken of multiple inspections in a repeatable manner; Written descriptions of the stream at each of the photographic points, focussing on evidence of erosion and exposed soils; and Cross sections at strategic locations."

[5] Trigger levels for stream health are referred to in the Annual Review but not apparent in the Surface Water Management Plan or LW401-408 Water Management Plan.

[6] UCML SW02 is the Ulan Coal site, which is not the same site as the Applicant's SW02 (see Figure 8).

Adequate monitoring plans are in place for impacts to Bora Creek. With regard to the planned baseline channel stability monitoring of Drainage Line 1 (see Table 1), it is possible that impacts will occur during the mining of LW406. Therefore, the Panel recommends that the baseline for Drainage Line 1 should be undertaken prior to commencement of LW406. Similarly, the baseline for Bora Creek should be undertaken prior to commencement of LW401.

Surface water analysis and monitoring for Goulburn River are limited, considering the natural heritage context. Additional groundwater monitoring recommendations for LW401-408 have been made and have been adopted (see Section 4.3 of this Advice); however there are no such recommendations made for surface water. WRM (2021) indicates that the modest level of surface water monitoring is due to the low level of expected impacts: "*As described in Section 4, the surface water impacts of subsidence for LW401-408 are likely to be limited in spatial extent. In the absence of specific performance measures for drainage lines in the UG4 area in the Stage 1 approval conditions (05_0117), the monitoring of potential impacts will be limited to sections of Bora Creek above LW401 and LW402. Periodic visual inspection is also recommended for the reach of Goulburn River adjacent to UG4 LW401-408 (although subsidence is not predicted to impact Goulburn River).*" The Panel does not fully agree with this, primarily due to the potential for baseflow losses and for impaired water quality from the Drainage Lines. The limited degree and type of monitoring proposed may lead to difficulties in ascertaining whether changes to the hydrology, water quality or ecology of the river have occurred and to what extent the mine is responsible for any changes. An extended surface water monitoring and management program is warranted (see Recommendations in Section 5).

4.4.4. Trigger Action Response Plans (TARPs)

The performance indicators and TARPs for Bora Creek are adequate.

For Drainage Lines 1 and 2, considerable effort is planned for baseline and impact monitoring but no TARPs are in place. TARPs should be proposed for water quality, with the purpose of identifying and managing significant adverse impacts on water quality of discharges to the Goulburn River.

The performance indicators and TARPs for the Goulburn River are largely reliant on visual observation at a number of sites focussing on the river adjacent to LW401-408. There are no performance indicators related to Goulburn River water levels, flow or water quality (although there are TARPs for water quality). Due to the potential impact of LW401-408 and potential further longwalls in UG4 on baseflows and water quality at the northern end of UG4 and further downstream, additional, objective performance indicators and TARPs should be proposed.

Performance indicators for the Goulburn River for the purpose of LW401-408 should include: 1) Indicators of baseflow loss at two sites in the length of river from SW02 to the Corner Gorge. Due to the various upstream influences on flow rates and pool levels, the option of a hydraulic gradient indicator is likely to be more satisfactory. 2) Indicators of water quality at SW01. Should there be indications of baseflow loss or reduced groundwater levels with the potential to substantially reduce baseflow or induce stream losses then it is recommended that Yancoal prepare a Remediation Action Plan to reinstate groundwater baseflows in the area downstream of SW02. Any future mining in UG4 that has possible subsidence effects on the river bed will also require channel stability performance indicators in this length of river.

Normally, at least 2 years of baseline data would be recommended at TARP and performance indicator monitoring sites, as well as control sites that are known to be unimpacted. If this is not practicable for LW401-408, the proposals for additional TARPs and performance indicators should propose how the lack of baseline will be effectively managed. The Panel accepts that risks of impacts downstream of the river diversion will become more significant as LW401-408 proceeds and therefore a 2-year baseline may not be necessary prior to mining LW401.

5.0 SUMMARY RECOMMENDATIONS

5.1 Approval Conditions

1. The performance measure associated with protection of heritage site S1MC280 should be reviewed by the Department and should incorporate a parameter associated with impact, rather than simply likelihood. The level of acceptable impact should be set to ensure that any form of collapse of the rock shelter at site 280 would be deemed unacceptable.

5.2 Subsidence Assessment

Impacts on The Drip and Corner Gorge

2. It is recommended that the Applicant immediately install an array of surface satellite monitoring stations (GNSS) that are capable of detecting surface horizontal movements down to +10mm or better accuracy, on a 24/7 continuous basis, prior to the commencement of extraction of LW401. A line of GNSS stations should be positioned from the edge of LW401, at an appropriate regular spacing, extending from LW401 towards the Drip and also the Corner Gorge.

3. This monitoring system should also include a GNSS station on either side of each of these surface features, in order to detect any potential adverse valley closure, either now, or as a result of any future mining.

4. Data gathering and analysis from these proposed sites should be incorporated into the Subsidence Management Plan for the proposed LW401 to LW408 Extraction Plan.

Heritage Site S1MC280

5. The Applicant should identify and design a suitable "early warning" subsidence monitoring site above the 402/403 row of chain pillars, at least several pillars inbye of Site S1MC280, to monitor the subsidence effects and impacts of both LW402 and 403, ahead of reaching Site S1MC280, to determine the actual subsidence, tilt and strain figures, by comparison to the predicted values.

6. Establish a comprehensive TARP for both the "early warning" site listed in (e) above, and for monitoring at the rock shelter.

7. Provide a comprehensive mitigation plan for the site, to cover all actions to prevent any significant cracking or instability of the shelter due to subsidence, tilt or strain. This should include the planned stress-relief slotting design; consideration of temporary support of the overhang; and design of a LW403 Panel face shortening, to leave some additional coal in the vicinity of the site. This mitigation plan should also be linked to the above TARPs.

8. Full details of this mitigation strategy and associated monitoring program and TARPs should be submitted to the Department for approval, prior to the commencement of Longwall 402.

5.3 Groundwater Assessment

The following are the Panel's groundwater recommendations regarding predicted impacts associated with the extraction plan for LW401 to 408 and protecting consumptive water bore users and environmental receptors (most importantly "The Drip" and the Goulburn River):

9. Complete a geological structural analysis as soon as practicable to determine whether there are any natural defects in the geology that could enhance or restrict groundwater migration and flow, and necessitate expanded monitoring and/or updated modelling

10. Submit an interim report on the geological structure to the Panel by 30 June 2022. Based on this report the Panel may provide further advice on additional groundwater monitoring or the siting of proposed monitoring bores

11. Update the numerical groundwater model predictions by:

    i. Revisiting the model conceptualisation for the leakage between the Triassic sandstones and the Permian ICM (overburden)

    ii. Revisiting the model conceptualisation of surface water – groundwater connectivity

    iii. Reassessing aquifer drawdowns and water budget estimates particularly mine water inflow volumes and groundwater baseflow losses to the Goulburn River

    iv. Reassessing the predicted groundwater take

    v. Completing an independent peer review of the current and updated model by an expert groundwater modeller acceptable to the Department and providing report/s to the Panel within 12 months

    vi. Rerunning the updated numerical model and providing a detailed technical report on all the cumulative approved mining and just the impact of LW401-408 panels. Reports to be supplied to the Panel within 12 months.

12. Consider a hold point at the completion of LW403 (anticipated to be August 2023) to allow the Panel to provide further advice to the Department as to whether any additional EP conditions are required, prior to the commencement of LW404

13. Install additional groundwater monitoring bores at six sites (in addition to those nominated by the Applicant in the Extraction Plan):

    i. Nested dual standpipes (two sites) (each monitoring lower Triassic sandstone and Permian ICM overburden) along the eastern boundary of UG4, ideally at the start of LW401 and LW403

    ii. Nested triple standpipes (one site) (monitoring lower Triassic sandstone, Permian ICM overburden, and Permian Ulan Seam) at least 500m north of LW408 towards location PZ101

    iii. Nested triple standpipes or VWP (one site) (monitoring Triassic sandstone, Permian ICM overburden, and Permian Ulan Seam) located on the eastern boundary of UG4 between PZ192 and PZ105 locations

    iv. Nested triple standpipes close to the Goulburn River (two sites) (monitoring alluvium if present, Triassic sandstone, and Permian ICM overburden) north of PZ101 and west of PZ128 in the vicinity of SW02, and at a second location near SW01 (subject to suitable site access and appropriate approvals from National Parks)

14. Install all the expanded monitoring network (i.e. the nominated sites and recommended new sites) as a priority within the next 6 months with the two extra monitoring sites located at the start of LW401 and LW403 to be completed prior to the commencement of LW401

15. The performance measure of negligible impact to Goulburn River flows and water quality should be represented by water level and hydraulic gradient performance indicators that aim to ensure that the Goulburn River remains connected gaining downstream of SW02 and that groundwater discharges continue to contribute to baseflows

16. Maintain current performance measures and recommended trigger levels for existing sites

17. Add additional groundwater investigation trigger levels for new monitoring bores monitoring the regional water table towards "The Drip":

    i. PZ-A once 12 months of baseline data is collected

    ii. At least two other new sites monitoring Triassic sandstone aquifers located in the area north of LW408 towards "The Drip" once 12 months of baseline data is collected

18. If investigations are triggered, then a report on the investigations and potential remediation options should be submitted to the Department for the Panel's review within 3 months.

5.4 Surface Water Assessment

19. If the Extraction Plan is approved, conditions should include increased monitoring of the Goulburn River and Drainage Lines 1 and 2 following consultation with National Parks. The monitoring should include the following:

    i. The baseline inspection of the Goulburn River should be extended downstream at least to the Corner Gorge, including the elements in Table 12 of Yancoal (2021d).

    ii. Two sets of nested triple standpipes in the river alluvium in vicinity of SW01 and SW02 (Recommendation 13, above)

    iii. At least two water monitoring sites in the river within the State Conservation Area or National Park with continuous monitoring of water level, pH, temperature, EC; and monthly monitoring of other water quality parameters.

    iv. Monitoring water quality in Drainage Lines 1 and 2 during flow events, immediately upstream of their discharge to Goulburn River, including two years of baseline monitoring prior to the start of LW406.

    v. Feasibility of developing a rating curve at SW01 or nearby site should be investigated by the Applicant for the purpose of flow measurement, with attention to accuracy of baseflow measurements.

20. If the Extraction Plan is approved, conditions should include an extended set of performance indicators and TARPs for the Goulburn River and drainage lines including:

    i. Water quality TARPs at discharge of Drainage Lines 1 and 2 to Goulburn River (variables as for SW01) with site-specific trigger values.

    ii. Performance indicators for water quality at SW01.

    iii. Performance indicators for baseflow loss based on measuring the water level-groundwater hydraulic gradient as recommended above.

Should there be indications of baseflow loss or reduced groundwater levels with the potential to substantially reduce baseflow or induce stream losses then it is recommended that Yancoal prepare a Remediation Action Plan to reinstate groundwater baseflows in the area downstream of SW02.

Prior to determination of the Extraction Plan, the Applicant should explain the apparent reliance on Ecovision (2008) for the purpose of assessing potential aquatic ecology impacts in the Goulburn River, including commenting on whether the baseline and impact analysis are adequately up to date and extensive. If their adequacy remains questionable, then the Department should seek further advice on whether a new or updated study is necessary. This is not an urgent matter for determining the Extraction Plan, but if a new or updated study is deemed necessary then it should be addressed in the next 12 months.

REFERENCES

AGE 2021, *Groundwater Technical Report for Moolarben UG4 LW401 to LW408 Extraction Plan*

Ecovision 2008, Ecological Impact Assessment – Stage 2 of the Moolarben Coal Project.

Imrie J. 2019, Changing land use in an uncertain climate: impacts on surface water and groundwater in the Goulburn River, NSW. PhD Thesis, Australian National University

RPS Aquaterra 2011, *Moolarben Coal Complex Stage 2 Preferred Project Report – Groundwater Impact Assessment*

Yancoal 2020a, Site Water Balance

Yancoal 2020b Groundwater Management Plan

Yancoal 2020c, Surface Water Management Plan

Yancoal 2020d, Biodiversity Management Plan.

Yancoal 2021a, *UG4 Longwalls 401 to 408 Extraction Plan*

Yancoal 2021b, UG4 Longwalls 401 to 408 Heritage Management Plan

Yancoal 2021c, *Moolarben Coal Complex – Annual Review 2020*

Yancoal 2021d, Longwalls UG4 LW401 to 408 Water Management Plan

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WRM 2021, Surface Water Technical Report