MOOLARBEN COAL PROJECT

Response to Submissions

APPENDIX A10

Preferred Project Groundwater Assessment

MOOLARBEN COAL MINES PTY LIMITED

MOOLARBEN COAL PROJECT
GROUNDWATER ASSESSMENT

PREFERRED PROJECT PROPOSAL

BY

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13 DECEMBER 2006

05-0158-R04C

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1 INTRODUCTION

Moolarben Coal Mines Pty Ltd (MCM) lodged an Environmental Assessment (EA) Report (MCM,2006a) on 15 September 2006 for the proposal to develop the Moolarben Coal Project (the Project) incorporating 3 open cut mines, an underground mine and associated infrastructure. The EA was placed on public exhibition from 18 September to 23 October 2006.

The Minister for Planning appointed an Independent Hearing and Assessment Panel (IHAP) to assess the following aspects of the project in more detail:

- Groundwater impacts
- Subsidence impacts
- Noise impacts.

Following the IHAP formal hearings in Mudgee between 7 and 9 November 2006, MCM has prepared a Preferred Project Proposal (PPP) which incorporates some minor changes to the Project from that outlined in the EA (MCM, 2006a).

This report provides an assessment of the potential impacts of the PPP, including recommended management and mitigation measures, and supplements the more comprehensive groundwater assessment (Dundon, 2006a) which was presented as Appendix 5 in the original EA (MCM, 2006a).

The additional studies that have been carried out to assist preparation of this report include the installation and hydraulic testing of Triassic piezometers and further groundwater flow modelling.

Three new piezometers have been installed above the proposed Underground 4 mine area, to supplement the information available from published UCML Annual Environmental Management Reports (AEMRs). Permeability testing has been carried out as well.

The groundwater model has been modified to accommodate some changes to the input parameters and the modelling approach arising as a result of submissions and other issues raised by the IHAP panel. It also addresses the modifications to the original mine plan, and the effect that these modifications will have on the previously assessed groundwater impacts.

2 PREFERRED PROJECT MINE LAYOUT

The mine layout modifications involved in the Preferred Project mainly affect the Underground 4 mine, and include the following:

- Eight longwall panels orientated generally east-west, and 6 panels orientated north-south (previously seven east-west and seven north-south);

- The starting positions (northern ends) of Longwall Panels 13 and 14 have been moved 240m and 575m south respectively to provide additional setbacks from the Goulburn River gorge area;

- The starting position (northern end) of Longwall Panel 9 has been moved 135m further south;

- The starting position (eastern end) of Longwall Panel 5 has been moved 50m to the west;

- The east-west panels have been moved approximately 50m to the north from their original positions.

The Preferred Project mine layout for Underground 4 is shown on **Figure 1**.

Minor changes have been made to Open Cuts 1 and 3, comprising additional environmental/acoustic bunding, which have no bearing on the groundwater impacts.

3 TRIASSIC NARRABEEN GROUP

A considerable amount of information relating to the Triassic Narrabeen Group aquifer system was available from published sources, and was used to develop our understanding of the inter-relationship between the Permian and the Triassic aquifers, and between the Triassic and the Goulburn River and its tributaries. This information also enabled the assignment of appropriate hydraulic parameters for the Triassic in the groundwater model. Only a representative selection of relevant data was presented in the reports accompanying the EA (MCM, 2006). Further information was obtained during our investigations.

The available information is summarised in more detail below.

3.1 Available Information from UCML

UCML (2003) reported the results of pumping tests on three private bores drawing from the Triassic aquifer system, viz

- Imrie Bore
- Elward North Bore
- Keiren's Bore.

The test results indicate average hydraulic conductivities for these bores of 0.07m/d, 0.3m/d and 0.5m/d. On the basis of these results, we adopted aaverage horizontal hydraulic conductivity value of 0.1m/d in our modelling.

UCML had constructed nine (9) piezometers screened in the Lower Triassic sandstones up to the end of 2005, viz

- PZ01A
- PZ04A
- PZ06C
- PZ07C
- PZ08C
- PZ09C
- PZ10A
- R753A
- R755A.

In their 2005 AEMR, UCML (2006) suggested that DDH58-25 is also screened in the Triassic. However, information presented by UCML in previous AEMRs confirms that this piezometer is in fact screened in the Permian Coal Measures (specifically the Moolarben A and B seams). The geological log of DDH58 (UCML, 2002) showed the base of the Triassic (and top of the Permian) at a depth of 77m, whereas DDH58-25 is screened between 104 and 110m depth (UCML, 2005a). A second piezometer at that site (DDH58-50) is screened at 162-165m depth in the Ulan Seam (UCML, 2005a).

Locations of the UCML piezometers and the private bores are shown on **Figure 1.** UCML's Triassic piezometers are all situated to the north of the longwall panels completed up to the end of 2005, although PZ07C, PZ09C and PZ10A are situated above the main development headings. There are no piezometers located directly above completed longwall panels.

Hydrographs regenerated from plots in UCML's 2005 AEMR are shown in the upper pane on **Figure 2**. The available water levels for the three private Triassic bores are included on **Figure 2**. The records extend back to 1996, and all bores show minimal water level change with time. The hydrograph for DDH58-25 has been added on the lower pane on **Figure 2**. It shows marked drawdown but the Triassic bores do not.

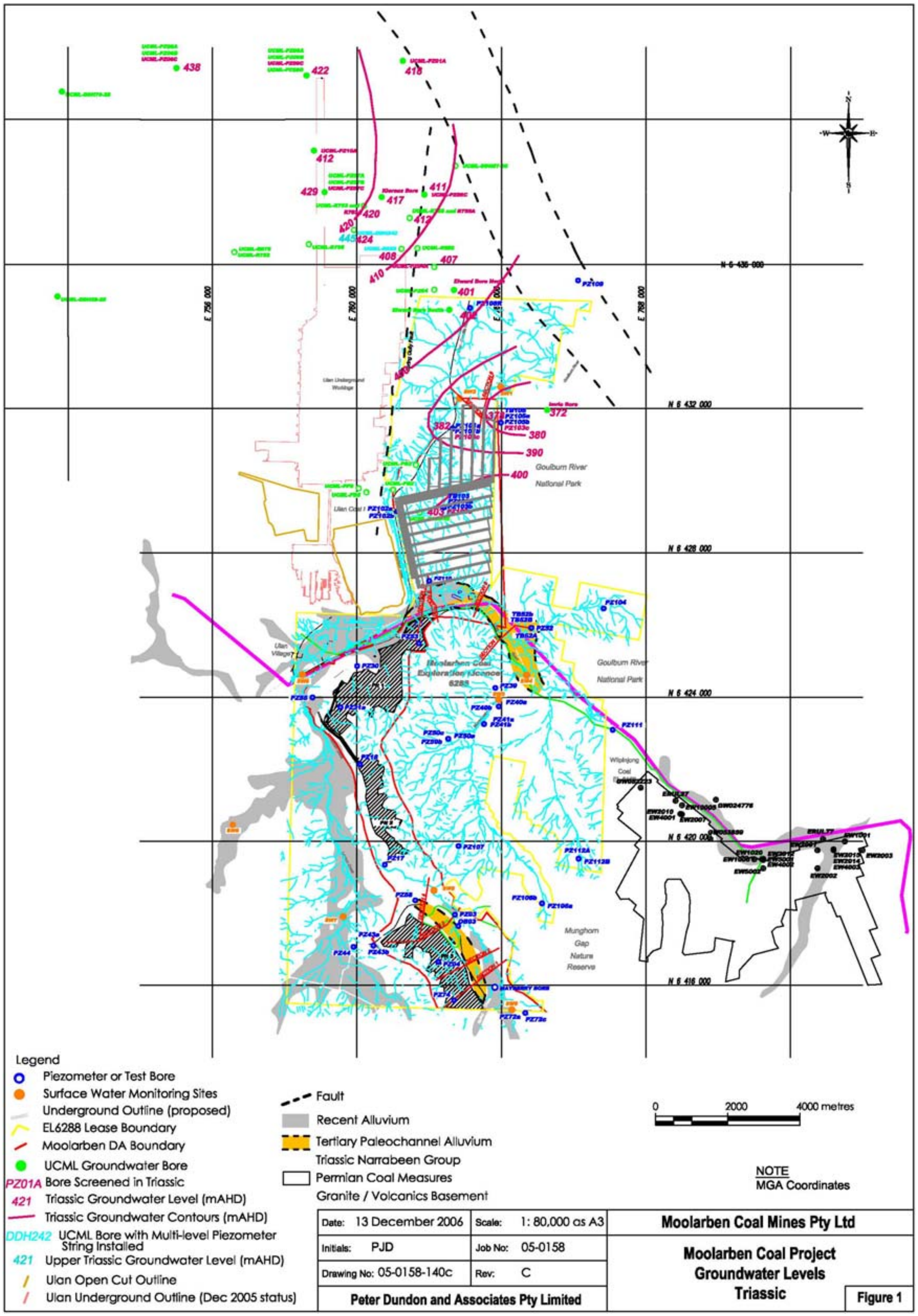
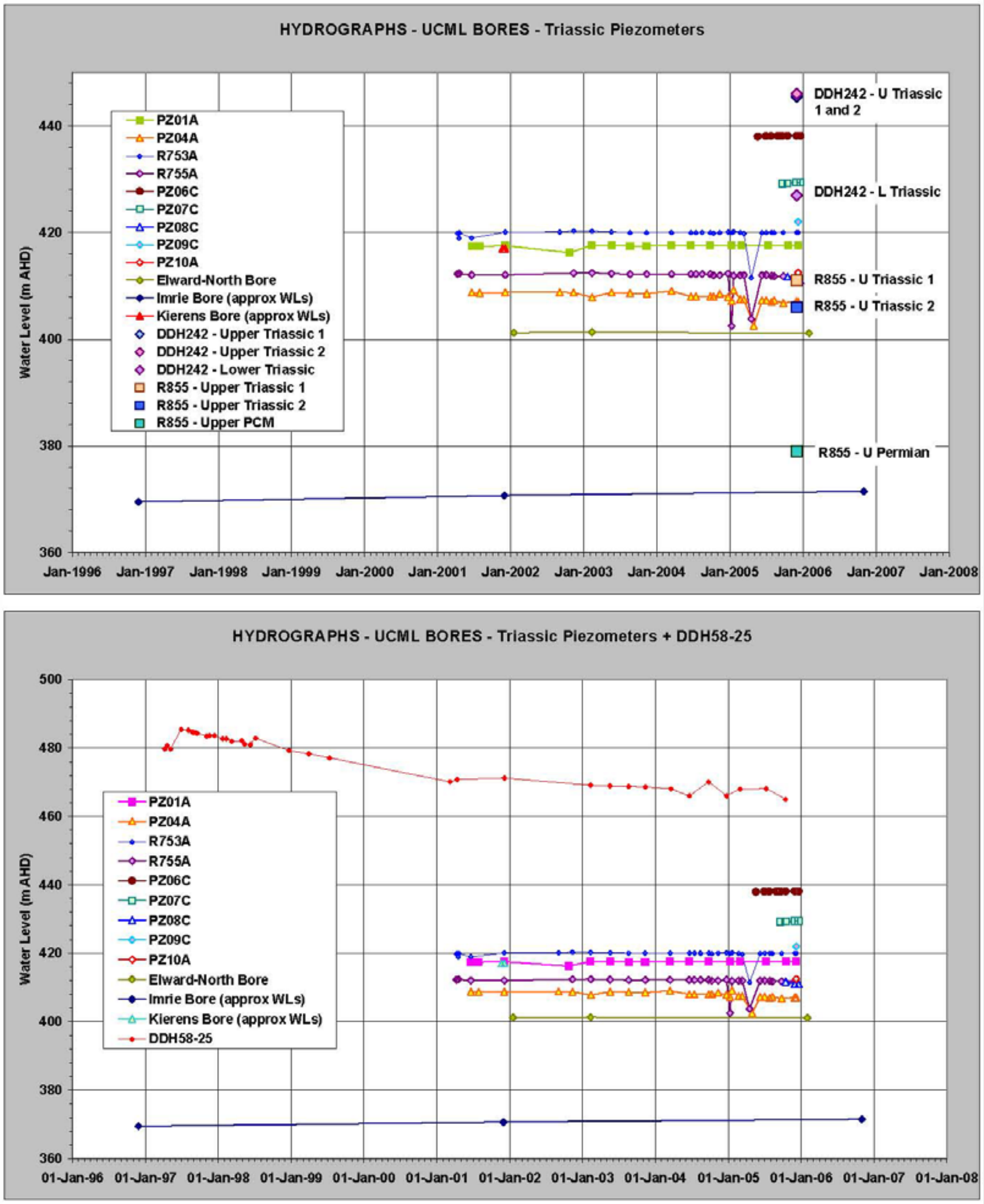
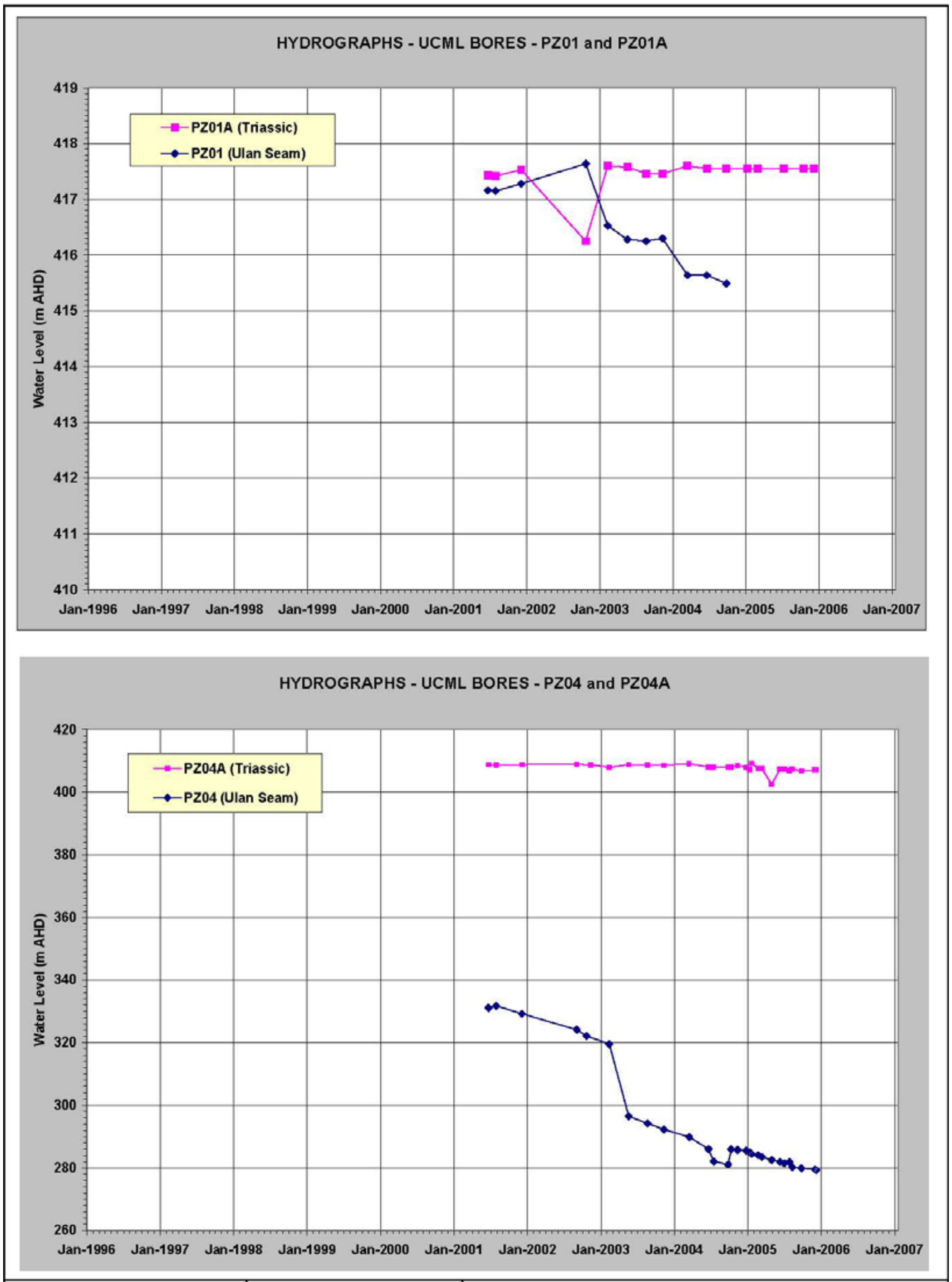


Figure 1: Triassic Groundwater Levels



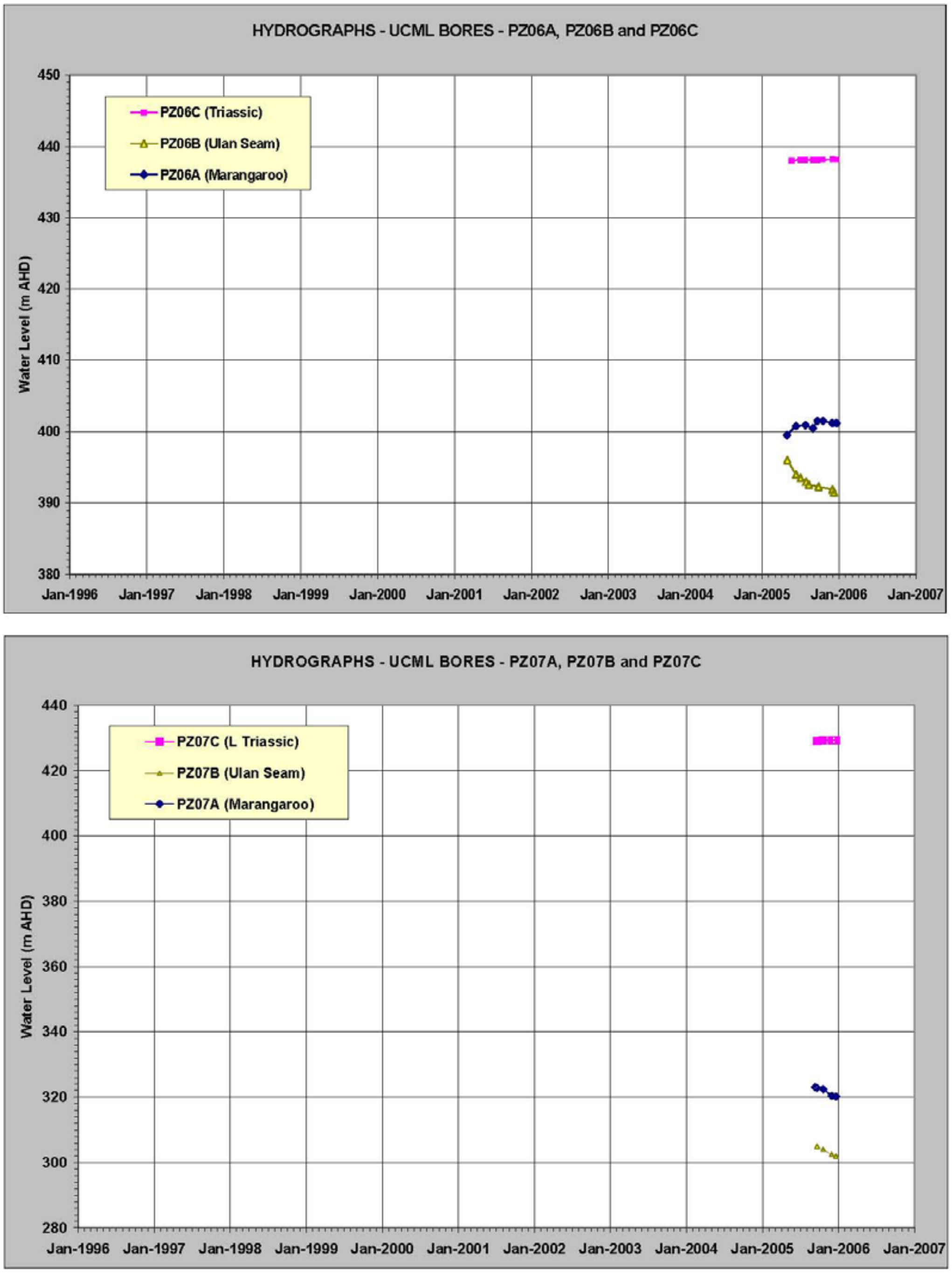
Date:	13 December 2006	Scale:	as indicated	**Moolarben Coal Mines Pty Ltd**
Initials:	PJD	Job No:	05-0158	**MOOLARBEN COAL PROJECT PIEZOMETER HYDROGRAPHS - UCML Triassic Piezometers**
Drawing No:	05-0158-130a	Rev:	A	
Peter Dundon & Associates Pty Limited				**Figure 2**

Figure 2: Piezometer Hydrographs – UCML Triassic Piezometers



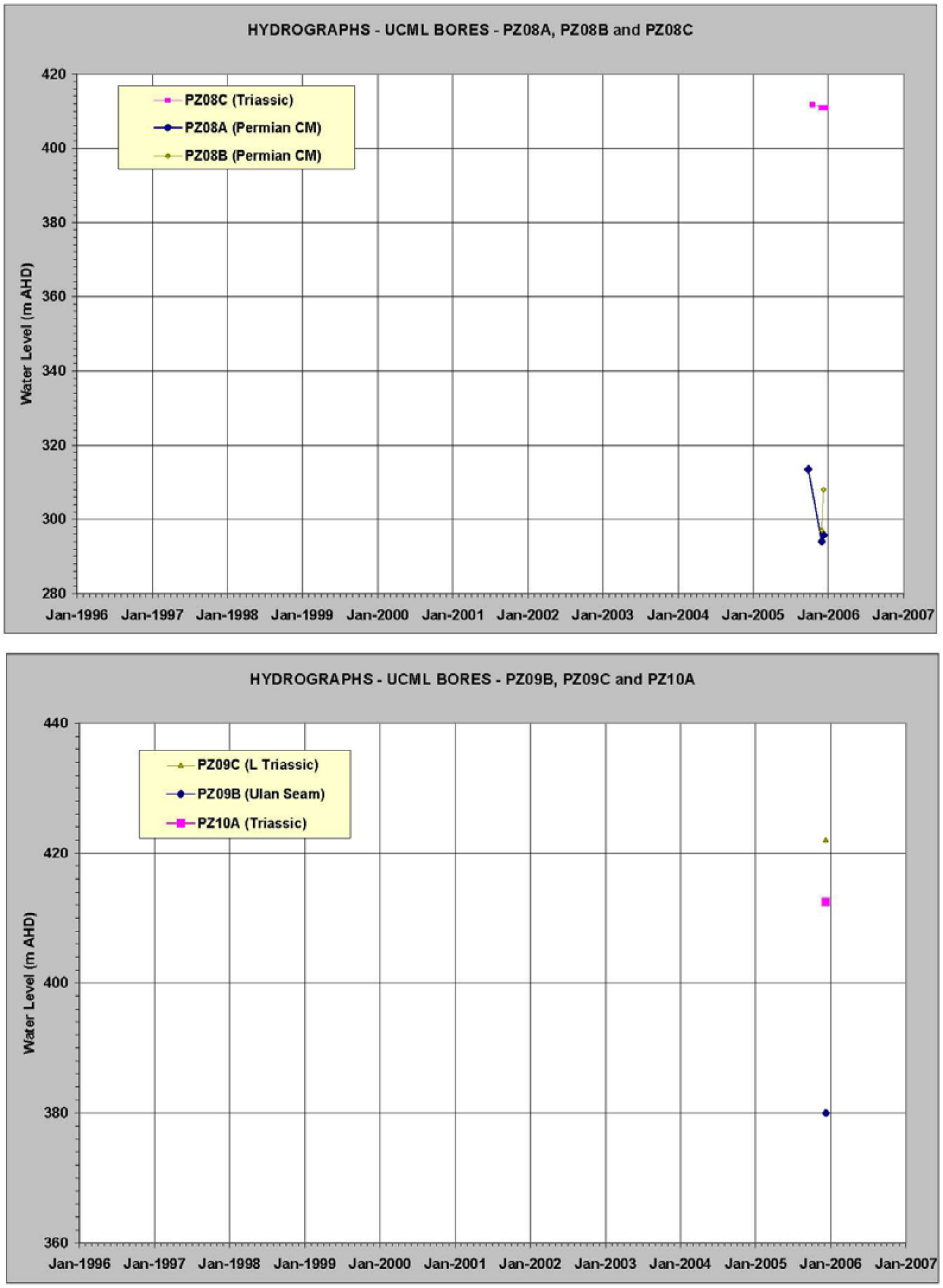
Date: 21 November 2006	Scale:	as indicated	**Moolarben Coal Mines Pty Ltd**	
Initials: PJD	Job No:	05-0158	**MOOLARBEN COAL PROJECT PIEZOMETER HYDROGRAPHS - UCML Triassic Piezometers PZ01, PZ01A; PZ4, PZ4A**	
Drawing No: 05-0158-131	Rev:	0		
Peter Dundon & Associates Pty Limited				**Figure 3**

Figure 3: Piezometer Hydrographs – UCML Multi-Level Piezometers PZ01, PZ01A; PZ04, PZ04A



Date: 21 November 2006	Scale: as indicated	**Moolarben Coal Mines Pty Ltd**
Initials: PJD	Job No: 05-0158	**MOOLARBEN COAL PROJECT PIEZOMETER HYDROGRAPHS - UCML Multi-Level Piezometers PZ06A, B and C; PZ07A, B and C**
Drawing No: 05-0158-132	Rev: 0	
Peter Dundon & Associates Pty Limited		**Figure 4**

Figure 4: Piezometer Hydrographs – UCML Multi-Level Piezometers PZ06A, B and C; PZ07A, B and C



Date:	21 November 2006	Scale:	as indicated	**Moolarben Coal Mines Pty Ltd**
Initials:	PJD	Job No:	05-0158	**MOOLARBEN COAL PROJECT PIEZOMETER HYDROGRAPHS - UCML Multi-Level Piezometers PZ08A, B and C; PZ09B and C; PZ10A**
Drawing No:	05-0158-133	Rev:	0	
Peter Dundon & Associates Pty Limited				**Figure 5**

Figure 5: Piezometer Hydrographs – UCML Multi-Level Piezometers PZ08A, B and C; PZ09B and C; PZ10A

Most of UCML's groundwater monitoring sites comprise multi-level piezometers, with separate piezometers screened in the Triassic and the Ulan Seam, and at some sites in the Marrangaroo as well. Coffey Geosciences (Coffey, 2005) stated in their report accompanying UCML's SMP Application for the first of their 400m wide panels LW23-26 and W1 (UCML, 2005b) that *"… hydrographs for piezometer nests PZ01 and PZ04 located east of Panel 22 indicate that the Mesozoic Sandstone is able to maintain hydraulic head while the Ulan Coal Seam depressurises significantly".*

Composite hydrographs for the UCML sites (**Figures 3** to **5**) show substantial head differences of up to at least 130m between the Triassic and the deeper units, with the Ulan Seam and Marrangaroo Conglomerate both showing substantial drawdown due to mine dewatering, whereas the Triassic shows no significant impact, apart possibly from PZ04A. The water levels in PZ04A appear to have fallen approximately 0.9m from early 2004 to the end of 2005, which may represent either a small mining-related impact or a seasonal water level decline.

The IHAP panel has made available information provided to it on 4 December 2006 by UCML's subsidence consultants (SCT, 2006), that claims to provide evidence of Triassic drawdowns due to mining activity. We have viewed this information, and are not convinced that it is an indication of mining related impact on the Triassic groundwater.

The SCT letter details piezometric data from multi-level piezometer strings in two bores DDH242 and R855 installed prior to the commencement of Longwall 23, the first of the 400m wide longwall panels. SCT interpret the data as indicating that *"… the pore pressure in the lower part of the Triassic sandstone has been drawn down below hydrostatic by mining activity*.*"* The information provided is not time-series data, and therefore does not of itself indicate any drawdown, merely that the heads in the lower Triassic may be lower than those in the upper Triassic. There is abundant evidence, at sites well beyond the limit of possible influence of Ulan mine, of large natural head differences within the Triassic, and also in the Permian sediments, that are related to the presence of numerous perching aquitards within the sequence, and not to any mining related impacts.

When the piezometric head data presented on Figure 1 of the SCT letter report are converted to absolute heads (**Table 1**), it is seen that the heads in the Lower Triassic piezometer at bore DDH242 are consistent with the Lower Triassic water levels in nearby UCML bores that have shown no significant drawdown since at least early 2001. Only PZ04A shows a slight downward trend from 2004 (apparent water level decline of 0.9m from early 2004 to the end of 2005). This slight decline is insignificant compared with the 20m decline implied by SCT's interpretation of the piezometric heads in DDH242 and R855.

Table 1: Interpreted Piezometric Data – Bores DDH242 and R855

Bore DDH242 **-Collar 523 mAHD** **-Top Ulan Seam 285 mAHD**	**Piezometer 1**[1]	**Piezometer 2**	**Piezometer 3**
Piezometer level (mAHD)	444	416	385
Geological Unit	Upper Triassic	Upper Triassic	Lower Triassic
Piezometric head (m)	1	30	39
Piezometric head (mAHD)	445	446	424
Bore R855 **-Collar 492 mAHD** **-Top Ulan Seam 242 mAHD**	**Piezometer 1**	**Piezometer 2**	**Piezometer 3**
Piezometer level (mAHD)	395	366	317
Geological Unit	Upper Triassic	Upper Triassic	Upper Permian
Piezometric head (m)	15	40	63
Piezometric head (mAHD)	410	406	380

The heads at the two Upper Triassic piezometers in DDH242 are about 20m higher than heads in the other Triassic bores nearby, and they are inconsistent with the Triassic groundwater contours shown on **Figure 1**. The head in the Lower Triassic piezometer is consistent with the contours.

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[1] Only relevant piezometers included in Table

It is also noted that there is no piezometer in the Lower Triassic in bore R855, and no conclusions can be drawn concerning the groundwater levels or pressures in the Lower Triassic at that site.

SCT also state that their inferred drawdown *"… would appear to extend laterally for a considerable distance given that the piezometric profile is essentially the same at 260m and 800m from a goaf."* If that were the case, drawdown would be expected to be evident in a number of UCML's Lower Triassic piezometers in the general vicinity of the two new piezometer holes (ie PZ04A, R753A, R755A, PZ07C, and others more distant). PZ04A may be displaying small drawdown as indicated above (0.9m from 2004 to 2005), but this is not of sufficient magnitude to be consistent with SCT's interpretation of the R855 and DDH242 piezometers.

3.2 Information Obtained from Moolarben Groundwater Investigations

3.2.1 Investigations for EA

During the piezometer installation program carried out for the Moolarben project in 2005-2006, no piezometers were installed in the Triassic, due to a lack of groundwater inflows above the top of the Permian during drilling. (All piezometer drilling was carried out by the air rotary method, so groundwater inflows were easy to recognise if there were any.)

Relevant information from the eleven piezometers and two test bores drilled within or north of the Underground 4 area is summarised as follows:

- PZ101A -
    - First water intersection occurred at 30m (top of Permian) - minor flow.
    - Piezometer screened in Ulan seam, and Triassic sealed off by annular grout.
    - Maximum airlift yield during drilling was 3L/s from the Permian above the Ulan Seam.
    - SWL at this site is below top of Permian.

- PZ101B -
    - First water intersection was at 40m (10m below the top of the Permian).
    - Piezometer screened at 54-60m in Permian Coal Measures overburden.
    - Airlift yield at completion was 0.4L/s.

- PZ102A -
    - No Triassic present (eroded).
    - First water intersection was at Ulan Seam, minor flow.
    - More water was intersected at 113m (Marrangaroo Conglomerate), minor flow.

- PZ102B -
    - No Triassic present.
    - Maximum airlift yield 0.6L/s.

- PZ103A -
    - No significant water intersection (drilled after PZ103B).

- PZ103B -
    - Top of Permian at 25m.
    - First water intersection at 55m (0.2L/s).
    - No increase in flow to TD.

- TB103 -
    - Moisture at 15m in Triassic. No measurable flow.
    - First measurable flow occurred at 67m in Permian (0.2L/s).
    - Increased to 5L/s by 96m (coal measures above Ulan Seam).

  - SWL in completed bore is 55m below surface (ie 30m below base of Triassic).

- PZ105A -
  - Base of Triassic 29m.
  - First water intersection 38m in Permian coal measures (1.4L/s).

- PZ105B -
  - Base of Triassic 27m.
  - No water intersected until 55m (0.2L/s).

- TB105 -
  - Base of Triassic 27m.
  - First water intersected 30m (2.8L/s).
  - Main water intersection 81m (8.5L/s).

- PZ108 -
  - No significant water intersection entire hole.
  - Base of Triassic 118m depth (301mAHD).
  - Open hole SWL was 402mAHD (hole open to both Triassic and Permian).
  - After Triassic sealed off, WL fell to 333mAHD.

- PZ109 -
  - No recorded water intersection.

- PZ110 -
  - No Triassic present.
  - First water intersection at 55m depth in Permian coal measures.

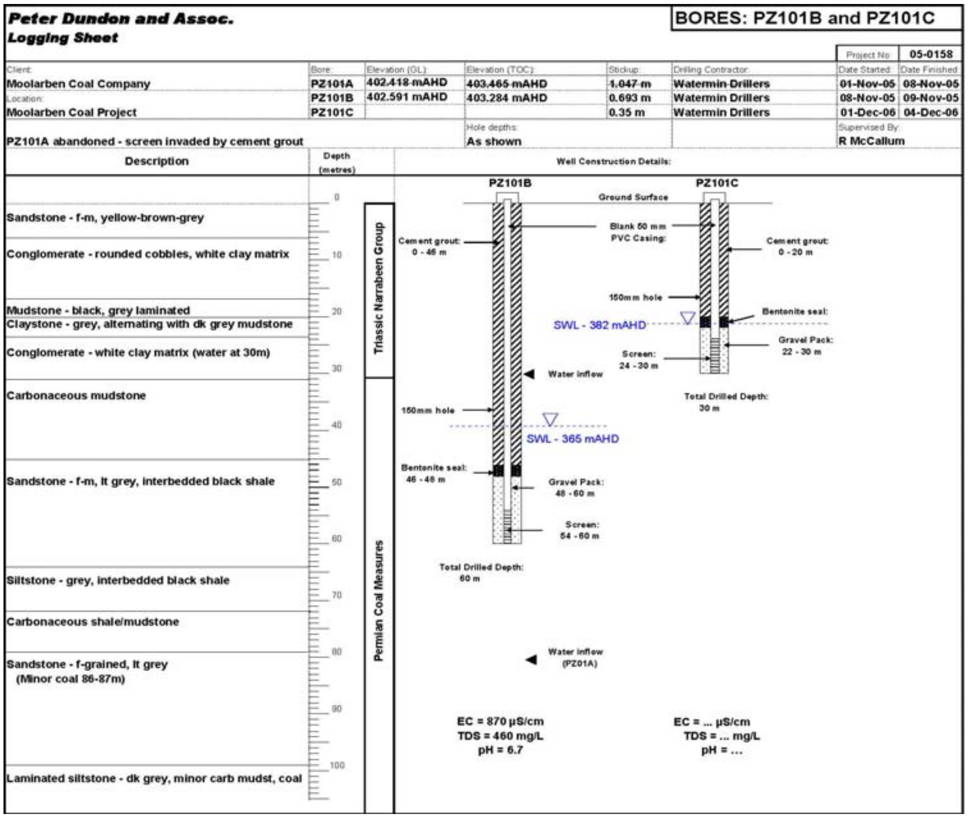
3.2.2 December 2006 Drilling of Piezometers

New piezometers have been installed (December 2006) at three sites above the northern half of Underground 4, viz PZ101C, PZ103C and PZ105C. Locations are shown on **Figure 1.** At all other sites previously drilled within the Underground 4 area, the Triassic was absent.

The drilled depths and screen intervals of the new piezometers are detailed in bold in **Table 2**, together with the existing piezometers at the same sites. Construction details are shown on **Figures 6** to **8**.

Table 2: Details of Triassic Piezometers above Underground 4.

Piezometer	Depth	Screen Interval	Groundwater Level		Aquifer	Status
			m below GL	m AHD		
PZ101A	131m	120-129m	-	-	Ulan seam	Failed piezometer
PZ101B	60m	54-60m	39.0	364.3	PCM o/b	Piezometer
PZ101C	**30m**	**24-30m**	**21.5**	**381.5**	**Triassic**	**Piezometer**
TB103	100m	76-79m 82-85m 94-97m	55.9	369.3	PCM o/b	Test/Production Bore
PZ103A	128m	118-127m	68.8	356.4	Ulan seam	Piezometer
PZ103B	87m	81-87m	55.9	369.2	PCM o/b	Piezometer
PZ103C	**30m**	**24-30m**	**22.7**	**402.3**	**Triassic**	**Piezometer**
TB105	133m	78-84m 126-132m	29.3	359.5	PCM o/b Ulan seam	Test/Production Bore
PZ105A	115m	87-96m	29.4	359.2	PCM o/b	Piezometer
PZ105B	64m	58-64m	11.9	377.1	PCM o/b	Piezometer
PZ105C	**28m**	**22-28m**	**11.0**	**378.0**	**Triassic**	**Piezometer**

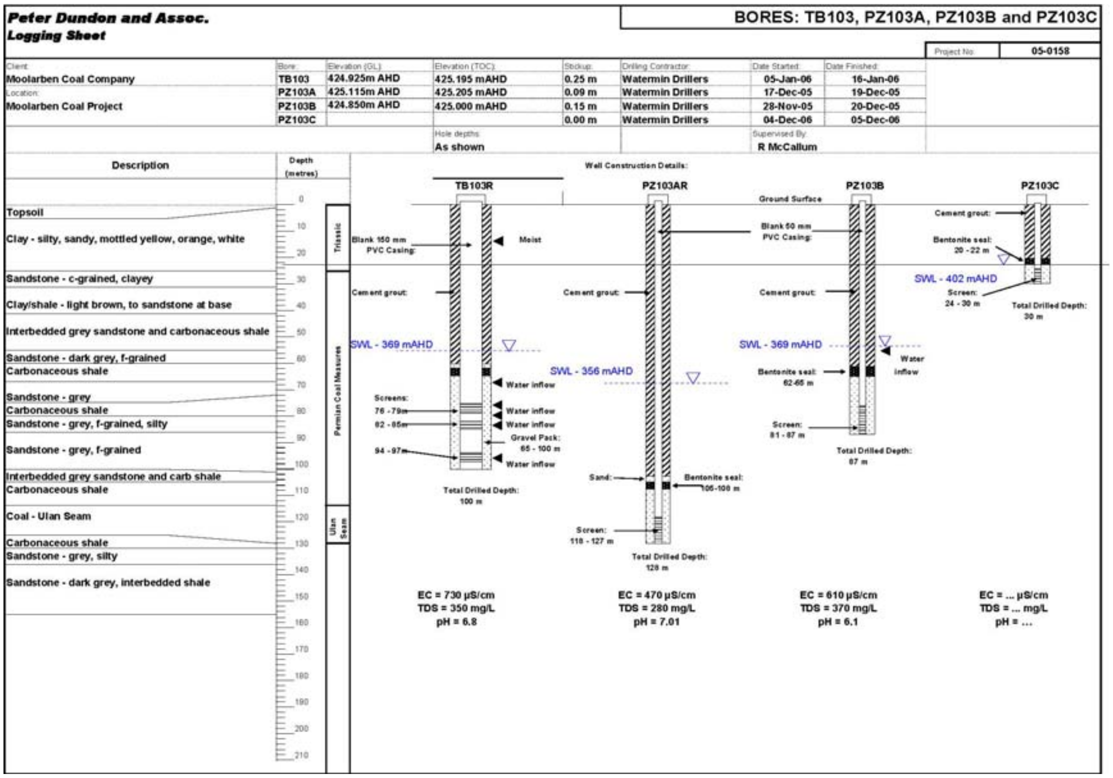


Peter Dundon and Assoc.
Logging Sheet

BORES: PZ101B and PZ101C

						Project No:	05-0158
Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Moolarben Coal Company	PZ101A	~~402.418 mAHD~~	~~403.465 mAHD~~	~~1.047 m~~	~~Watermin Drillers~~	~~01-Nov-05~~	~~08-Nov-05~~
Location:	PZ101B	402.591 mAHD	403.284 mAHD	0.693 m	Watermin Drillers	08-Nov-05	09-Nov-05
Moolarben Coal Project	PZ101C			0.35 m	Watermin Drillers	01-Dec-06	04-Dec-06
PZ101A abandoned - screen invaded by cement grout			Hole depths: As shown			Supervised By: R McCallum	

Figure 6: Bore Log – PZ101A, PZ101B and PZ101C



Peter Dundon and Assoc.
Logging Sheet

BORES: TB103, PZ103A, PZ103B and PZ103C

						Project No:	05-0158
Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Moolarben Coal Company	TB103	424.925m AHD	425.195 mAHD	0.25 m	Watermin Drillers	05-Jan-06	16-Jan-06
Location:	PZ103A	425.115m AHD	425.205 mAHD	0.09 m	Watermin Drillers	17-Dec-05	19-Dec-05
Moolarben Coal Project	PZ103B	424.850m AHD	425.000 mAHD	0.15 m	Watermin Drillers	28-Nov-05	20-Dec-05
	PZ103C			0.00 m	Watermin Drillers	04-Dec-06	05-Dec-06
			Hole depths: As shown			Supervised By: R McCallum	

Figure 7: Bore Logs – TB103, PZ103A, PZ103B and PZ103C

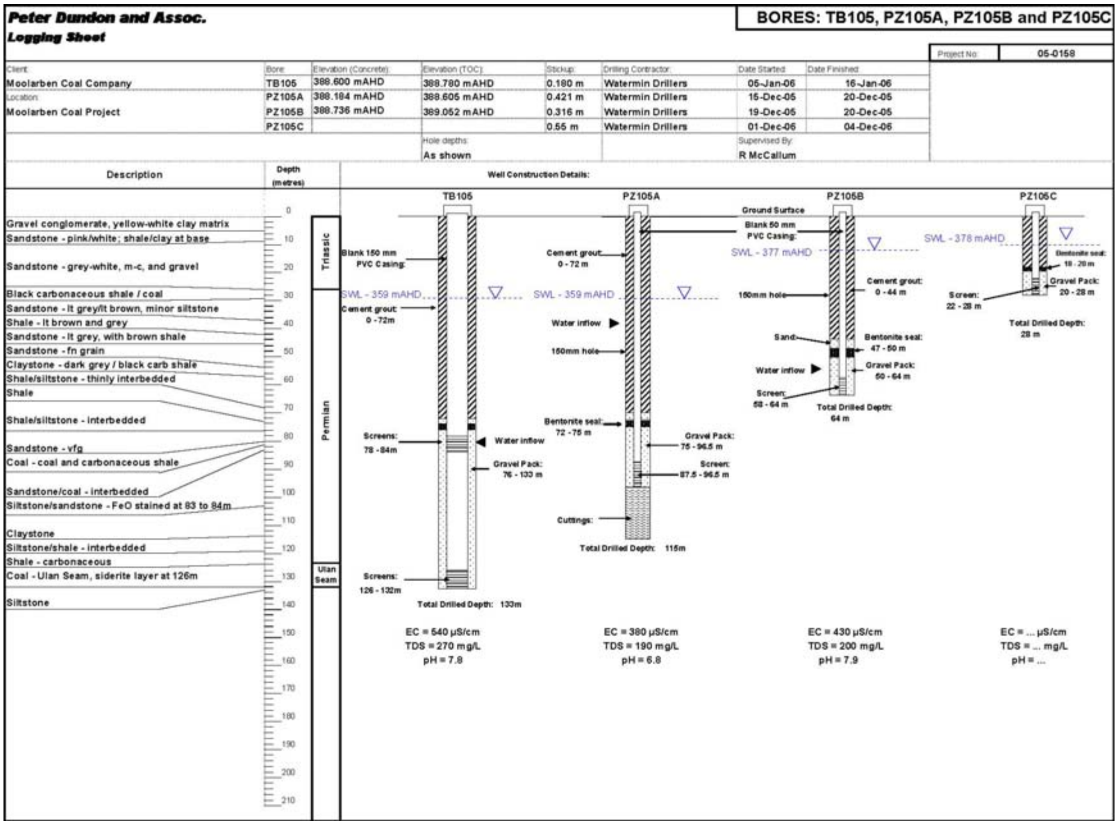


Figure 8: Bore Logs – TB105, PZ105A, PZ105B and PZ105C

None of the three new piezometers yielded water during air drilling, although moist samples were reported. After completion, water levels were measured as above.

A pumping test has been attempted on PZ105C, and falling head permeability tests have been conducted on the other two new piezometers. The test on PZ101C was affected by a cavity above the water table, and could not be analysed. The results are detailed in **Table 3**. The results of tests on PZ103C and PZ105C are shown on **Figures 9** and **10**.

Table 3: Hydraulic Testing Program – Triassic Piezometers

Bore	Test Date	Type of Test	Pumping Rate (kL/d)	Duration (min)	Transmissivity (m^2/d)	Hydraulic Conductivity (m/d)
PZ101C	5 Dec 2006	Slug test	-	-	-	ND
PZ103C	5 Dec 2006	Slug test	-	-	-	0.01
PZ105C	5 Dec 2006	CR Pumping Test	3	60	0.07	0.01
PZ105C	5 Dec 2006	Slug test	-	-	-	0.02

The above results are consistent with the results of testing of private Triassic water supply bores by UCML (2003) and with the horizontal permeability values adopted in our modelling.

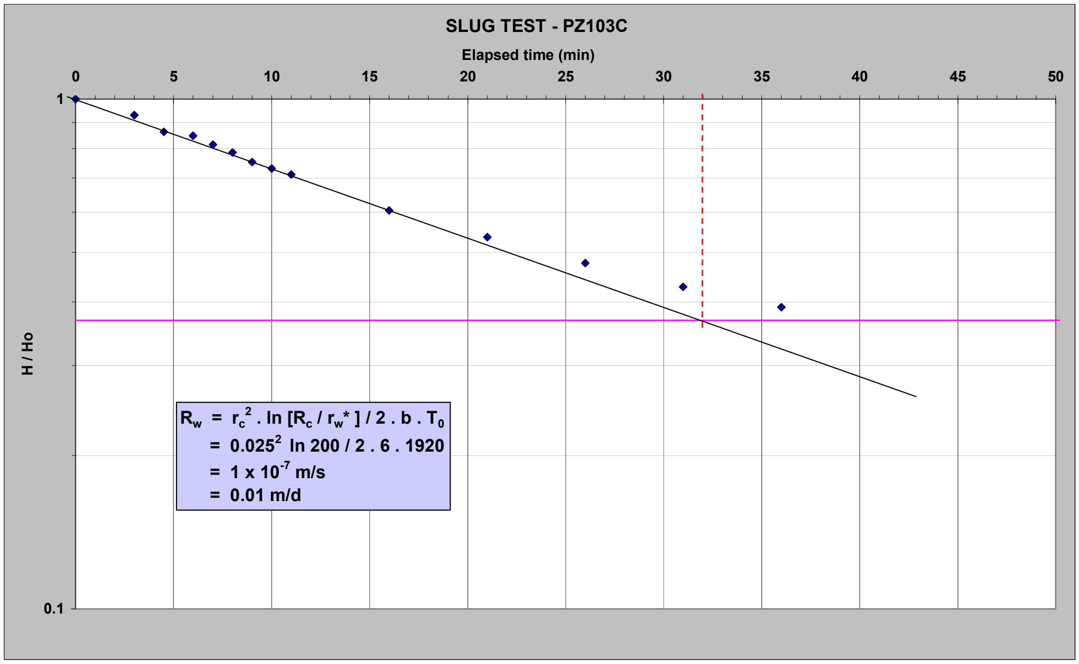


Figure 9: Slug Permeability Test on Triassic Piezometer PZ103C

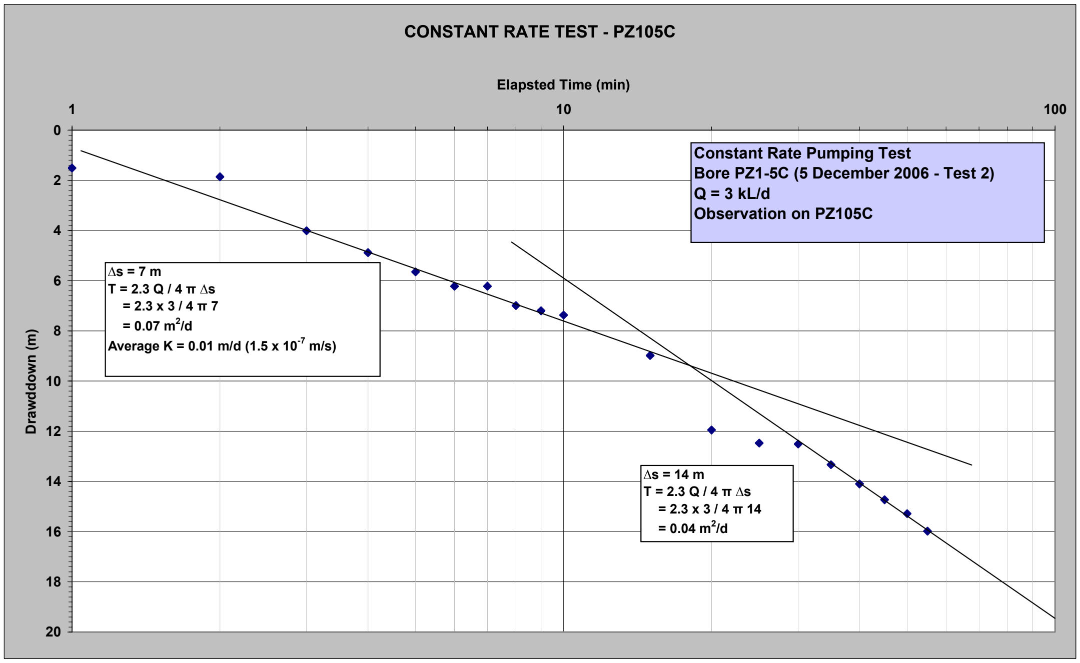


Figure 10: Constant Rate Pumping Test on Triassic Piezometer PZ105C

3.3 Summary

The most recent measured water levels in each Triassic bore are shown on **Figure 1**, and the water levels have been contoured. The contours show a general decline in groundwater levels to the south-east from the UCML area, and to the north across the northern part of MCM's Underground 4 (ie towards Goulburn River). This pattern seems to be related to topography, and is unrelated to either the underlying Permian or to the longwall mining. The water levels from the new MCM piezometers show that the groundwater in the Triassic flows generally towards Goulburn River, both from the north and the south.

The SCT material provided to us by the IHAP Panel does not constitute evidence of mining related drawdowns.

All the available information from both the long-term and recent standpipe piezometers indicates that irrespective of what height of fracturing might have occurred above the Ulan goaf areas, the longwall mining at Ulan has had minor or negligible impact on the Triassic aquifer system. The substantial head differences between the Triassic and Permian also confirm that the connectivity between the Triassic and the Permian is very poor (ie vertical permeability extremely low).

Coffey Geosciences (Coffey, 2005) stated in their report accompanying UCML's 2005 SMP Application (UCML, 2005b) that *"… proposed mining within the application area is not expected to have a significantly greater impact on three* (private) *bores located some 2km to the south east of the application area (Bore E, GW047495, GW047195) than previous mining has already had. …. Bore GW047495* (Elward North bore) *is expected to have already been impacted from mining as it is located east of Panel 20. The owner was consulted in relation to the operation of the bore and informed UCML that it was still in use and that if it has been impacted then the result has not been noted."* We measured the water level in bore GW047495 (Elward North Bore) in February 2006 during the course of the Moolarben investigations, and found the water level unchanged from historical measurements dating back to January 2002 (**Figure 2**).

In relation to height of fracturing above the extracted longwall panels, Coffey (2005) state that *"… the base of the sandstone is located around 80m above the roof of the working section and is therefore not expected to intersect the caved zone."*

In their assessment of likely impacts of UCML's plan to commence mining from 400m wide panels compared with the previous 261m, SCT (2005) stated that *"… ground-water aquifers are likely to be affected by mining in a similar way to which they have been affected over previous longwall panels at the mine …"* and *"…proposed mining within the application area is not expected to have a significantly greater impact on three bores located some 2km to the south east of the application area (Bore E, GW047495, GW047195) than previous mining has already had."*

Notwithstanding our view that the published UCML monitoring data and other piezometer records do not provide any evidence of material drawdown impacts having occurred in the Triassic sandstones, nevertheless we consider it prudent to anticipate the possibility that such impact may occur. Accordingly, we have adopted hydraulic parameters in the groundwater model, including a failure zone that extends up into the Triassic, to assess the impacts if such mining impacts were to occur. This is discussed in **Section 5** below.

As proposed in the EA report, additional Triassic piezometers are to be installed above Underground 4 and to the north, prior to the commencement of longwall extraction. The EA also outlines a subsidence impact monitoring program to be implemented initially above the first few panels, where the Triassic is either absent or is dry, so that the actual fracturing response to longwall extraction can be studied prior to mining extending beneath saturated Triassic. The results of this program will be used to confirm or modify the mining approach in the more sensitive northern panels if necessary.

4 MARRANGAROO CONGLOMERATE

Within the Underground 4 area, two piezometers were completed with screens in the Marrangaroo Conglomerate:

- PZ102A -
    - Average hydraulic conductivity 0.2 m/d, determined from falling head test.
    - Groundwater level broadly similar to the Ulan Seam (**Figure 11**). Both PZ102A and PZ102B appear to be responding to changes in pumping rates at Ulan.

- PZ110 -
    - Drilled through full sedimentary sequence to top of underlying volcanics.
    - Screened in Ulan Seam, floor coal measures, Marrangaroo Conglomerate and basement.
    - Average hydraulic conductivity (all above units combined) 6.8m/d (believed to be dominated by Ulan Seam - first water intersection).

Five further piezometers were completed in other parts of EL6288 with screens in the Marrangaroo Conglomerate or equivalent lithologies below the Ulan Seam:

- PZ17 - dry.

- PZ30 -
    - Partly unsaturated - water level 15m below top of Marrangaroo.
    - Very low hydraulic conductivity - pumped dry in less than 1 minute.

- PZ31A - dry.

- PZ41A -
    - Screened 77-80m depth. Adjacent PZ41B screened at 66-69m in Ulan Seam.
    - SWL in Marrangaroo is 40m lower than Ulan Seam at same site (PZ41B) despite there being less than 5m vertical separation (**Figure 12**).
    - Hydraulic conductivity 0.06m/d, determined from falling head test.

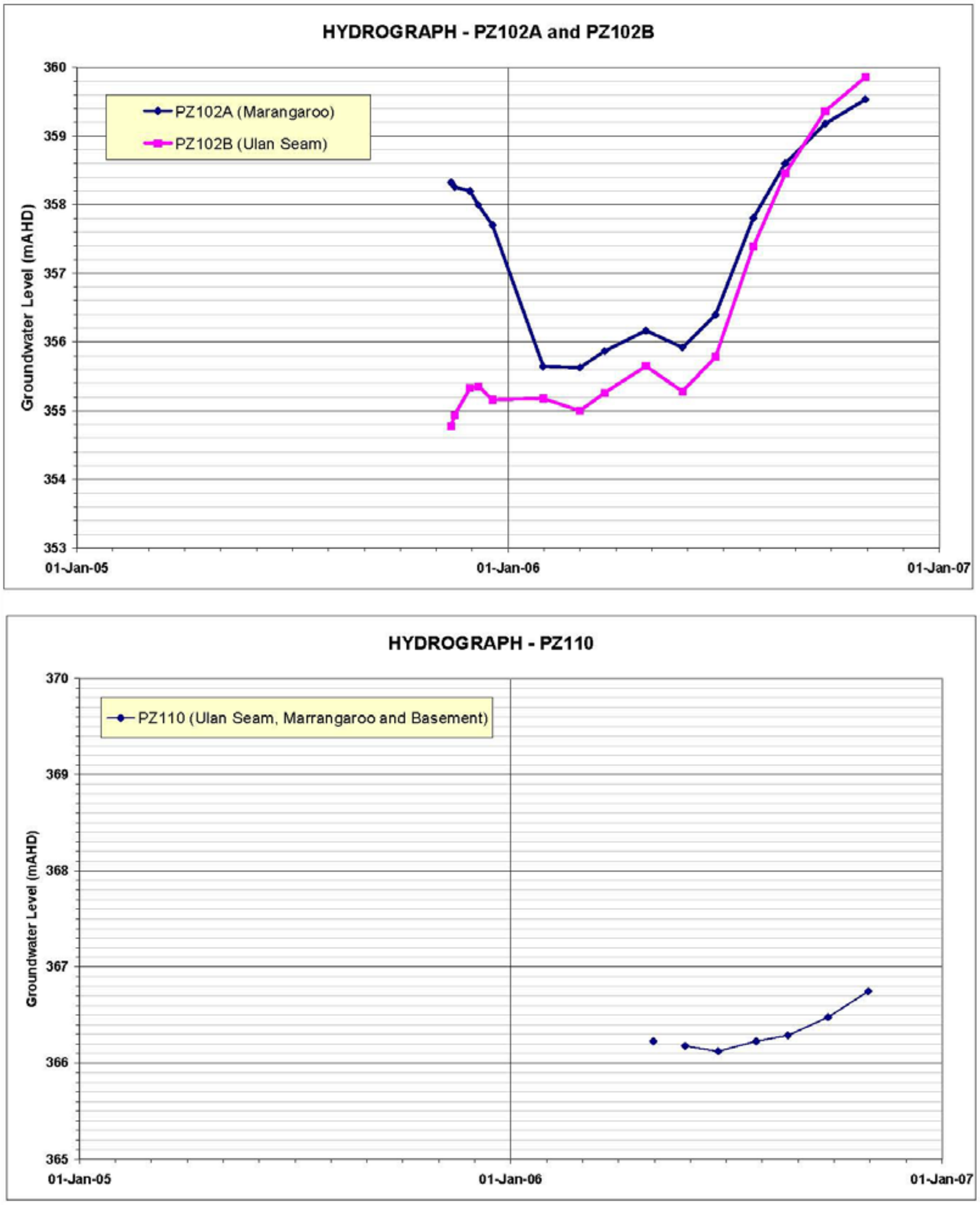
- PZ106A -
    - Screened 125-131m depth. Adjacent PZ106B screened at 29-35m in Permian coal measures.
    - SWL in Marrangaroo is 80m lower than in the coal measures above the Ulan Seam (**Figure 12**).
    - Average hydraulic conductivity 0.005 m/d, determined from falling head test.

The hydraulic testing results indicate that the Marrangaroo Conglomerate has low to very low horizontal hydraulic conductivity. The very large head differences between the Marrangaroo and the overlying Permian in the southern part of EL6288 indicate a very low vertical hydraulic conductivity as well. However, in the Underground 4 area, the Marrangaroo Conglomerate and Ulan Seam appear to be in reasonable hydraulic connection. The UCML multi-level piezometers (**Figure 4**) suggest a reasonable degree of hydraulic connection between the Marrangaroo and the Permian in the UCML underground area as well.

UCML have 4 Marrangaroo Conglomerate piezometers:

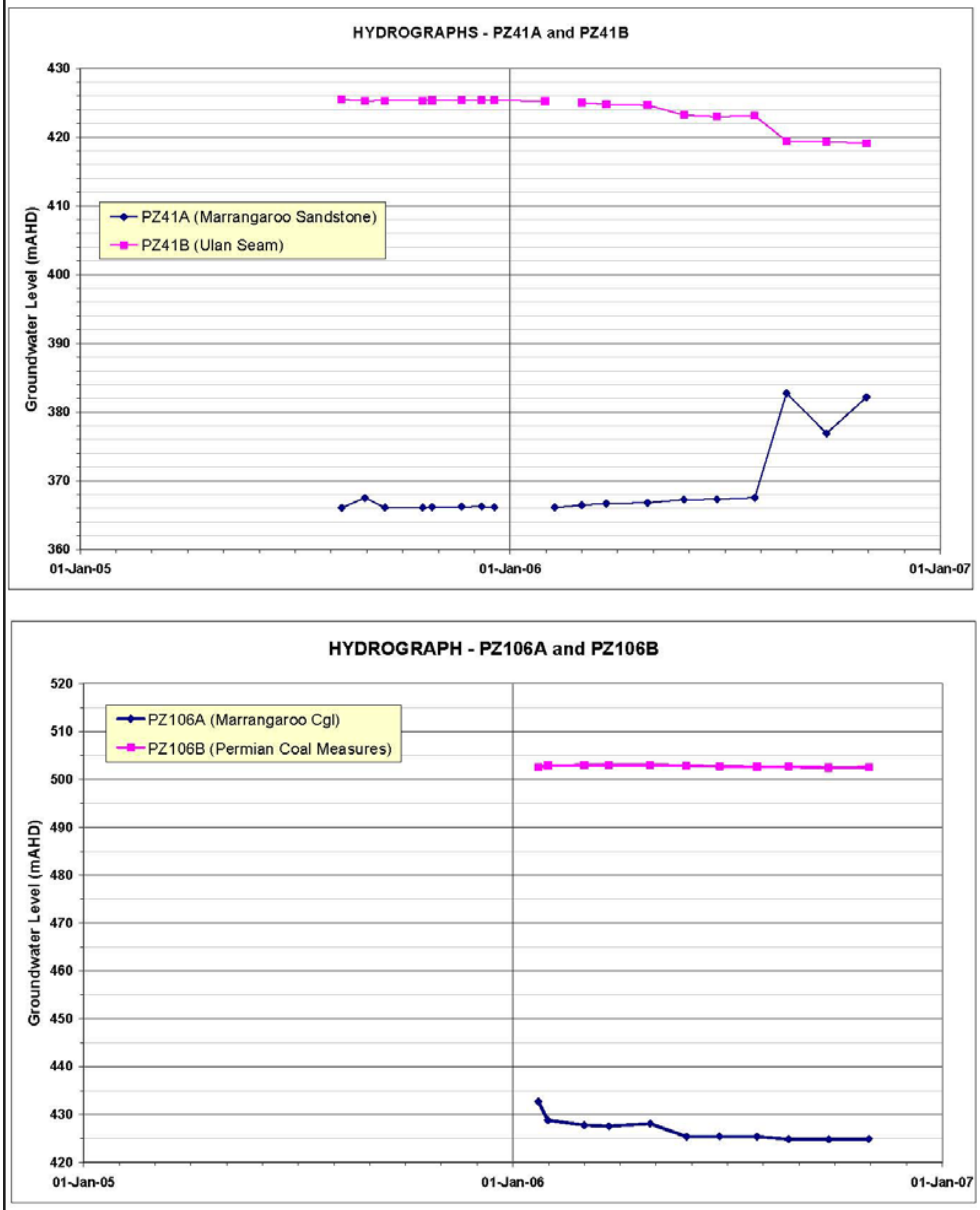
- DDH116
- PZ06A
- PZ07A
- PZ09A.

A composite plot of hydrographs for the UCML and MCM Marrangaroo Conglomerate piezometers is shown on **Figure 13**.



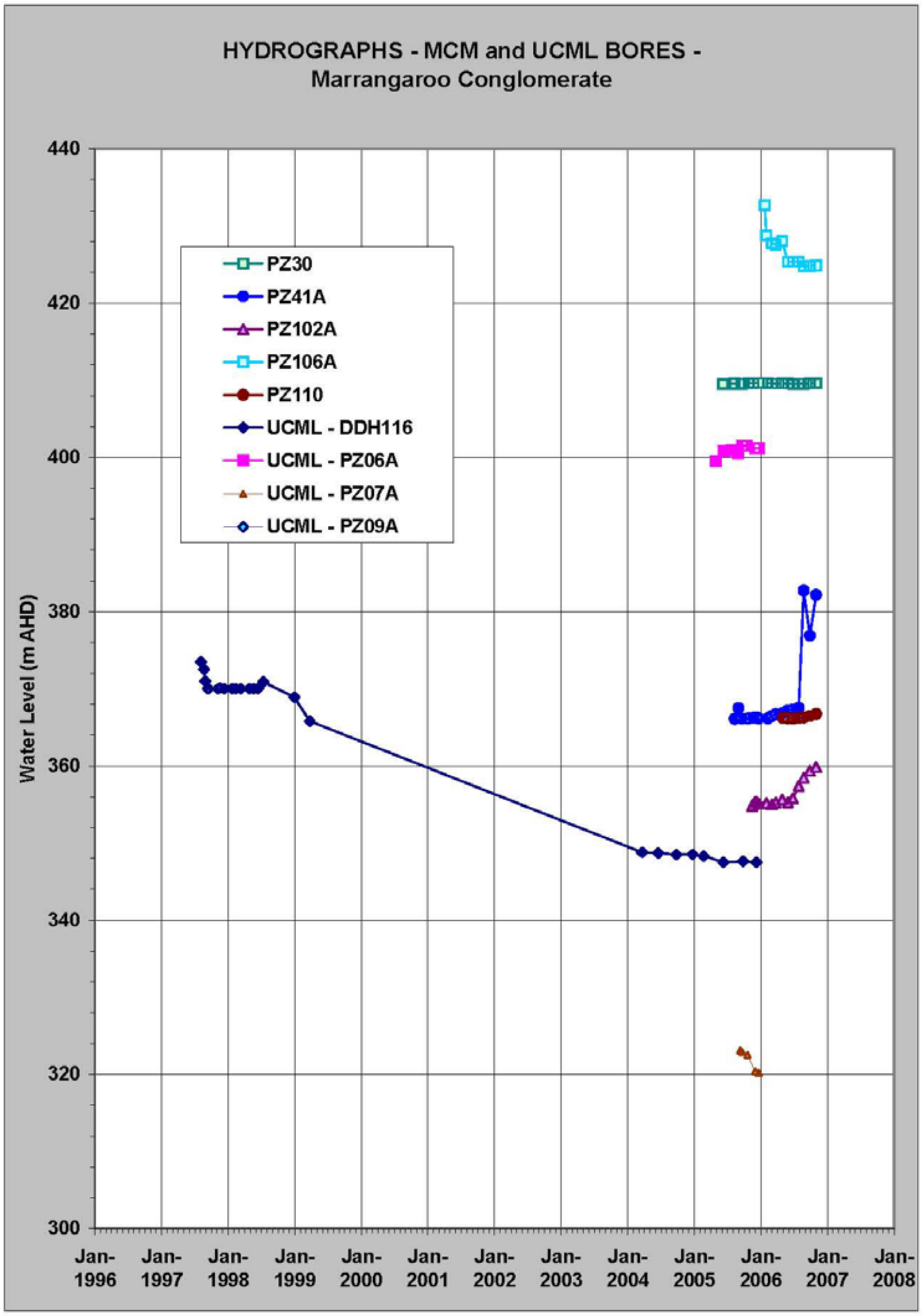
Date: 21 November 2006	Scale: as indicated	**Moolarben Coal Mines Pty Ltd**
Initials: PJD	Job No: 05-0158	**MOOLARBEN COAL PROJECT PIEZOMETER HYDROGRAPHS - PZ102A-B; PZ110**
Drawing No: 05-0158-134	Rev: 0	
Peter Dundon and Associates Pty Limited		**Figure 11**

Figure 11: Piezometer Hydrographs – PZ02A and B; PZ110



Date: 21 November 2006	Scale: as indicated	**Moolarben Coal Mines Pty Ltd**
Initials: PJD	Job No: 05-0158	**MOOLARBEN COAL PROJECT PIEZOMETER HYDROGRAPHS - PZ41A-B; PZ106A-B**
Drawing No: 05-0158-135	Rev: 0	
Peter Dundon and Associates Pty Limited		**Figure 12**

Figure 12: Piezometer Hydrographs – PZ02A and B; PZ110



Date: 21 November 2006	Scale: as indicated	**Moolarben Coal Mines Pty Ltd**
Initials: PJD	Job No: 05-0158	**MOOLARBEN COAL PROJECT PIEZOMETER HYDROGRAPHS - Marrangaroo Conglomerate**
Drawing No: 05-0158-136	Rev: 0	
Peter Dundon and Associates Pty Limited		**Figure 13**

Figure 13: Piezometer Hydrographs – Marrangaroo Conglomerate

5 GROUNDWATER FLOW MODELLING

Further groundwater flow modelling has been carried out to assess the impacts of the preferred project plan. This modelling has utilised the same basic groundwater flow model used for the initial project impact assessment, but a number of modifications have been made to input parameters, arising from issues raised in submissions or directly by the IHAP Panel. These modifications and the results of modelling are outlined in the following sections. A more comprehensive report on the modelling is presented in Aquaterra (2006b).

5.1 Groundwater Flow Model

The EA (MCM, 2006) was prepared on the basis of a groundwater flow model development, calibration and prediction that used the industry-standard MODFLOW package in an approach consistent with the Australian best practice guideline for groundwater modelling (MDBC, 2001). Although the MODFLOW package has been used in a large number environmental assessment projects, including open cut and underground coal mines (and notably for Ulan and Wilpinjong), the IHAP expressed concern that the MODFLOW application to Moolarben may have been subject to numerical instability, or that the results may have been affected by model cells drying out due to dewatering and thus affecting groundwater flow paths in an unrealistic manner. It is agreed that such problems can potentially occur and can be quite significant in some cases, but they did not affect the Moolarben MODFLOW model application, and the concern expressed by the IHAP is unwarranted in this case.

A benchmarking run was undertaken to demonstrate that the standard MODFLOW application is valid for the Moolarben case. The benchmark run was based on the MCM model version MC1.3 that was used to prepare the environmental assessment report. MC1.3 utilises the Processing MODFLOW software (IES, 2006), which does not support SURFACT, so the MC1.3 model was transferred into the Groundwater Vistas groundwater modelling software (ESI, 2006), which does support SURFACT. For the benchmarking run, no changes were made to any model parameters, nor to any hydrological stresses or mine plan details, and the SURFACT model was run with the “pseudo-soil” function active to prevent dry cell problems.

Figures 14 and **15** show the predicted Moolarben mine dewatering rates, and **Figures 16** and **17** the predicted groundwater level contours, for the MODFLOW and the SURFACT applications of the MC1.3 model version. Very slight differences in dewatering rates (less than 5% at both Ulan and Moolarben) are apparent in the comparative plots on**Figures 14** and **15**. Slight differences in the groundwater level contours are apparent between the two model results (comparing **Figure 16** and **Figure 17**), which arise from the very slight differences between the pattern of dry cells in the MODFLOW case and the pattern of unsaturated cells in the SURFACT case. These differences are within the range of the normally accepted accuracy of modelling predictions of 10% to 20%.

Based on these comparisons, the SURFACT benchmarking run has confirmed the validity of using the MODFLOW model in the Moolarben case, as reported in the EA (MCM, 2006) and subsequent presentations to the IHAP.

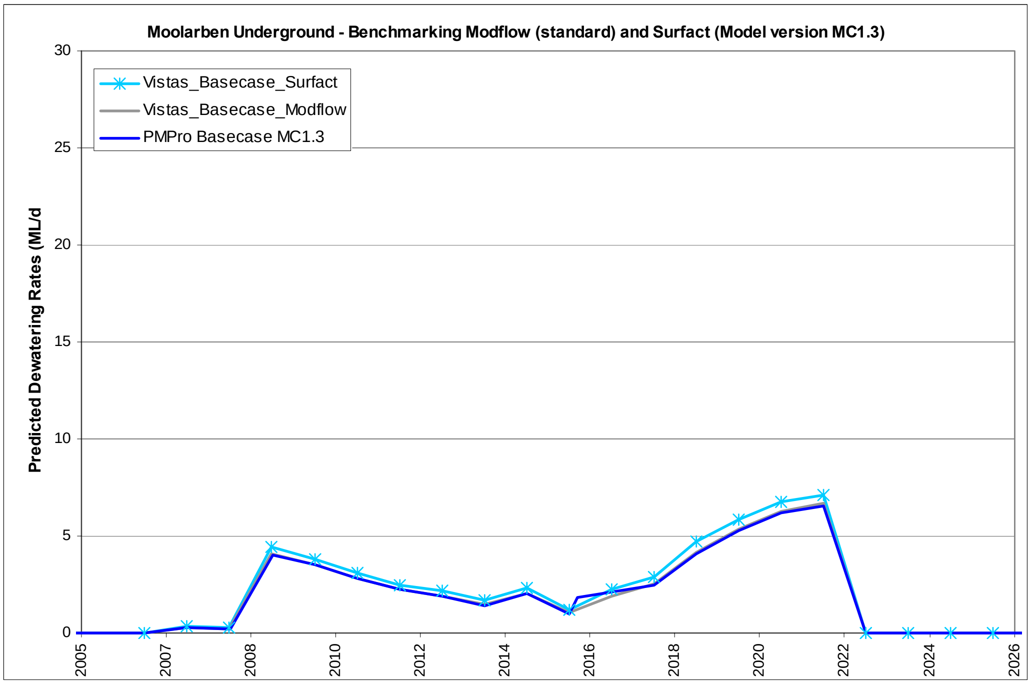


Figure 14: Predicted groundwater inflows to Moolarben underground mine

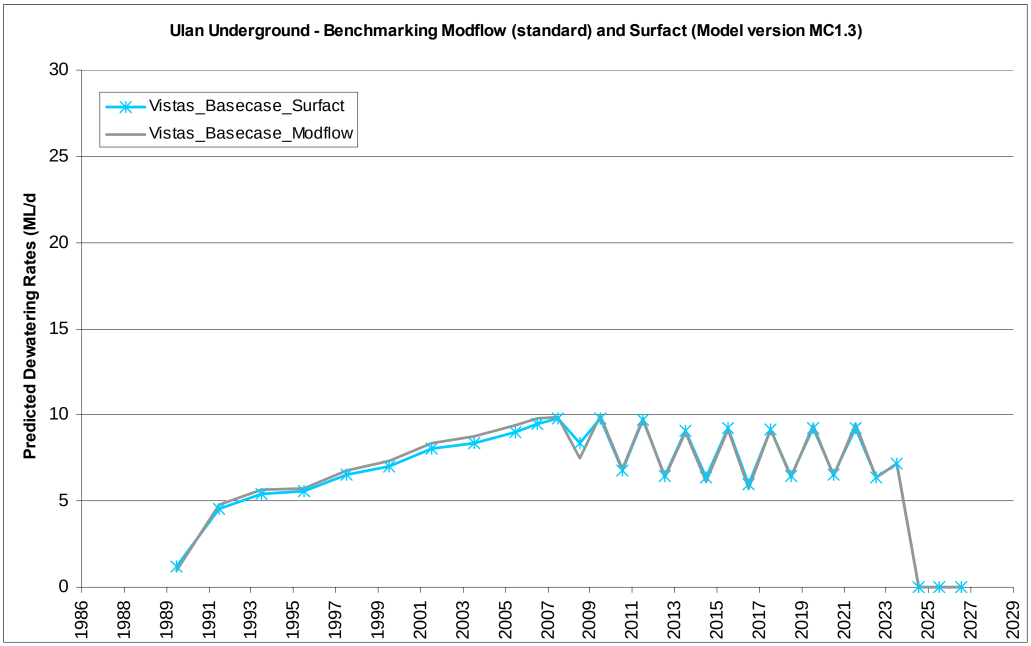


Figure 15: Predicted groundwater inflows to Ulan underground mine

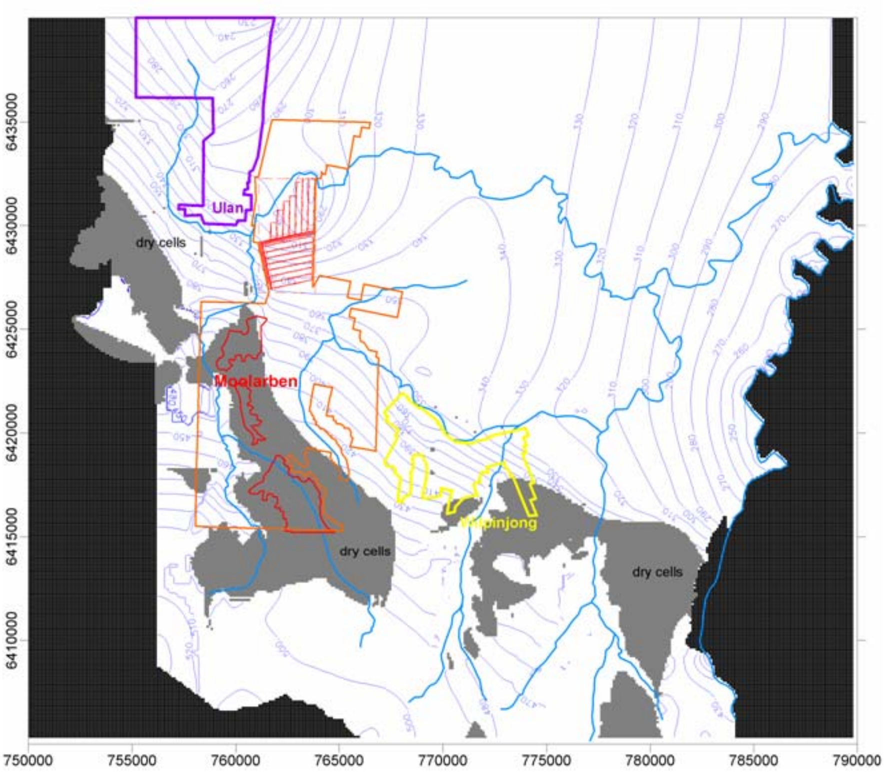


Figure 16: Predicted groundwater levels (PMPro MODFLOW simulation)

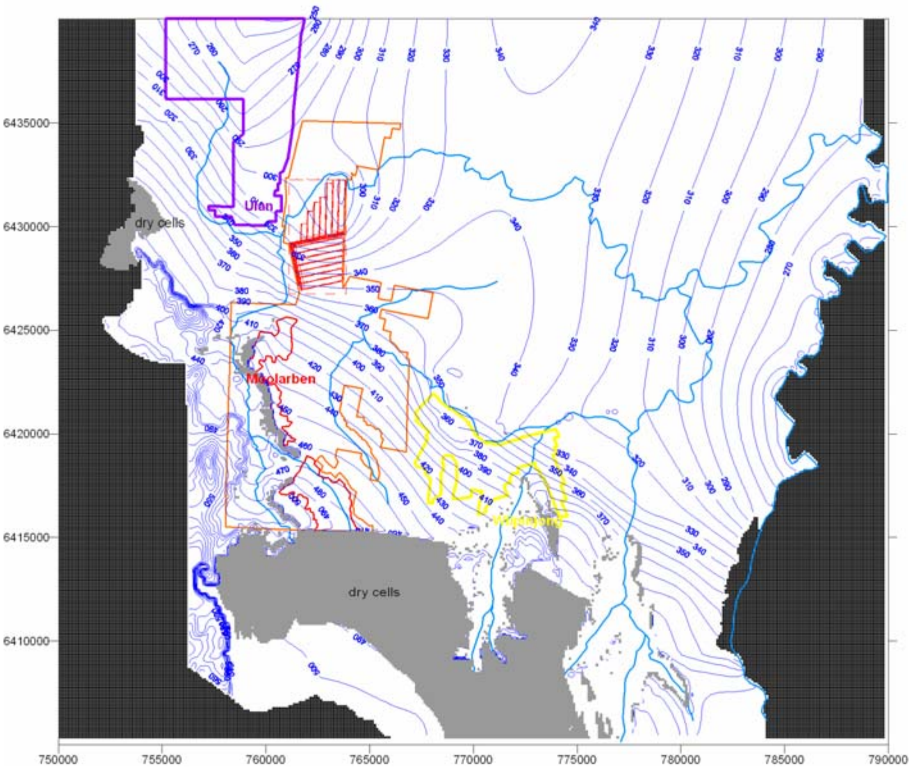


Figure 17: Predicted groundwater levels (Vistas SURFACT simulation)

5.2 Base Case Simulation

5.2.1 Model Structure

The basic layer structure, model cell configuration and boundary conditions from the original model have been retained. However, some modifications to the hydraulic properties have been made.

The base case simulation incorporates the following changes from the base case run reported in the EA (MCM, 2006a):

- More detailed application of the SURFACT modelling package (Hydrogeologic, 2006), which allows for de-saturation of model cells that are subjected to dewatering;
- Updating the model for the revised layout and schedule for Underground 4;
- Incorporation of a failure regime above the longwall panels at both Ulan and Moolarben;
- Invoking of very high drain conductance parameter values for the longwall panel cells at both Ulan and Moolarben;
- Changing hydraulic conductivity values with time, through a process of successive simulations of short segments of the mine life;
- Retention of all drains throughout the simulation (mining and recovery periods) once activated;
- Changes to some model parameters to achieve greater consistency through the modelled area.

Compared with MODFLOW, the SURFACT modelling package allows for more detailed simulations of underground mining, as might be required for operational design and optimisation purposes. SURFACT allows for drainage of model cells subject to dewatering, usually without causing model stability problems, and it also allows for detailed simulation of seepage faces in a mining context. SURFACT is an enhanced version of the MODFLOW code, which enabled simple transfer of the existing MC1.3 Modflow model into SURFACT, using the Vistas software package.

5.2.2 Hydraulic Parameters

Upon transfer of the MC1.3 model into SURFACT, some of the aquifer hydraulic conductivity parameters for the MC1.3 model were rationalised, based on questions raised by the IHAP, and the model was then run in a calibration simulation against the observed impacts of the Ulan operations up to 2006. Given the changes involved, the new model setup is now referred to as version MC1.4. The model calibration performance was good in terms of a history match to dewatering rates and aquifer water levels at Ulan in 2006 (discussed below in **Section 5.3**).

The model parameters were rationalised in the MC1.4 model version to address questions raised by the IHAP regarding the spatial distribution of parameters within layers in the MC1.3 model, most notably abrupt changes across a north-south alignment between Wilpinjong and Moolarben, and an east-west alignment coinciding with the Wilpinjong Creek palaeochannel.

The abrupt changes across the north-south alignment have now been either removed or greatly reduced in magnitude in the MC1.4 model.

The area south of the east-west alignment covers the area of the Moolarben and Murragamba Creeks, where the geology comprises mainly Illawarra Coal Measures outcrop, with less extensive outcrops of the Narrabeen Group, and where there are also several occurrences of basalt intrusions. This area is bounded on the west by Carboniferous granite outcrop, giving an overall geological distribution that differs markedly from other parts of the model area, and thus warrants different parameters. During the parameter refinement process for the MC1.4 model, it was found that changes to the hydraulic conductivity parameters in this area perturbed the model simulations, causing poor solution convergence.

Attempts were made to render more uniform parameters within layer 3, but convergence problems again affected the results. Accordingly, some of the parameter differences across the model layers have had to be retained for calibration and model stability reasons, and this is considered to reflect the actual variable nature of the various layers across the relatively large model area.

Table 4 summarises the model parameters applied to the MC1.4 model, showing that the main abrupt changes of concern to the IHAP have been removed or greatly reduced. The notable parameter changes include a reduction in the Kh value for the Ulan seam (Layer 4) in the Ulan and Moolarben areas from 3 to 1.7 m/d to be consistent with the rest of the model area, and more uniform parameters for the basement units. These changes did not prevent a reasonable match to Ulan inflows.

The parameter values adopted for vertical hydraulic conductivity are conservatively high, which should have the effect of over-estimating the drawdown due to pumping. Results from a 42-day pumping test that was undertaken adjacent to Wilpinjong Creek for the Wilpinjong project (Resources Strategies, 2005) confirmed a vertical leakance parameter of 10^{-6} day^{-1}, equivalent to a vertical hydraulic conductivity (Kv) value of about 5 x 10^{-5} m/d for a 50 metre thick unit, which is lower than most values in **Table 4**.

Table 4: MC1.4 Model (SURFACT) Aquifer Parameters

Main Layer	Aquifer/Aquitard	K_h (m/d)	K_v (m/d)	Unconfined S_y (-)	Confined S (-)
1 & 2	Alluvium (Goulburn River and minor creeks)	1.0 to 1.5	1.e-3 to 7.e-3	0.20	n/a
4	Alluvium (Moolarben Creek)	0.7	7.e-2		
2	Tertiary Palaeochannels	1.0	5.e-5	0.05	5.e-5
1	Triassic Narrabeen Group	0.1	1.e-3 to 5.e-3	0.05	5.e-5
2	Illawarra Coal Measures (undisturbed)	0.5 to 0.8 in Ulan & Moolarben areas and Goulburn R NP 0.06 in Murragamba Ck area	7.e-4	0.05	5.e-5
3	Illawarra Coal Measures (undisturbed)	0.8 Ulan+Moolarben area 0.01 to 0.05 generally	2.5e-5 (1.e-4 Murrag.Ck area)	0.05	5.e-5
4	Ulan Coal Seam (undisturbed)	1.7	2.e-4 (2.5e-2 Murrag.Ck area)	0.05	5.e-5
5	Marrangaroo Sandstone and Nile Sub-Group	1.0	1.e-5	0.05	5.e-5
4 & 5	Basement (granites and metamorphics)	0.001	1.e-5	0.05	5.e-5

5.2.3 Simulation of Progressive Development of Goaf and Failure Zone

Although SURFACT does not allow for changing of hydraulic conductivity parameters with time to represent the development of the failure regime as underground mining progresses at Ulan and Moolarben, a simplified modelling approach was adopted. This simplified approach involved running the model in short time frames (time “slices” of 3-5 years), applying the final water level conditions from the previous run as the initial conditions for the subsequent run, and adjusting the hydraulic conductivity parameters at the start of each run. The time “slices” are shown in **Table 6**.

The parameter adjustments that were made at the start of each run (time “slice”) were changes to the hydraulic conductivity parameters to represent the extracted panels and the overlying zone of enhanced hydraulic conductivity caused by subsidence and fracturing up from the goaf (referred to as the “failure” zone). The changes were made progressively as the Ulan underground mine developed for the runs covering the calibration period up to 2006, and also to represent the future concurrent development of the Ulan and Moolarben mines for the predictive runs going forward from 2006. The horizontal and vertical hydraulic conductivity parameters were changed in Layer 4 (Ulan Coal seam), and also in the overlying layers 2 and 3 (Permian overburden) to represent a failure zone extending to

100m above the Ulan seam. A sensitivity run has been carried out involving the failure zone extending into the Triassic (Layer 1) as well.

The hydraulic conductivity parameters that were applied to the Ulan and Moolarben underground areas for failure zones extending 50-100m above the Ulan Seam are summarised in **Table 5**. A sensitivity run has also been undertaken to extend the failure zone more than 100m (ie to the surface), with results presented later.

Table 5: MC1.4 Model Aquifer Hydraulic Conductivity Parameters Applied to Failure Zones above Extracted Longwall Panels

Layer	Aquifer/Aquitard	K_h (and multiple factor)	K_v (and multiple factor)
1	Triassic aquifer (**sensitivity run** of 100+m failure zone)	0.2 (factor 2X background)	1.e-3 (no factor applied)
2	Illawarra Coal Measures (50 to 100m failure zone)	1.6 (factor 2X background)	1.4e-3 (factor 2X background)
3	Illawarra Coal Measures (0 to 50m failure zone)	8.0 (factor 10X background)	2.5e-4 (factor 10X background)
4	Ulan Coal Seam (goaf zone)	17 (factor 10X background)	2.e-3 (factor 10X background)

(Note that aquifer storage parameters are unchanged, and that the failure zone parameters apply to the Ulan underground and Moolarben UG4 footprints only in Layers 4, 3 and 2. Note also that a thin transition zone of two cells wide was applied with intermediate values between the background parameter value and the failure zone parameter value to ensure model stability).

The model has not been further discretised by splitting the existing layers into thinner units in the model, as suggested by the IHAP, but such approaches will be undertaken during further model development as the project proceeds. It is considered that the use of only 3 model layers at this stage (Layers 1, 2 and 3) above the Ulan Seam would in any case lead to a conservative over-estimation of the potential impacts of dewatering on the surficial aquifer water levels (ie in the Triassic).

At the start of each time “slice” simulation, cells corresponding to the longwall panels to be mined at Ulan and Moolarben in that time period were assigned a drain condition, with a very high drain conductance parameter value applied, to facilitate free drainage conditions from the strata. The drain condition was kept on once activated for the remainder of the simulation. A drain conductance parameter value of 1,000 m^2/d was applied, consistent with the value applied to the open cut areas.

This resulted in almost complete de-saturation of the Ulan Coal Seam (ie water levels reduced to the base of the seam in Layer 4, which is approximately 10 metres thick, as shown in plots presented later in **Section 5.5**), while the shallow water table is shown to remain in the Triassic aquifer of Layer 1 (subject to some drawdown but not de-saturation).

5.2.4 Changes Associated with Preferred Project Mine Plan

The MC1.4 model was updated to account for the latest mine plan. Mine plan changes have been made during the IHAP process, as described in accompanying reports. The modifications only affect the UG4 layout as detailed in **Section 2** above. The changes also affect the mine schedule, with mining now ceasing in 2021 (rather than 2022 in the previous plan).

5.3 Model History Match to Ulan Operations

With the parameter changes and application of drain cells described above, the MC1.4 model was run for the calibration period to 2006, with the Ulan dewatering operation active and the failure zone progressively invoked in the model. In summary, and as shown in the figures below, an acceptable history match was achieved in terms of:

- Ulan dewatering at 1987 was reportedly about 3 ML/d, and the MC1.4 model result is just over 3 ML/d (**Figure 18**).
- Ulan dewatering at 2004 was reportedly about 10 ML/d, and the MC1.4 model result is just over 10 ML/d (**Figure 18**).
- The scaled RMS error is 10%, which is slightly higher than the 8.9% achieved for the MC1.3 model (Aquaterra, 2006), but is within the target range of 5% to 10%.
- The Ulan Seam (Layer 4) is dewatered to 1m above the base of Layer 4 across the entire Ulan underground mine area (see plots in Aquaterra, 2006b).
- The Triassic aquifer directly above the Ulan underground has predicted water levels affected by drawdown of up to 8 m, but the natural hydraulic gradients result in drawdown impacts of around 1m or less in areas near Goulburn River. This appears to be over-estimating drawdown impacts, as UCML's reported monitoring data from a series of piezometers screened in the Lower Triassic aquifer show no or minimal drawdown to date (**Section 3**). Note that the parameter values adopted for vertical hydraulic conductivity in the model are conservatively high, which should have the effect of over-estimating the Triassic drawdowns due to pumping.

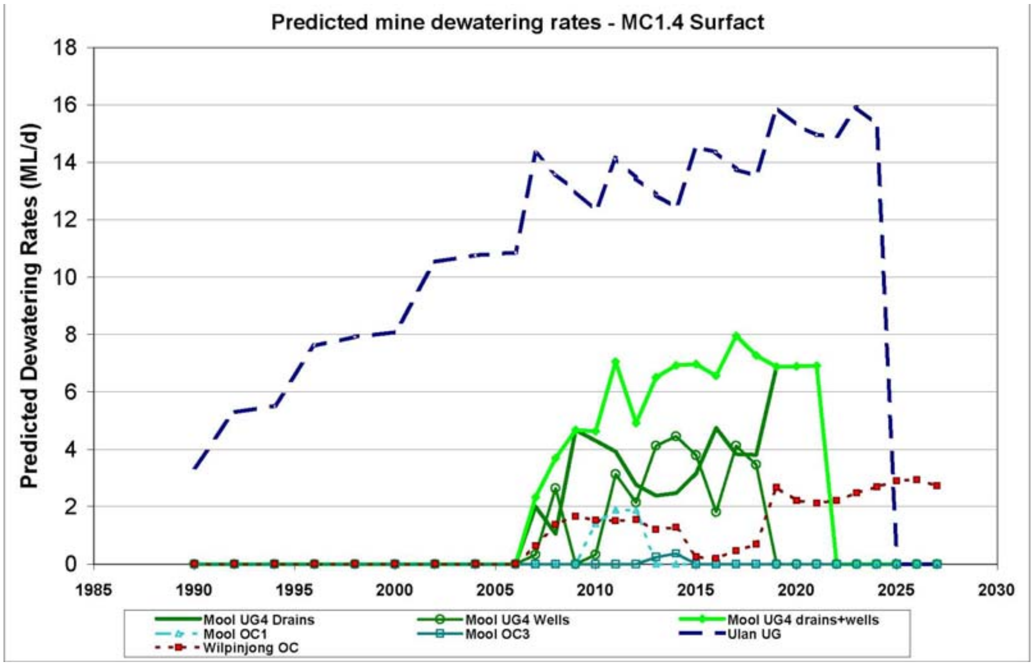


Figure 18: Predicted Mine Dewatering Rates – Moolarben, Ulan and Wilpinjong

5.4 *Predictions of Mine Dewatering Impacts*

Using the results at 2006 as the initial conditions, the SURFACT model was run in a series of 4-year time "slices" for the period 2006 to 2027 (ie from the present time through to the end of Wilpinjong mining), as shown in the schedule in **Table 4**. For the revised Moolarben mine plan, mining ceases at 2021, while mining at Ulan is assumed to continue until 2024. The water level conditions for the end of each run were specified as the starting heads for the next run, and the appropriate longwall drain cells, and goaf and failure zone parameters were invoked at the start of each timeframe. Following the cessation of mining, pit void parameters were invoked for the residual open cut areas at Wilpinjong and Moolarben, the storage parameters were modified for the longwall and failure zone cells, and the model was run for a further 40 years to simulate the recovery of the groundwater systems post-decommissioning.

The predicted mine inflow rates are listed in **Table 6**, and shown graphically in **Figure 18**.

Table 6: Predicted Annual Groundwater Abstractions (kL/d)
Moolarben, Ulan and Wilpinjong Projects

Mine Year	Time Slice	Period	Moolarben Mine Water Inflows				Moolarben Pumping Bores	Ulan	Wilpinjong
			OC 1	OC 2	OC 3	UG 4		OC and UG	OC
	1	1987-90	-	-	-	-	-	3371	-
		1990-92	-	-	-	-	-	5296	-
		1992-94	-	-	-	-	-	5522	-
	2	1994-96	-	-	-	-	-	7609	-
		1996-98	-	-	-	-	-	7922	-
		1998-00	-	-	-	-	-	8086	-
	3	2000-02	-	-	-	-	-	10540	-
		2002-04	-	-	-	-	-	10764	-
		2004-06	-	-	-	-	-	10861	-
1	4	2006-07	0	-	-	2009	330	14316	631
2		2007-08	0	-	-	1055	2640	13595	1383
3		2008-09	0	-	-	4666	-	12994	1664
4		2009-10	1406	-	-	4296	330	12320	1536
5	5	2010-11	1884	-	-	3922	3135	14140	1511
6		2011-12	1871	-	-	2770	2145	13452	1547
7		2012-13	-	-	239	2386	4125	12860	1202
8		2013-14	-	-	370	2472	4455	12424	1278
9	6	2014-15	-	-	0	3163	3795	14534	252
10		2015-16	-	-	0	4746	1815	14360	205
11		2016-17	-	-	0	3826	4125	13746	457
12		2017-18	-	-	-	3803	3465	13544	686
13	7	2018-19	-	-	-	6878	-	15902	2677
14		2019-20	-	-	-	6889	-	15293	2226
15		2020-21	-	-	-	6915	-	14960	2123
16		2021-22	-	-	-	-	-	14921	2225
	8	2022-23	-	-	-	-	-	15906	2468
		2023-24	-	-	-	-	-	15313	2686
		2024-25	-	-	-	-	-	-	2894
		2025-26	-	-	-	-	-	-	2946
		2026-27	-	-	-	-	-	-	2726

Comparison of combined Moolarben water production from all mine inflows and the pumping bores with water demands are shown in **Table 7**. The rates shown for the Moolarben pumping bores were introduced in the model to meet anticipated shortfalls in some years, based on previous modelling. The groundwater inflows and pumping from bores are interdependent, and it requires a number of successive model runs to optimise the necessary pumping rates to satisfy the water supply shortfalls without pumping excessive quantities of water. This optimisation has not been completed, and additional runs will be undertaken to optimise the well pumping rates (as was done for the environmental assessment prior to the IHAP process).

Consequently, the nominal “surplus” shown in **Table 7** is overstated in some years, as it arises only because the bore pumping rates have not yet been optimised. There are some years that pumping would not be required at all to meet water demand (ie Years 1, 3 and 4), and other years when a significantly lower production rate from the bores than indicated would be sufficient to meet demand (ie Years 2, 5 and11). In other years, the adopted bore pumping rates are slightly higher or lower than will actually be required.

The actual rates pumped during the mining operation will be driven mainly by demand, however it is likely that in years of predicted large surpluses (eg Years 1, 4, and 13-15), the bores will be pumped to enable some groundwater to be intercepted prior to entering the underground workings so that sufficient higher quality water is available for discharge with minimal treatment to meet the DEC discharge criteria of ANZECC ecosystem protection guidelines and receiving water quality. The smaller magnitude surpluses and shortfalls in **Table 7** would be avoided by adjustment to bore pumping rates to better match water demands.

Table 7: Moolarben Water Demand and Model Predictions of Water Production

Mine Year	Period	Moolarben Mine Water Inflows					Moolarben Pumping Bores	Water Demand	Surplus / (Shortfall)
		OC 1	OC 2	OC 3	UG 4	Total			
1	2006-07	0	-	-	2009	2009	330 *	570	1769
2	2007-08	0	-	-	1055	1055	2640 **	2740	955
3	2008-09	0	-	-	4666	4666	-	3995	671
4	2009-10	1406	-	-	4296	5702	330 *	4137	1895
5	2010-11	1884	-	-	3922	5806	3135 **	6277	2664
6	2011-12	1871	-	-	2770	4671	2145	6850	(34)
7	2012-13	-	-	239	2386	2625	4125	6850	(100)
8	2013-14	-	-	370	2472	2842	4455	6850	447
9	2014-15	-	-	0	3163	3163	3795	6850	108
10	2015-16	-	-	0	4746	4746	1815	6850	(289)
11	2016-17	-	-	0	3826	3826	4125 **	6850	1101
12	2017-18	-	-	-	3803	3803	3465	6850	418
13	2018-19	-	-	-	6878	6878	-	2567	4311
14	2019-20	-	-	-	6889	6889	-	2282	4607
15	2020-21	-	-	-	6915	6915	-	2282	4633

* Bores will not be required.

** Significantly lower pumping rates from bores will be sufficient.

The predicted dewatering rates shown in **Figure 18** and **Table 6** are consistent with historical pumping rates and forward projections at Ulan, and are also consistent with the predicted rates for Moolarben and Wilpinjong as reported in the EA (MCM, 2006a; Dundon, 2006a; and Aquaterra, 2006a). The combination of predicted Underground 4 mine inflows (drains) and dewatering wells reaches a maximum of about 7.2ML/d in 2011 and 2017, compared to the previous combined total prediction of 7.3 ML/d in 2017. Therefore, the water balance for the revised predictions is consistent with the existing water management arrangements, as previously reported in the EA (MCM, 2006a).

However, until Year 12, when the production bores will not be needed to make up any shortfall in supply, in fact the combined extraction from mine inflows and production bores will not have to exceed the projected water demand, ie a maximum combined rate of 6.9 ML/d. The mine inflow rates predicted for the final 3 years of the project will exceed demand, and inflow rates are predicted to reach a maximum of 6.9 ML/d in Years 13, 14 and 15.

5.5 Groundwater Level Impacts

Figures 19 to **22** present contour plans of predicted drawdowns in groundwater levels to the end of the Moolarben project in the four main model layers:

- Layer 1 - Triassic aquifer
- Layer 2 - upper Permian aquifer
- Layer 3 - lower Permian aquifer
- Layer 4 - Ulan Seam.

These results are consistent with the previous predictions (Aquaterra, 2006; Peter Dundon and Associates, 2006; Moolarben Coal Mines, 2006).

It is seen that drawdowns of up to about 6m are predicted to occur in the Triassic above the Ulan longwalls, and up to about 3m above the Moolarben longwalls, by the completion of Moolarben mining in 2021. Drawdowns of less than 1m at Goulburn River are predicted. Note that the southern part of the Moolarben's Underground 4 is essentially dry in the Triassic.

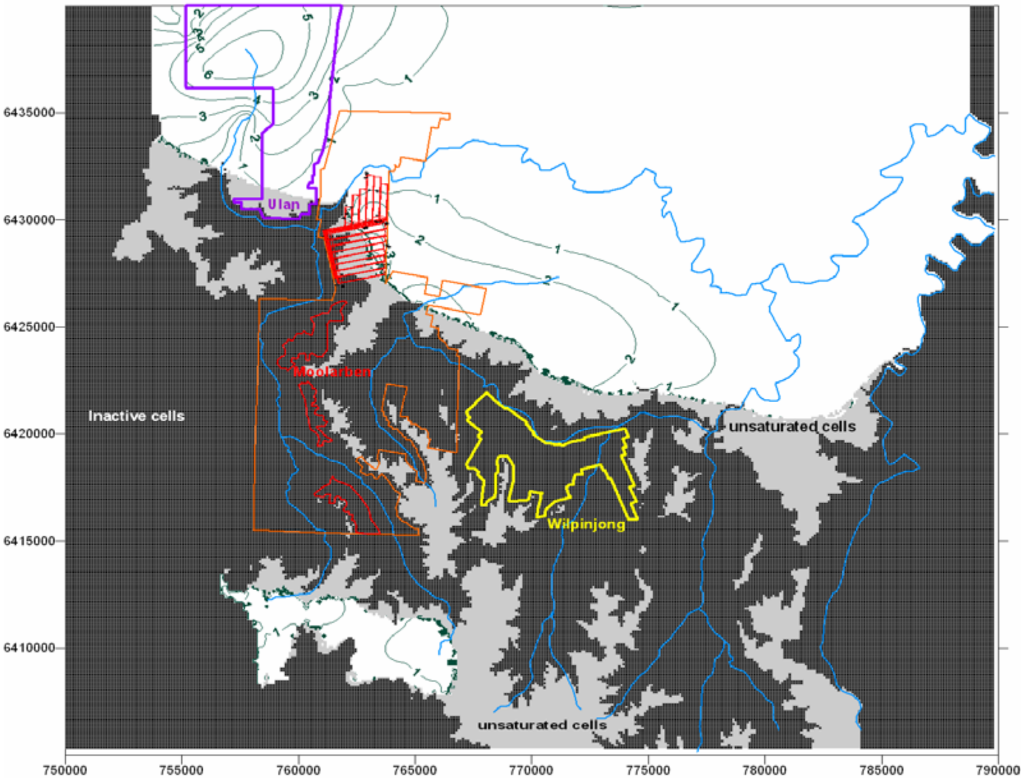


Figure 19: Predicted Drawdowns to End of Moolarben Project (2021) in Triassic (Layer 1) – Cumulative Impacts

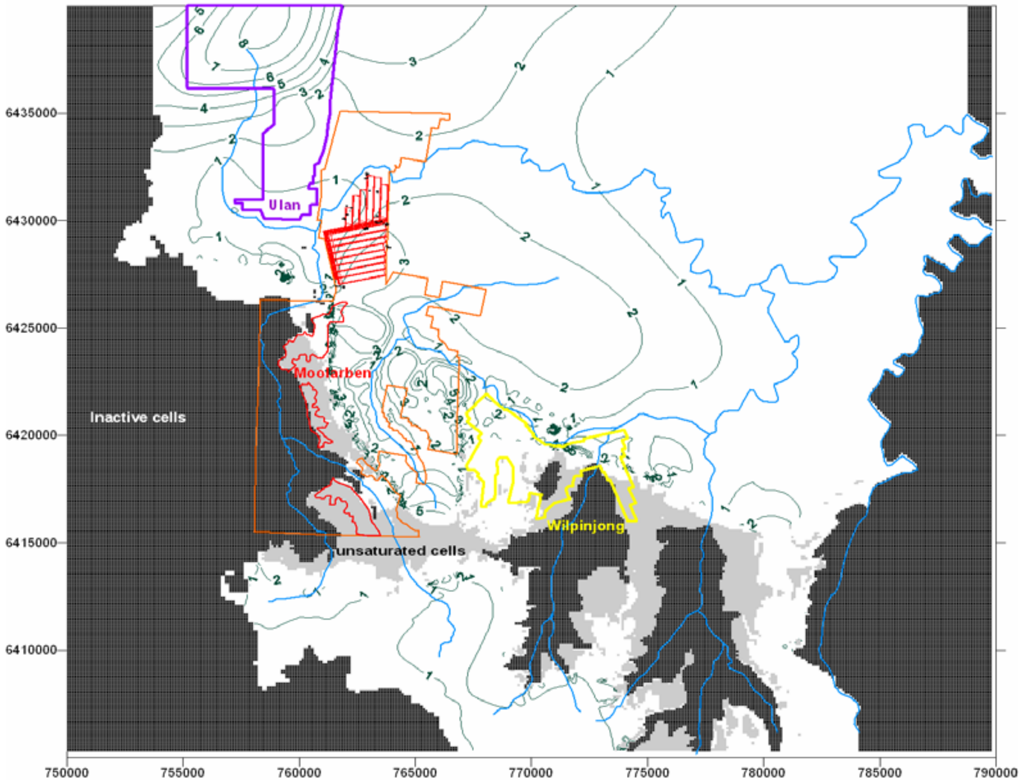


Figure 20: Predicted Drawdowns to End of Moolarben Project (2021) in Upper Permian Coal Measures (Layer 2) – Cumulative Impacts

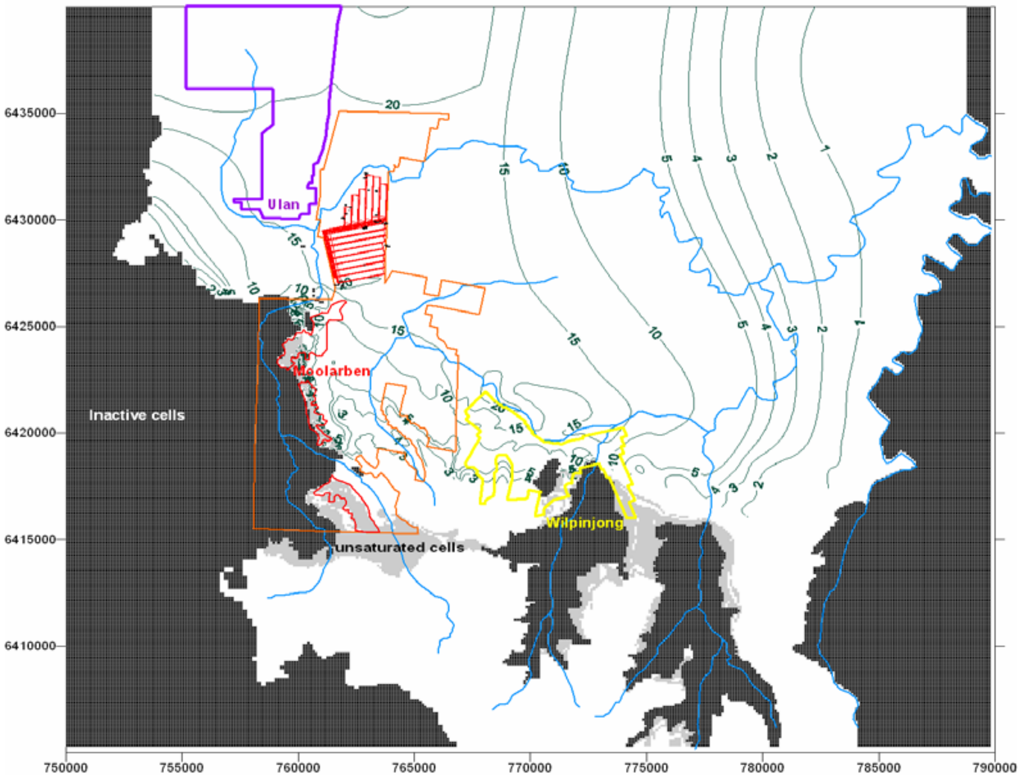


Figure 21: Predicted Drawdowns to End of Moolarben Project (2021) in Lower Permian Coal Measures (Layer 3) – Cumulative Impacts

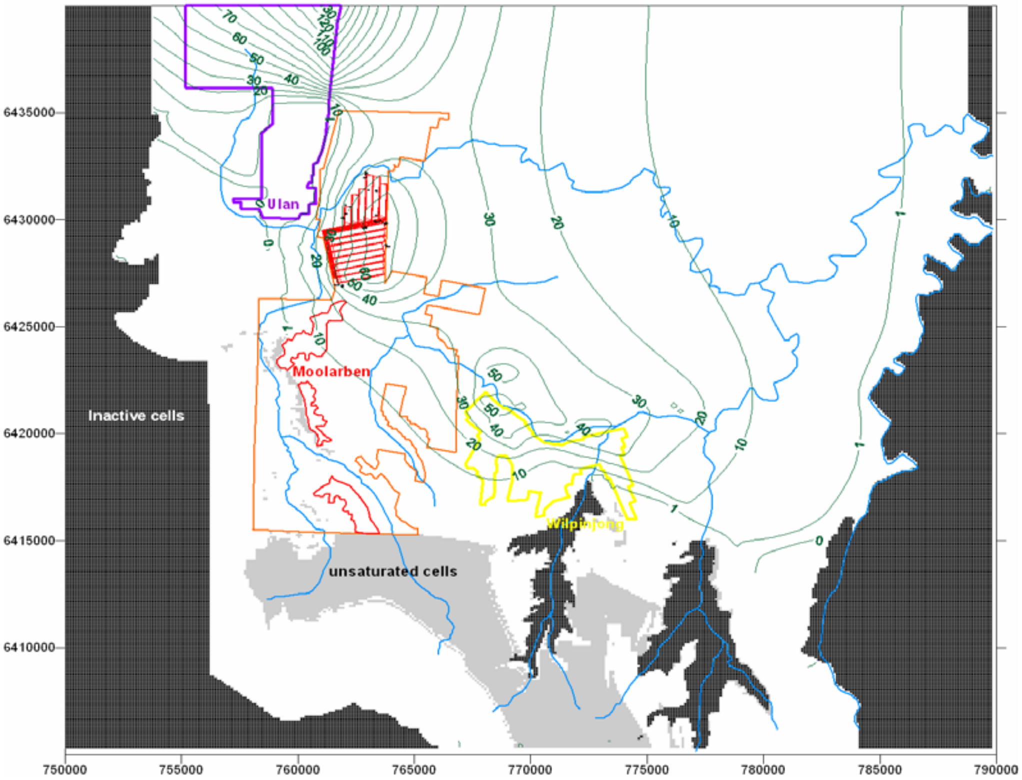


Figure 22: Predicted Drawdowns to End of Moolarben Project (2021) in Ulan Seam (Layer 4) – Cumulative Impacts

The predicted impacts on groundwater levels in the Triassic (ie up to about 3m above the northern half of Underground 4, and less than 1m at Goulburn River) have been derived from the base case model run, in which failure zone parameters were adopted up to 100m above the top of the Ulan seam goaf areas. A further sensitivity run in which permeability enhancement was assumed to extend up into the Triassic resulted in very slightly greater drawdowns in the Triassic above the longwall panels, but still less than 1m at Goulburn River.

5.6 *Baseflow Impacts on Goulburn River and Minor Tributary Streams*

The total water balance components derived from the modelling are discussed in the modelling report (Aquaterra, 2006b). The predicted impacts due to mining are very similar to the previous predictions, especially in relation to changes in predicted river and creek flows (Table 4.4 of Aquaterra, 2006a). The individual values are slightly different from the previously reported values due to the different way that SURFACT deals with dry/unsaturated cells, and hence different recharge rates and evaporation rates.

Table 8 presents a summary of the components dealing with interchanges with the surface water system (Goulburn River and minor tributaries.

Table 8: Water Balance Changes – Goulburn River and Minor Tributary Streams

MC1.4 Model Water Balance Component volumes (kL/d)	Rainfall Recharge	Head-dependent Flow	Goulburn River	Minor Creeks	Evap'n	Wells	Mine dewatering	Storage replenishment	Storage depletion	Total
2006 (Ulan o/c & u/g active; stress period 9)										
Into model	99,880	265,440	43,615	-	-	-	-	-	15,855	424,790
Out of model	-	284,955	64,920	3,420	58,120	-	10,860	3,025	-	425,300
2022 (End Moolarben mining; stress period 25)										
Into model	99,880	266,225	43,770	-	-	-	-	-	25,355	435,230
Out of model	-	283,365	64,540	2,865	53,275	6,555	17,145	7,515	-	435,260
2024 (End Ulan mining; stress period 27)										
Into model	99,880	266,035	43,790	-	-	-	-	-	22,530	432,235
Out of model	-	283,890	64,510	2,845	52,855	-	18,000	9,920	-	432,020
2027 (End Wilpinjong mining; stress period 30)										
Into model	99,880	265,980	43,800	-	-	-	-	-	16,450	426,110
Out of model	-	284,130	64,505	2,825	52,485	-	2,725	19,000	-	425,670
2067 (End Recovery Run; stress period 31)										
Into model	99,880	265,845	43,530	-	-	-	-	-	3,180	412,435
Out of model	-	284,730	65,385	3,025	56,235	-	-	3,095	-	412,470

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It is seen from **Table 8** that the predicted change in both baseflow contributions to and recharge from Goulburn River are small, amounting to a net reduction in River flow of 535 kL/d between now and the end of mining at Moolarben (2021). This represents the cumulative impacts of the three coal projects over the entire model area. This is equivalent to approximately 1 percent of total average streamflow in Goulburn River. Recovery of groundwater levels after completion of mining is predicted to see a net increase in River flow of 550 kL/d, leading to marginally higher flow than the present average flow rate.

The minor tributaries are predicted to experience a similar cumulative impact in absolute terms, but it would represent a larger percentage of current average streamflow. Total streamflow reduction is predicted to be around 550 kL/d by the end of the Moolarben project (2021), increasing to around 590 kL/d by the end of Wilpinjong (2027), and then recovering gradually, but with a residual net reduction of 325 kL/d by 2067 (40 years after completion of Wilpinjong).

The above impact is the cumulative impact across the entire model area, due to the three coal projects. Breaking down the reduction in streamflow by catchment, it is seen that the reduction in the Moolarben Creek – Lagoon Creek catchment is predicted to be 35 kL/d, while no change is predicted in the Murragamba Creek catchment. Negligible impacts are predicted for the other minor tributaries.

6 REVIEW OF IMPACT ASSESSMENT

The new groundwater flow modelling has predicted inflow rates to the Moolarben Underground 4 mine that are very similar overall to those predicted in the EA studies. Drawdown predictions are similar in the Ulan seam and the Permian Coal Measures overburden, but the new modelling has led to slightly higher predicted drawdowns in the Triassic sandstones compared with the previous modelling.

The groundwater levels are predicted to decline locally by up to about 3m in the Triassic above the northern half of the Moolarben Underground 4, but drawdowns at Goulburn River are predicted to be much less than 1m. This has arisen by the adoption of a higher failure zone than previously modelled. As indicated in **Section 3.3** above, based on the monitoring around Ulan, it is considered that impacts are unlikely to be this great.

The new modelling results indicate that regional impacts on baseflow contributions to Goulburn River and the minor tributaries are likely to be similar to those outlined in the EA.

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