Australasian Groundwater and
Environmental Consultants Pty Ltd

Report on

Historical Groundwater Review and Assessment Ashton Coal Mine

Prepared for
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Report on

Historical Groundwater Review and Assessment Ashton Coal Mine

1 Introduction and background

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) have been commissioned by Yancoal Australia Ltd (Yancoal) to assess groundwater conditions from historic monitoring data. The request follows the comments made by NSW Department of Planning and Environment (DPE) and NSW Department of Primary Industries–Water (DPI Water) regarding the recent submission of the extraction plan (EP) for longwall (LW) panels LW201 to LW204, to mine the Upper Lower Liddell (ULLD) coal seam.

DPE and DPI Water have granted conditional approval of the ULLD EP. However, DPE and DPI Water have expressed concern to Yancoal over "*the suitability of the groundwater model to adequately predict volumes and sources of mine inflow, including water from surface and near surface sources*".

DPE and DPI Water consider that this concern could be addressed "*through a technical review of historical water impacts at Ashton*". Historically, Yancoal and AGE have maintained that additional groundwater monitoring above and beyond what is currently carried out under the existing Water Management Plan (WMP) and for internal purposes is unnecessary. DPE and DPI Water suggested that a technical review would demonstrate Yancoal's understanding of the hydrogeological regime, and support the suitability of the existing monitoring network and WMP, and justify that additional monitoring is unnecessary.

1.1 Scope and methodology

In light of the above recommendations and suggestions from DPE and DPI Water, the scope includes the following tasks:

- review and summarise the annual groundwater monitoring reports (2004 to 2016);
- review and summarise the end of panel and mid panel reports (10 reports);
- review and summarise all additional groundwater assessment reports and investigations (approximately five groundwater impact assessments associated with subsidence management / extraction plans); and
- consider all groundwater level and quality data at the site.

Based on the above work, a report would be prepared which details the following:

- summarise surface water impact predictions versus observed impacts;
- summarise groundwater impact predictions versus observed impacts;
- summarise groundwater inflows to, and pumping from, the mine in relation to mining activities and subsidence; and
- compare surface water and groundwater take against licensing requirements over the life of the mine.

DPE and DPI Water have recommended the report include summary tables and figures throughout. DPE and DPI Water have also requested the inclusion of individual coal seam cross-sections identifying panel by panel subsidence, drawdown and depressurisation within the various aquifers and changes in baseflow (pre-mining, during mining and post-mining). To the extent possible, these presentations are included in Section 2.

1.2 Structure of this report

To address the scope of work presented in Section 1.1, the report is structured in the following way:

- Section 2 provides a summary of mining at Ashton and the conceptual hydrogeology.
- Section 3 details the previous reports that have been reviewed for this report, and summarises the findings. Detailed summaries of the reviews of each document are included in Appendix A. These reviews include comments in numbered/bulleted lists, followed by a tabular presentation of predicted and actual impacts to key environmental values/aspects: drawdown in the Permian strata and alluvium, baseflow depletion, and inflows to the underground mine.
- Section 4 presents an account of the progressive impacts from underground mining, compared with the impacts predicted in the EIS, and subsequent EAs and SMPs/Eps, based on the reviews presented in Section 5.1.
- Section 5 presents a summary of findings.

2 Summary of mining and hydrogeology

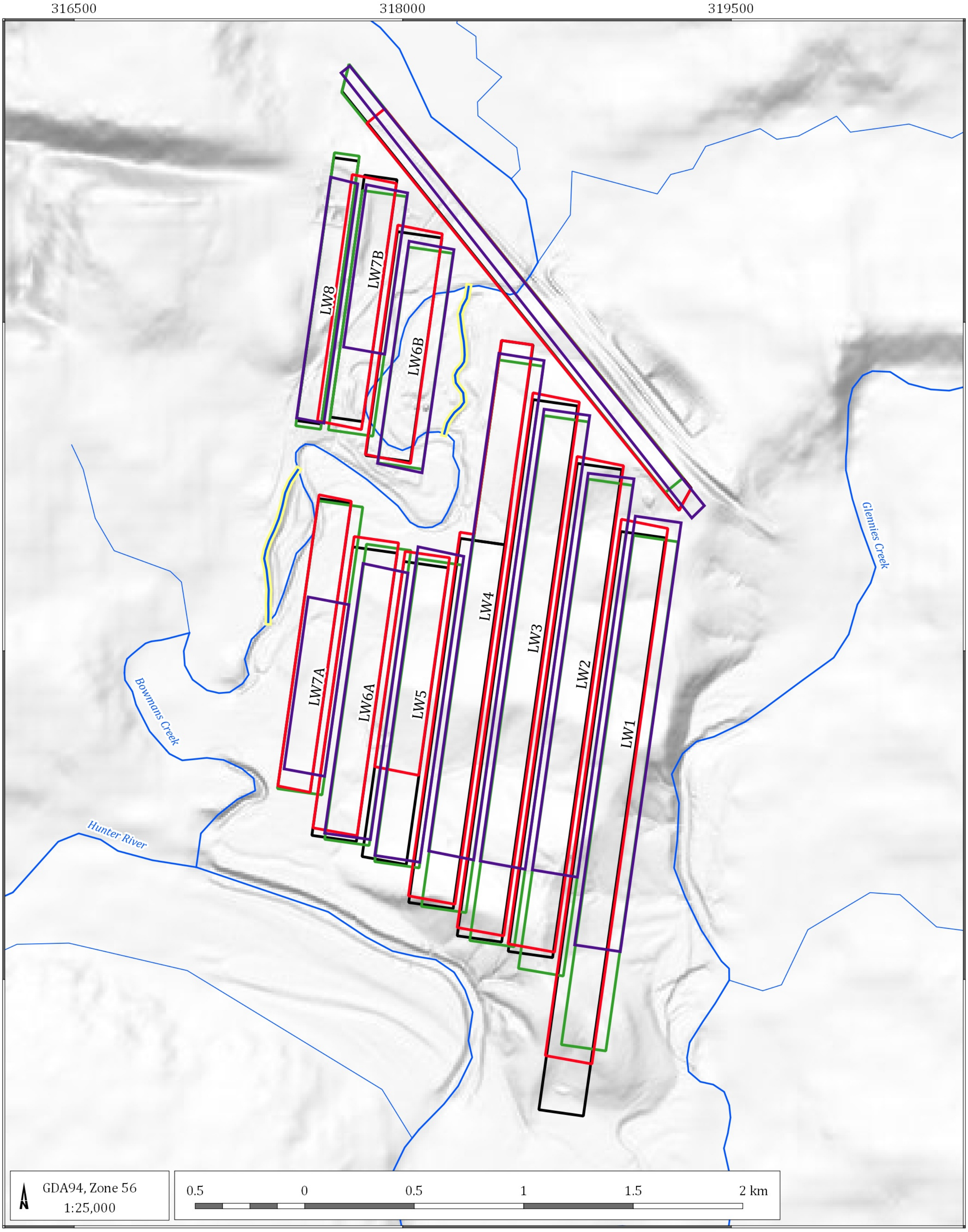
2.1 Overview of the mining operations at Ashton

The Ashton Coal Mine (Ashton) is located 14 km west of Singleton in the Hunter Valley region of New South Wales (NSW). Ashton consists of open cut (historical) and underground mining (current) to access a series of coal seams within the Permian Foybrook Formation of the Vane Sub-Group (Hebden to Lemington seams), with limited occurrence of the Bayswater seam which is the basal unit of the Jerry's Plains Sub-Group.

Ashton Coal Operations Ltd (ACOL) is wholly owned and operated by Yancoal Australia Limited (Yancoal). Ashton was granted development consent on 11th October 2002. Mining commenced at the north-east open cut mine (NEOC) in 2003 and open cut mining ceased in 2011. Coal was recovered from eleven seams of varying thickness, down to and including the Lower Barrett (LB) seam.

Underground mine development commenced in December 2005. The underground mine is located south of the New England Highway, and accessed via a series of portals from the former Arties pit on the northern side of the highway. The development headings for LW1, the first LW panel (LW1, Figure 2.1) in the Pikes Gully (PG) seam passed below the water table for the first time in June 2006. Longwall extraction commenced in LW1 on 12 March 2007.

At the time of writing, coal extraction has been completed from the Pikes Gully (PG) seam, and has also been completed in the Upper Liddell (ULD) seam, apart from two deferred panels (LW106B and LW107A/B). Mining is now proceeding in LW201, the first panel of the third seam, the ULLD seam. Ashton proposes to mine a further seam below the ULLD, the Lower Barrett (LB) seam (Table 2.1).



LEGEND

Underground Mine Level

- Pikes Gully Seam
- Upper Liddell Seam
- Upper Lower Liddell Seam
- Lower Barrett Seam

- Major drainage
- Minor drainage
- Diversion

Historical Groundwater Review and Assessment, Ashton Coal Mine (G1858H)

Plan of Ashton underground longwall panels

AGE

DATE 03/11/2017

FIGURE No: **2.1**

Table 2.1 Ashton mine progression (modified from AGE, 2016d)

LW panel	Seam mined	Start date	End date
LW1	**PG**	**12-03-07**	**15-10-07**
LW2	**PG**	**10-11-07**	**21-07-08**
LW3	**PG**	**20-08-08**	**03-03-09**
LW4	**PG**	**02-04-09**	**15-10-09**
LW5	**PG**	**04-01-10**	**07-06-10**
LW6A	**PG**	**09-07-10**	**22-11-10**
LW7A	**PG**	**22-03-11**	**08-08-11**
LW7B	**PG**	**03-10-11**	**17-01-12**
LW8	**PG**	**27-02-12**	**05-06-12**
LW101	**ULD**	**31-07-12**	**16-06-13**
LW6B	**PG**	**14-07-13**	**10-10-13**
LW102	**ULD**	**10-11-13**	**24-07-14**
LW103	**ULD**	**21-08-14**	**21-06-15**
LW104A	**ULD**	**23-07-15**	**16-01-16**
LW104B	**ULD**	**03-02-16**	**11-04-16**
LW105	**ULD**	**17-05-16**	**26-09-16**
LW106A	**ULD**	**18-10-16**	**31-05-17**
LW201	**ULLD**	**07-07-17**	
LW202	ULLD	Nov-2017	Jul-2018
LW203	ULLD	Aug-2018	May-2019
LW204	ULLD	Jun-2019	Mar-2020
LW205	ULLD	Apr-2020	Sep-2020
LW206A	ULLD	Oct-2020	Mar-2021
LW106B	ULD	Apr-2021	Aug-2021
LW107A	ULD	Sep-2021	Dec-2021
LW107B	ULD	Jan-2022	May-2022
LW206B	ULLD	Jul-2022	Oct-2022
LW207A	ULLD	Nov-2022	Mar-2023
LW207B	ULLD	Apr-2023	Aug-2023
LW208	ULLD	Sep-2023	Nov-2023
LW301	LB	Dec-2023	Oct-2024
LW302	LB	Nov-2024	Aug-2025
LW303	LB	Sep-2025	Jun-2026
LW304A	LB	Jul-2026	Jan-2027
LW304B	LB	Feb-2027	Apr-2027
LW305	LB	May-2027	Oct-2027

LW panel	Seam mined	Start date	End date
LW306A	LB	Nov-2027	Apr-2028
LW306B	LB	May-2028	Sep-2028
LW307A	LB	Oct-2028	Feb-2029
LW307B	LB	Feb-2029	May-2029
LW308	LB	Jul-2029	Sep-2029
Mains0_PG	**PG**	**Feb-2006**	**May-2008**
Mains1_ULD	**ULD**	**Aug-2011**	**Jan-2016**
Mains2_ULLD	**ULLD**	**Oct-2016**	Dec-2020
Mains3_LB	LB	Aug-2021	Jul-2025

***Bold** = completed or ongoing*

2.2 Conceptual hydrogeology

2.2.1 Hydrostratigraphy

Ashton is located in the central Hunter Valley of NSW where the lower sequences of the Whittingham Coal Measures (Singleton Supergroup) subcrop (Figure 2.2). Within the Ashton mining lease, the Hebden seam to the Bayswater seam (inclusive) subcrop. The underground operation targets the PG, ULD, ULLD and the LB seams.

The Whittingham Coal Measures dip west south-west in the Ashton area, an orientation locally controlled by the Camberwell Anticline to the east of the mine and the Bayswater Syncline to the west. The top target coal seam at Ashton, the PG seam, subcrops under the Glennies Creek alluvium (GCA) approximately 150 m east of the mine, while the lowest target coal seam, the LB seam, subcrops under regolith approximately 2 km to the east of the mine. In the western portion of the mining area, the overburden above the PG seam ranges in thickness between 100 m (north end of LW7) and 190 m (south end of LW7).

The stratigraphic sequence in the region comprises two distinct units: Quaternary alluvium and Permian strata. The Permian strata comprise coal seams (typically 2 m to 2.5 m thick) with overburden and interburden (typically 30 m thick between successive seams) consisting of sandstone, siltstone, tuffaceous mudstone, and conglomerate. The Quaternary alluvium consists of unconsolidated silt, sand and gravel in the alluvial floodplains of the Hunter River (HR), Bowmans Creek (BC) and Glennies Creek (GC). The alluvium unconformably overlies the Permian within the floodplains of the HR, BC and GC. Elsewhere, the Permian is overlain by a regolith comprising colluvium, eluvium and completely weathered rock, which interfaces with the floodplain alluvium at the flanks of the valleys.

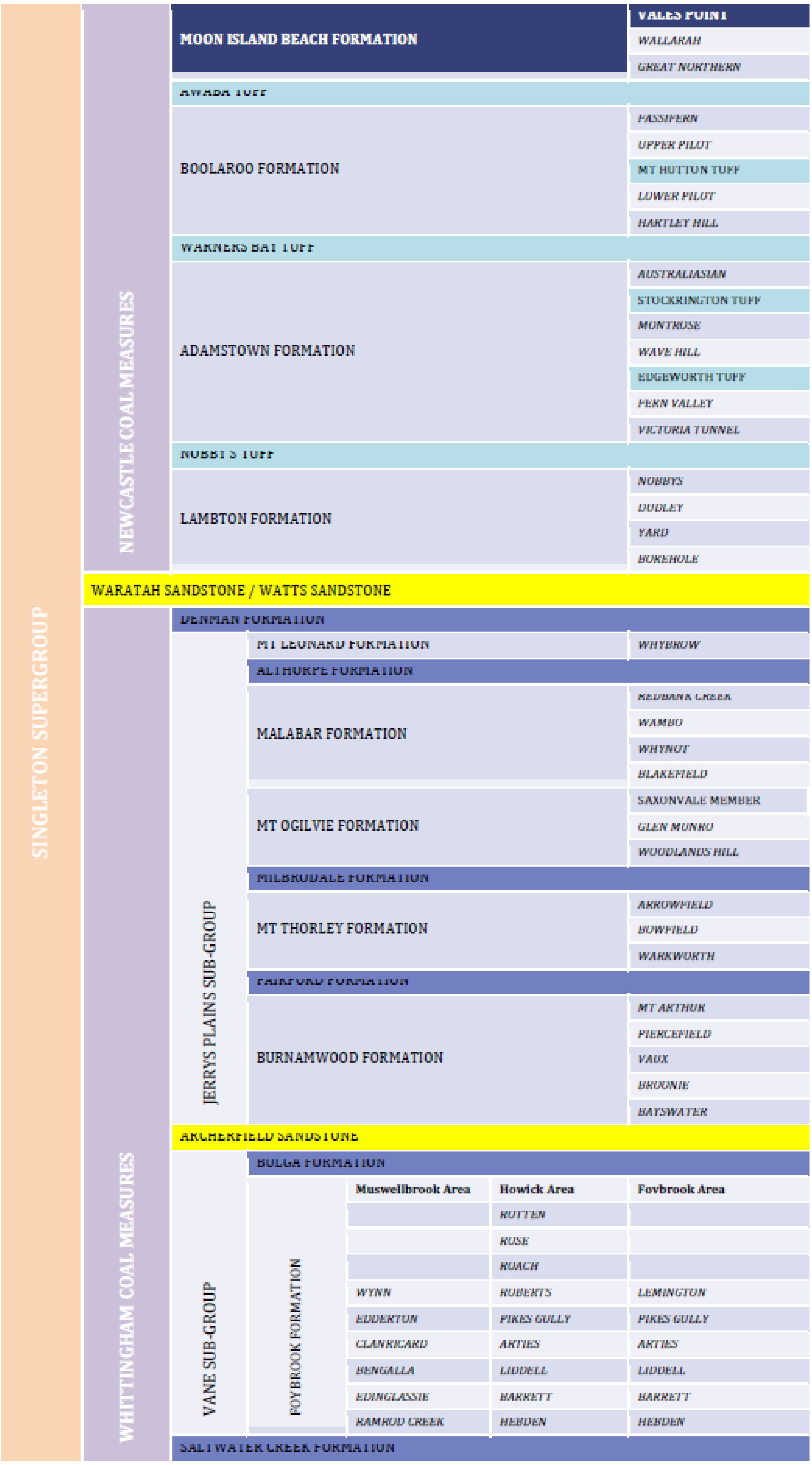


Figure 2.2 Singleton Super Group sequence stratigraphy (after AGE, 2016d)

2.2.1.1 Quaternary alluvium / Regolith

Ashton is overlain by Quaternary alluvium associated with the HR, BC and GC. The Bowmans Creek alluvium (BCA) and GCA are in direct connection to the Hunter River alluvium (HRA). The Quaternary/recent aged alluvium/colluvium along the HR, GC and BC flood plains comprises two distinct depositional units, a surficial fine grained sediment and coarser basal material. The surficial alluvium comprises shallow sequences of clay, silty sand and sands. Along the minor drainage lines, the surficial alluvium is typically constrained within 500 m of the creeks and is between 7 m to 15 m thick.

Away from the floodplain areas, the Permian coal measures sequence is overlain by a layer of regolith, comprising colluvium/eluvium, and completely weathered rock that collectively have soil rather than rock properties and interface with the alluvium at the flanks of the floodplain areas. The regolith layer varies in thickness, but is typically 15-20m thick above rock.

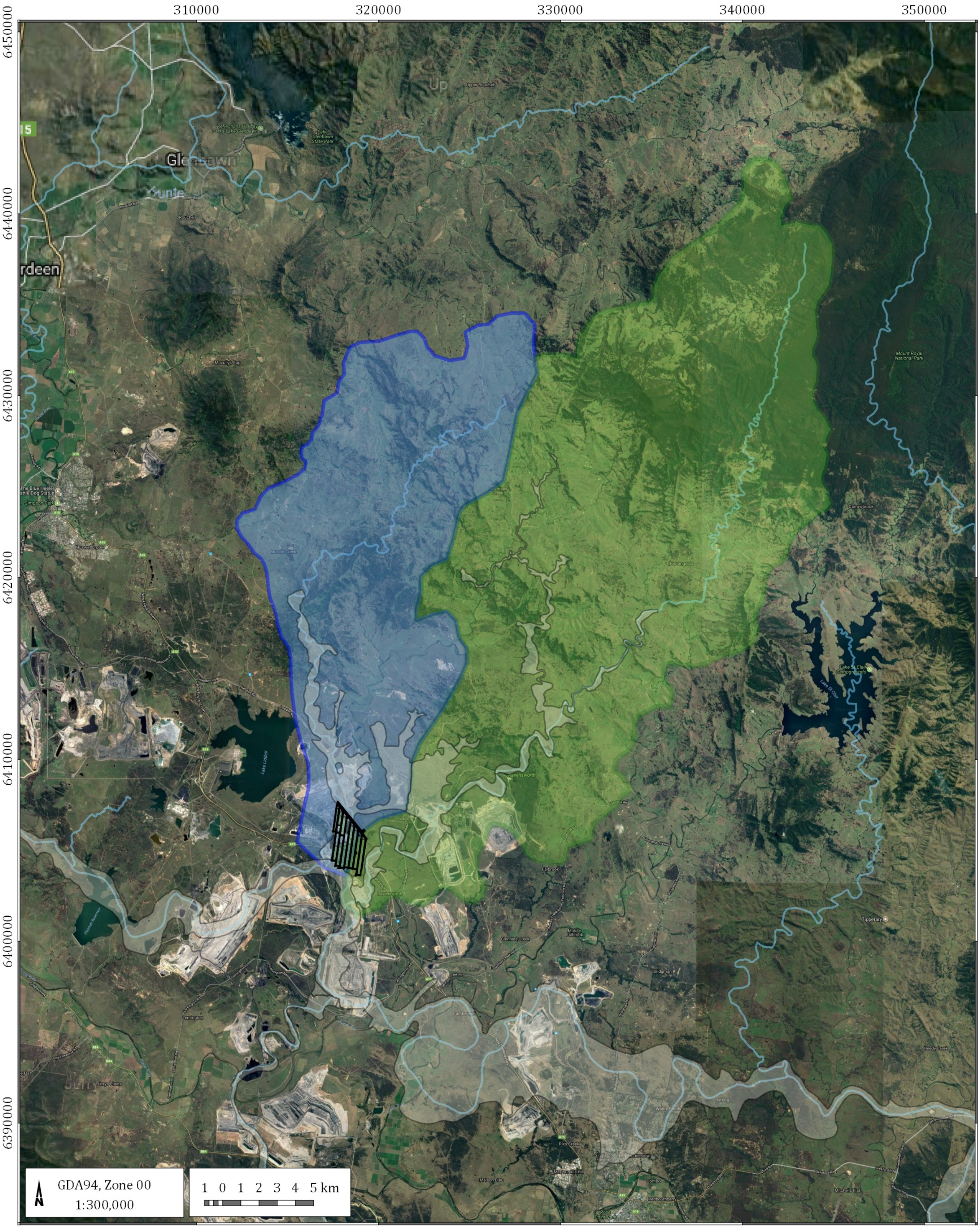
2.2.1.2 Permian strata

The Whittingham Coal Measures comprise Permian aged coal seams interbedded with siltstone, sandstone, shales and conglomerates. The Whittingham Coal Measures are up to 400 m thick at Ashton, but regionally they range from approximately 250 m to 600 m thickness. At Ashton, the lower portion of the Whittingham Coal Measures is present on site. The profile extends from above the Bayswater seam to the Hebden seam (Figure 2.3).

Locally, the Whittingham Coal Measures are further divided to (AGE, 2016c):

- four main target coal seams – PG, ULD, ULLD and the LB;
- a large number of coal seams and plies of varying thickness, including the Bayswater seam, up to 20 Lemington seam plies, the Arties seam, and a number of Liddell seam and Barrett seam plies that are not proposed to be mined in the Ashton underground mine; and
- interburden sediments comprising siltstone, sandstone, conglomerate and claystone.

Over 20 plies of the Lemington seam profile and the overlying Bayswater seam are present within the PG seam overburden. The largest Lemington seam plies are of similar thickness as the four target seams, and may have similar hydraulic properties.



LEGEND

Map

Approximate alluvium extents

Catchments

Bowmans Creek

Glennies Creek

Watercourse

Historical groundwater review and assessment
Ashton Coal mine (G1858H)

Bowmans and Glennies Creeks catchment areas

AGE

DATE 12/02/2018

FIGURE No: **2.3**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
N:/Groundwater Jobs/G1738.Yancoal Ashton UG - GW Inflows/3_GIS/Workspaces/Figure_00_catchment_areas.qgs

2.2.2 Recharge and discharge

Recharge is interpreted to occur from direct rainfall to the ground surface, infiltrating into the formations through the thin soil cover and weathered profile (regolith). The coal measures also occur at subcrop in localised zones beneath the HRA, GCA and the BCA. In these areas, the Permian coal measures are interpreted to be recharged by downward seepage and then downdip flow along the most permeable strata in the sequence, primarily the coal seams (AGE, 2016c).

The combined catchment area providing recharge to the Ashton area is significantly greater in size than the mine area itself. Ashton is located immediately adjacent the confluences of the Hunter River with Bowmans and Glennies Creeks. The Ashton surface and underground infrastructure is located entirely within the Bowman's and Glennies Creek catchments, which extend approximately 30 km and 45 km to the north of Ashton, respectively.

Bowmans and Glennies Creek have associated alluvium and have up to fourth order tributaries up-stream of the site and rainfall falling within the respective catchments flow through the Ashton area. The Bowmans and Glennies Creeks catchments span approximately 300 km2 and 600 km2, respectively.

2.2.3 Groundwater flow

The Quaternary alluvium and regolith combined is interpreted (AGE, 2016c) to be an unconfined groundwater system that is recharged by rainfall infiltration, streamflow and upward leakage from the underlying stratigraphy, particularly along GC and BC.

The water table in the alluvium/regolith is a subdued reflection of topography. Groundwater within the HRA flows generally in an easterly direction, while groundwater within GCA and the BCA flows generally in a southerly direction towards the HR, with local flow towards the respective river/creeks.

The direction of groundwater flow for the coal seams is influenced by the local geomorphology and structural geology as well as the long history of mining within the region. Groundwater flow within the Permian coal measures is understood to be to the south-west consistent with the dip direction fo the coal seams.

The mining of the PG seam and ULD seam has impacted the groundwater regime at Ashton. Mining has induced subsidence cracking that extends to the ground surface above parts of Ashton, and to a lesser height above the goaf in other areas where the cover depth above the PG seam is greater (ie near the western side of the mine area). It is likely that in areas of shallower cover depth, this cracking has penetrated both the overburden of the PG, along with the BCA. Surface cracking is also visible along and across the longwall panels areas immediately following subsidence. This surface cracking is expected to extend for only a limited depth below surface and may or may not intersect with the subsidence cracking emanating up from the goaf, depending on cover depth and subsidence magnitude.

There is also potential for recharge from the GCA through connectivity with the PG seam (AGE, 2016c), which hydraulic testing showed was significantly more permeable close to outcrop than at depth (Peter Dundon and Associates, 2006). Inflows into the workings during mining of LW1 were not significantly greater than during mining of LW1 tailgate (TG1A). This would indicate that mining of LW1 did not increase the connectivity or flow from the PG seam in subcrop beneath the GCA. Although inflows were higher during mining of TG1A than subsequent inflows from subsided strata during extraction of LW1, the total inflows to the end of LW1 were below predicted inflows, and the observed impacts on GCA were less than predicted, confirming that the proximity to Glennies Creek has not resulted in an unexpected level of connectivity and inflows from the Glennies Creek floodplain.

The presence of subsidence cracking over parts of the underground mine increases the potential connectivity of the mine with the water within the creeks and associated alluvium. Planned LW panels within the underlying ULD, ULLD and LB seams may allow for reactivation of subsidence and subsidence related fracturing within these areas (AGE, 2016c). Figure 2.4 shows the conceptual hydrogeology after AGE (2016c).

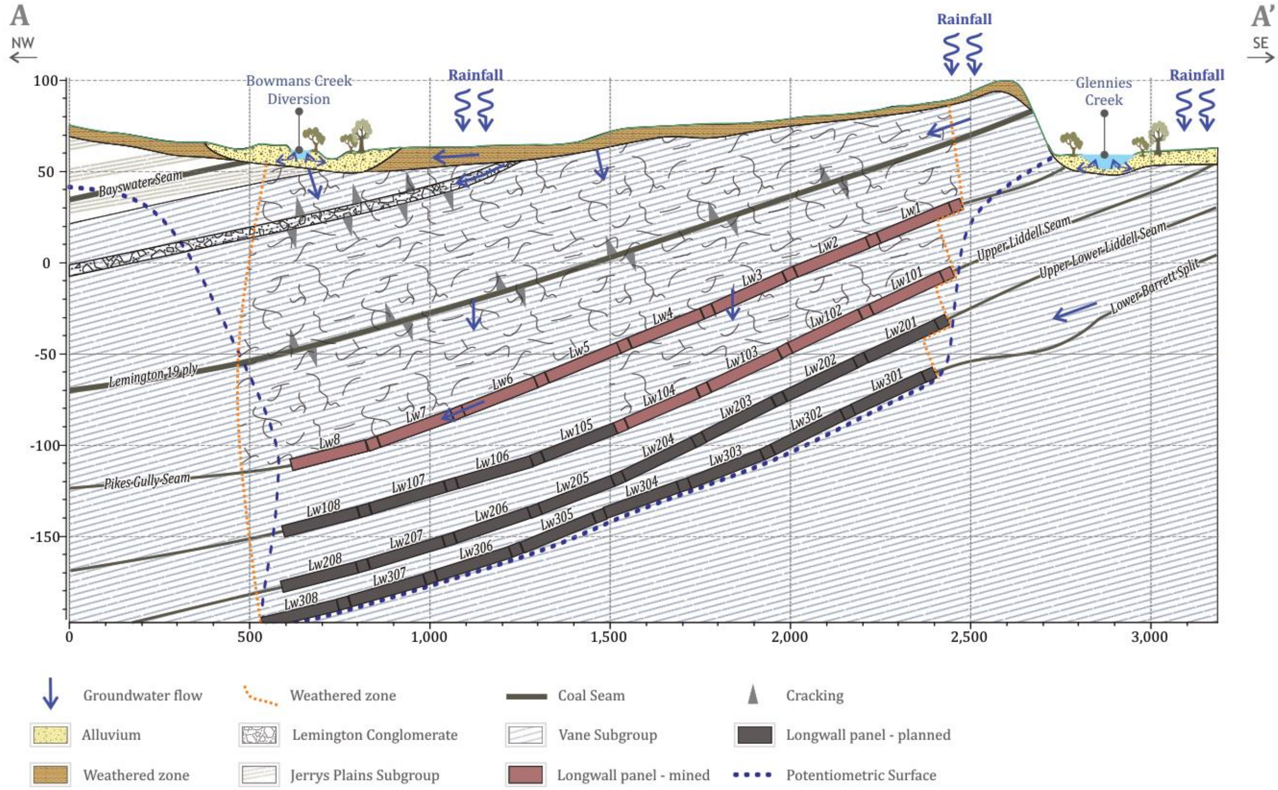


Figure 2.4 Conceptual hydrogeology – north-west to south-east – not to scale (after AGE, 2016c)

2.3 Hydrogeological cross-sections

Three hydrogeological cross-sections have been completed, all running from the north-west to the south-east (Figure 2.5). For each cross-section line, two cross-sections were completed: one pre-underground mining (pre-March 2007 where available) and one showing the current status (ie PG seam completely mined, ULD seam extensively mined, and ULLD seam partially mined.

Hydrostratigraphy is shown by a sequence of yellow (alluvium), brown (regolith), red (target coal seams) and green (coal measures interburden/overburden) colours.

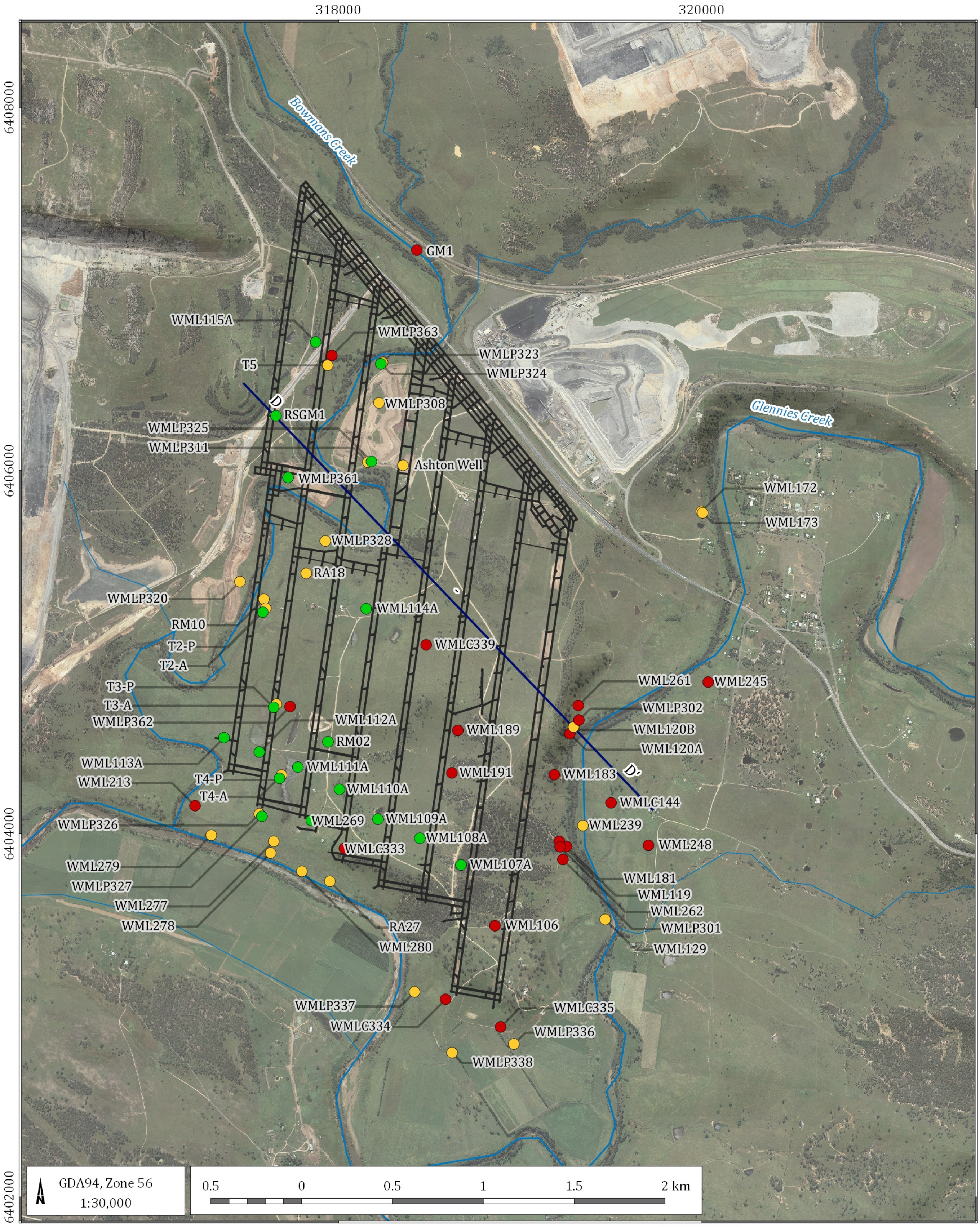
Data from wells were projected onto the cross sections if they were within 1.2 km of the section line to assist in interpreting the hydrostatic heads and water table positions on each section. The water table in the alluvium and regolith is depicted as a linear surface. The heads in the Permian are shown numerically on relevant wells (piezometers), and where relevant, the limits of saturation are shown by linear surfaces. Grey vertical lines represent well traces and these are sometimes displayed above the natural land surface for bores off-section. Note that some wells appear on more than one cross-section.

The numerical labels depict groundwater elevation in mAHD at the actual elevation of the screened or open zone. Often these are contoured to provide a groundwater head map in a vertical slice to analyse vertical flows. Contouring for the cross-sections (Figure 2.5 to Figure 2.8) was not completed because a comparison between pre- and post-underground mining indicate the drawdown processes adequately.

Figure 2.6 shows cross-section A-A' pre- (prior to mining in the PG seam). Pre-March 2007, the water table is shown around 58-60 mAHD near BC. The section also shows coal measure (Pikes Gully seam) potentiometric heads to be between 50 and 55 m AHD near BC and GC. The few available depth profiles at near BC and GC indicate groundwater heads at depth in general within 5 m of the water table.

Figure 2.7 shows cross-section A-A' post mining in LW6B (at the completion of mining in the Pikes Gully seam). The head (water table) in the alluvium does not appear to change significantly from pre-underground mining. Water levels are shown not to have changes (small localised water levels changes in the alluvium were noted elsewhere off the cross-section axis) and the potentiometric head in the Pikes Gully seam can be seen to be very low and close to the seam roof. During underground mining, the heads change so that considerable downward hydraulic gradient develops from the alluvium down to the mined seam. Subtle changes (reductions in head) also occur on the margins of the underground mine, towards GC.

Figure 2.8 shows section A-A' post mining in LW104 (Upper Liddell seam). Figure 2.8 also shows that groundwater heads in the alluvium show no significant change since underground mining commenced. Significant, > 100 m drawdown occurs in the mined seams and small drawdown beneath those in the deeper seams and overburden and in one location the potentiometric head of the ULD seam is drawn down to seam level. The vertical hydraulic gradients that develop during underground mining suggest a convergence (from the alluvium down and from seams deeper than the mined up) on the mined seam.



LEGEND

- Major drainage
- Minor drainage
- Ashton Underground 2: Upper Liddell Seam longwall panels
- Cross section

Monitoring bore lithology

- Alluvium
- Coal measures overburden (incl. Bayswater, Lemington)
- Pikes Gully Seam and deeper

Historical Groundwater Review and Assessment, Ashton Coal Mine (G1858H)

Cross section base map

AGE

DATE 13/02/2018

FIGURE No: **2.4**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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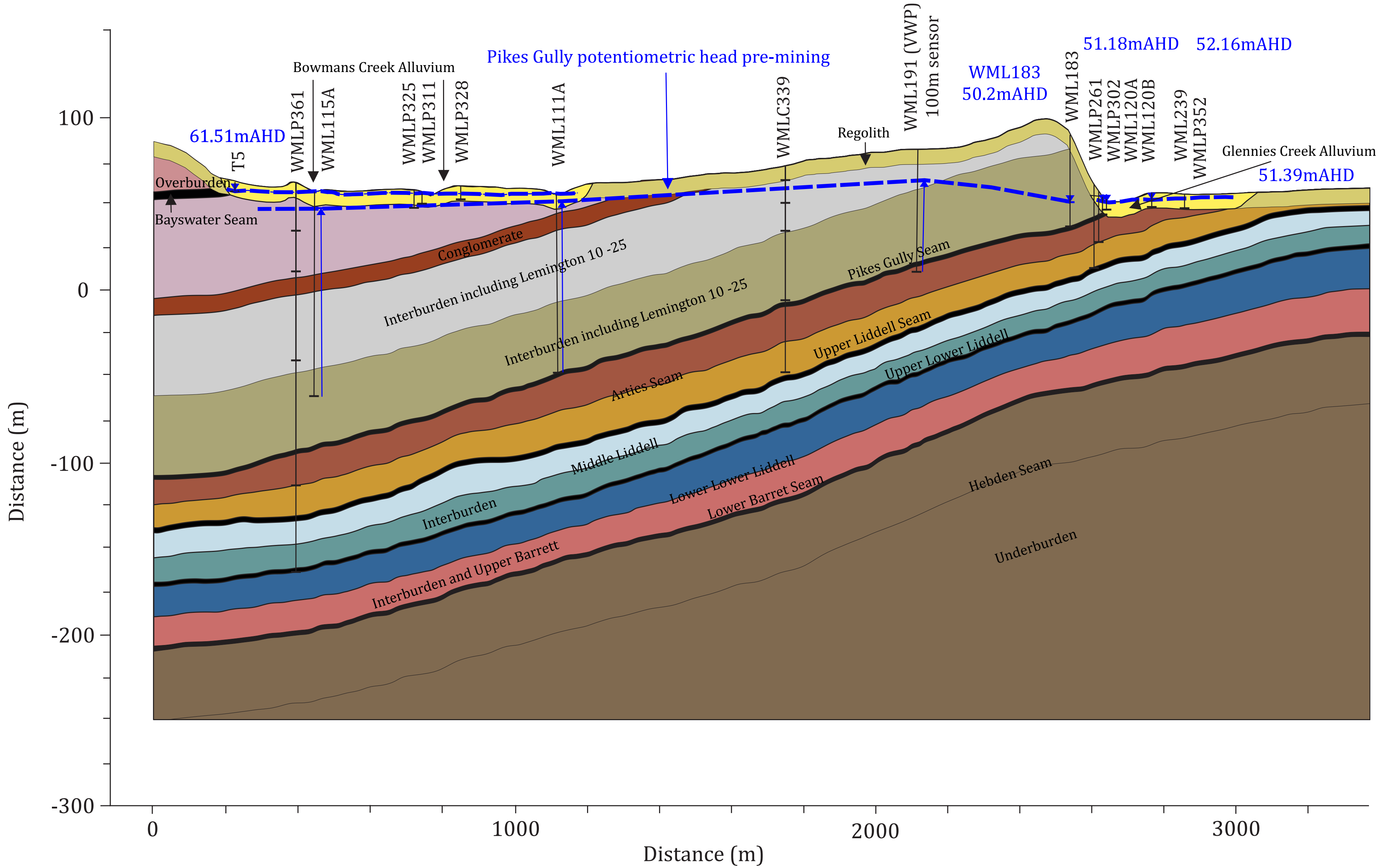


Cross section A-A' - Alluvium water levels & Coal Measure Heads (pre-mining March 2007)

Figure 2.6

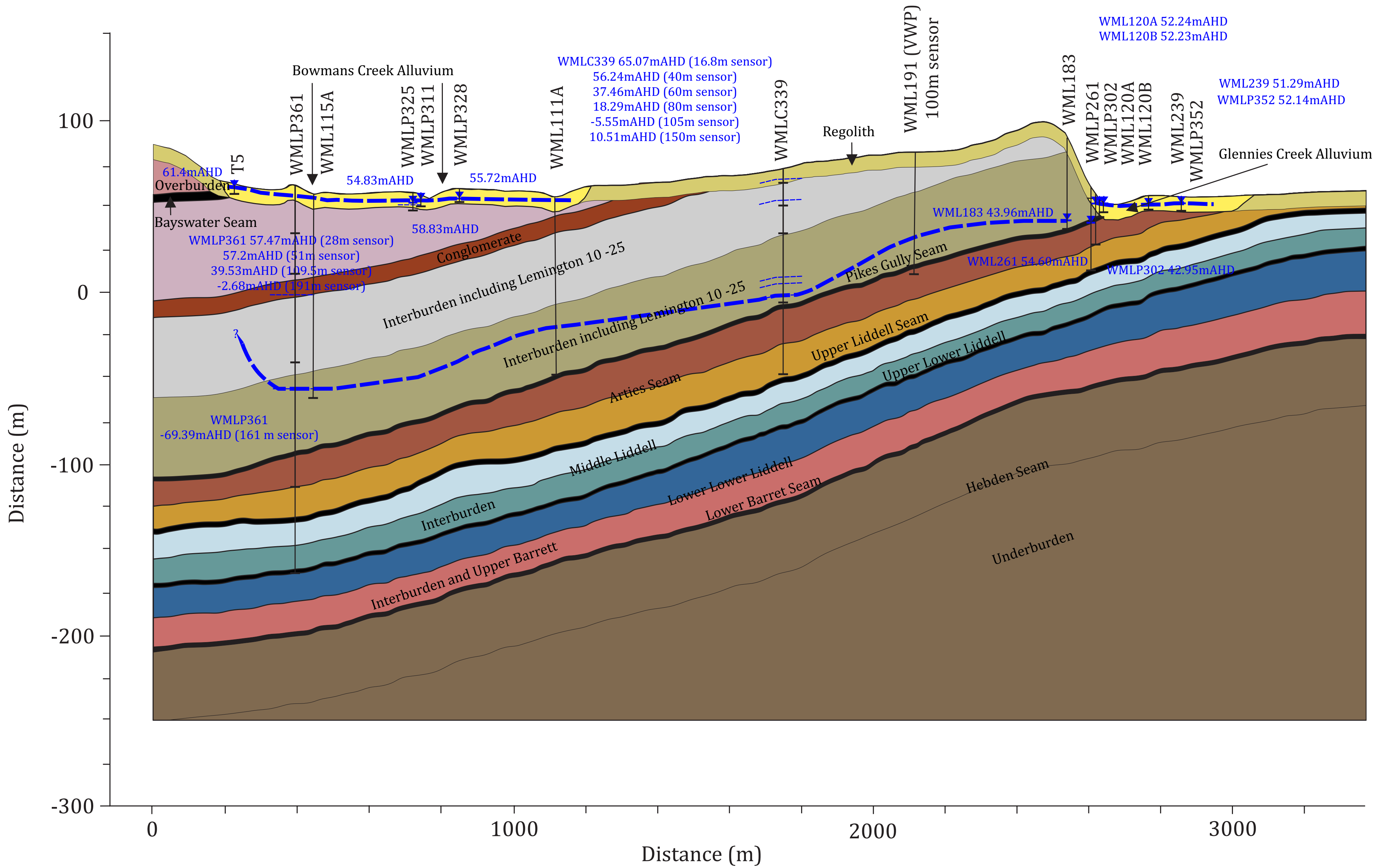
Historical Groundwater Review and Assessment, Ashton Coal Mine (G1858H)

LEGEND

- L01 Alluvium
- L02 Overburden
- L03 Bayswater Seam
- L04 Int incl. Lem 1 - 9
- L05 Conglomerate
- L06 Int incl. Lem 10 - 25
- L07 Int incl. Lem 10 - 25
- L08 Pikes Gully Seam
- L09 Int incl. Arties Seam
- L10 Interburden
- L11 Upper Liddell
- L12 Middle Liddell
- L13 Interburden
- L14 Upper Lower Liddell
- L15 Int incl. Lower Lower Liddell
- L16 Int incl. Upper Barrett
- L17 Lower Barrett
- L18 Underburden incl. Hebden

VWP/screen interval and SWL (mAHD)

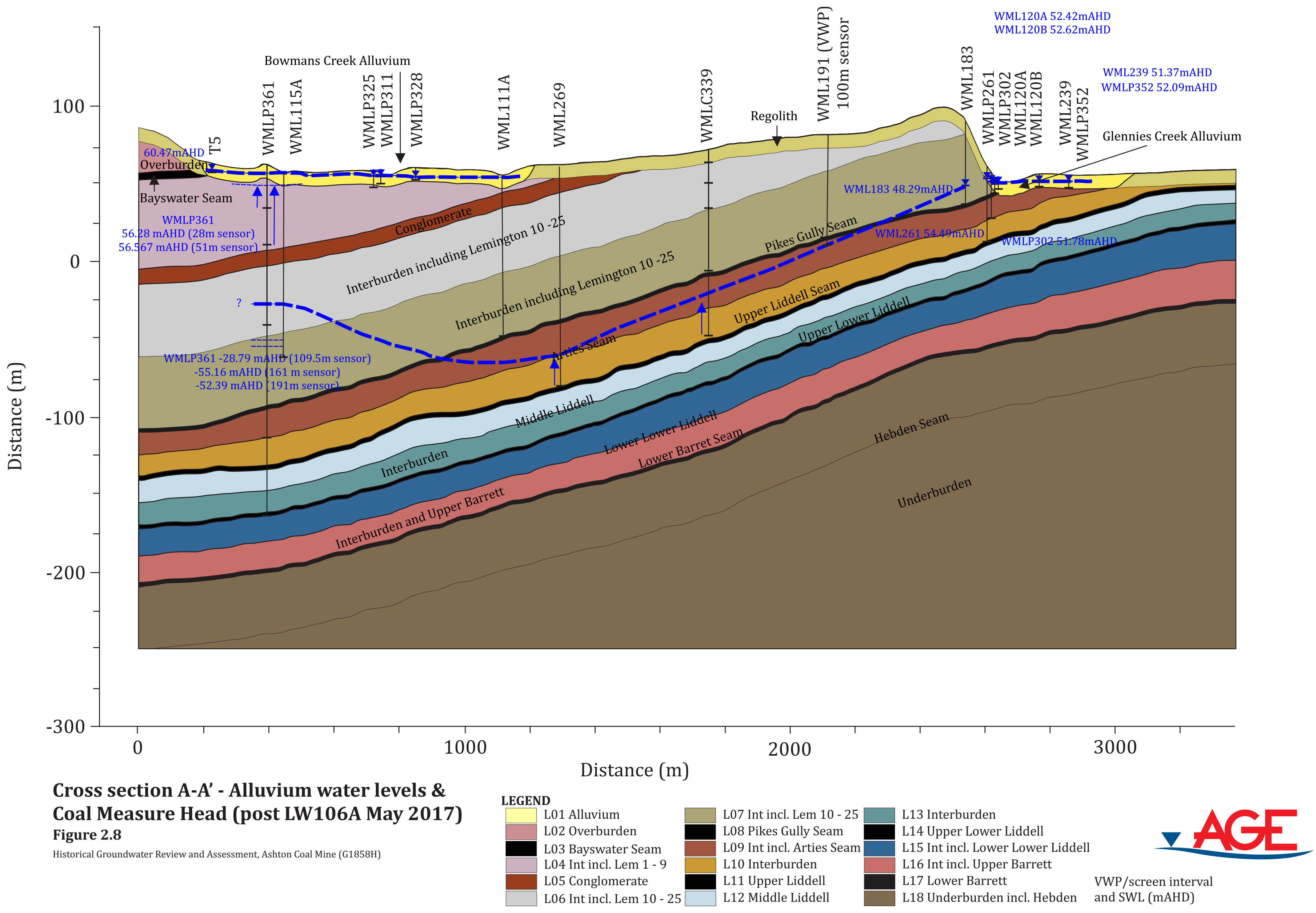
AGE



Cross section A-A' - Alluvium water level & Coal Measure Head (post LW6B October 2013)

Figure 2.7

Historical Groundwater Review and Assessment, Ashton Coal Mine (G1858H)



Cross section A-A' - Alluvium water levels & Coal Measure Head (post LW106A May 2017)

Figure 2.8

Historical Groundwater Review and Assessment, Ashton Coal Mine (G1858H)

3 Anticipated impacts at different stages of mining

The underground mining at Ashton to date can be considered as a number of distinct phases, each of which has a different potential for impact and each of which has been modelled and assessed for impacts prior to mining, viz:

3.1 LW1 development headings

The LW1 development headings (TG1A first then TG1B and then the MG headings) represented the first advance below the regional groundwater table in the underground mine. The headings cause groundwater depressurisation in the seam itself, but are not accompanied by subsidence, so inflows from the roof and floor are minor. There was no inflow from the overburden strata at the development stage. The first advance of TG1A below the water table was in June 2006, whereas the LW extraction did not start until March 2007.

The proximity of GC and GCA to the TG1A heading could result in impacts on GC baseflows and GCA groundwater.

3.2 LW1 to LW4 longwall panel extraction

LW1 to LW4 involve mining beneath a limited thickness of coal measures overburden (range 40 m at the northern end of LW1 to 140 m at the southern end of LW4), but with no overlying alluvium.

The relatively shallow cover depths above LW1 to LW4 mean that mining-induced subsidence could result in connective fracturing extending from the goaf to the very top of the Permian. However, with no overlying alluvium, the hydrogeological impacts from subsidence in this phase of the mine life were expected to be relatively benign.

The expected overall impacts of mining to the end of LW4 (Peter Dundon and Associates, 2006) would be:

- Full dewatering of the Pikes Gully Seam within the LW1-LW4 footprint and laterally extensive depressurisation outside the LW1-LW4 footprint.
- Probably full dewatering of the overburden strata within the LW1-LW4 footprint due to the connective cracking expected to extend virtually to the ground surface, but with limited lateral extent of overburden depressurisation outside the LW1-LW4 footprint; this arises because the primary flow paths in the coal measures are horizontal features (coal seam plies and bedding plane partings), and these flow paths tend to become disrupted by vertical displacements at the edges of the subsidence zones, resulting in an apparent reduction in horizontal hydraulic conductivity.
- Continuing impact on GCA as encountered in the TG1A heading.
- No noticeable impacts on BCA.

3.3 LW5 to LW8 longwall panel extraction

LW5 to LW8 involved mining substantially beneath the Bowmans Creek alluvial floodplain, with increasing cover depths (overburden thickness ranged from 98 m at the northern end of LW5 to 170 m at the southern end of LW8).

The effects described above for the Pikes gully seam and the PG overburden would be expected here as well, but in addition, for the first time, impacts on the BCA and BC baseflows could occur, due to the potential for hydraulic interconnection between the goaf and the base of the alluvium(Aquaterra, 2009a). Across the LW5-LW8 footprint, conditions may vary from connective cracking up to the base of the alluvium above parts of LW5 to perhaps to some depth below the base of the alluvium on the western side (LW8).

Overall, full dewatering of the PG seam and some of the overburden above the extracted panels was expected, with depressurisation and partial dewatering of the higher overburden strata. Some areas may remain unaffected at the higher levels, most likely on the western part of the area where cover depth is greatest.

Limited temporary impacts on groundwater levels in Bowmans Creek alluvium were anticipated, including:

- initial water level drops within the subsidence zones but without any reduction in saturated thickness (alluvium top, bottom and water table all dropped together); and
- subsequent recovery in levels as water flowed into subsidence zones, leading to increase in saturated thickness as water levels returned to pre-subsidence levels.

During mining of LW5-8, no further impacts on Glennies Creek or its alluvium were expected beyond those experienced during LW1-LW4.

No observable impacts on Hunter River or its alluvium were expected.

3.4 LW101 development headings

The headings for LW101 represented the first to be mined beneath the water table.

It was anticipated that any inflows from the ULD seam to the mine would likely be at their maximum during the development heading stage, as had been encountered with the LW1 headings in the PG seam. In the event, no inflows of note were encountered during the mining of LW101 development heading. It was concluded that the ULD is not locally enhanced in permeability as the PG seam appeared to be close to outcrop.

3.5 LW101 to LW104 longwall panel extraction

This was the first phase of longwall mining in the second seam at Ashton, and these panels involved mining below previously subsided overburden, but not beneath alluvium

3.6 LW105 to LW108 longwall panel extraction

This involved the continuation of longwall mining in the second seam beneath subsidence-affected overburden, in this case substantially beneath Bowmans Creek alluvial floodplain. It was expected that mining in the ULD seam might reactivate and enhance prior subsidence fracturing, and may result in connective cracking extending to or closer to the ground surface or the base of the BCA.

Due to remoteness from GC, no additional impacts on either GC baseflows or the GCA groundwater levels were expected during WL105 to LW108.

3.7 LW201 development headings

The LW201 development headings were the first mining below the water table at the third seam level, namely the ULLD seam. Impacts were expected to be similar to those expected during LW101 development headings.

3.8 LW201-202 longwall panel extraction

At the time of writing, mining has been substantially completed in LW201, and development is progressing through LW202. Development headings are being mined for LW203. This phase of mining is occurring beneath substantially subsidence affected overburden strata, but no overlying alluvium.

As with mining of the first two seams in this part of the mine, no impacts on BCA and HRA are anticipated, nor any incremental impact on GCA.

3.9 Future mining – LW202 to LW208 (ULLD), LW301 development headings (LB) and LW301 to LW308 (LB)

A similar range of impacts is expected to occur as described above for the upper seams, viz

- LW202 to LW204 beneath subsidence affected overburden strata, but with no overlying alluvium.
- LW205 to LW208 beneath subsidence affected overburden strata and also beneath BCA floodplain. Possible further activation and enhancement of prior subsidence fracturing may lead to increased connectivity with the alluvium.
- LW301 development headings, with minimal further impact expected as the LB seam subcrops east of the GCA floodplain.
- LW301 to LW304 beneath subsidence affected overburden, but no alluvium.
- LW305 to LW308 beneath subsidence-affected overburden and substantially beneath the BCA floodplain. Possible further activation and enhancement of prior subsidence fracturing may lead to increased connectivity with the alluvium.

4 Reported impacts

Reviews of selected publications are presented in chronological order in Appendix A. General comments about each publication are presented in numbered/bulleted lists, followed by a tabular presentation of predicted and actual impacts to key environmental values/receptors: drawdown in the Permian strata and alluvium, baseflow depletion, and inflow to the underground mine.

The predictions within the selected publications draw upon the most recent comprehensive numerical model in place at the time as follows:

- HLA Envirosciences (2001) to 2009;
- Aquaterra (2009a) for 2010-2014;
- RPS Aquaterra (2014c) for 2015 to 2016; and
- AGE (2016) from 2016.

The reported impacts are discussed below in terms of the main phases described above in Section 3.

4.1 LW1 development headings

The total inflows associated with LW1 (including development headings) from all sources, and the proportion of the inflows calculated to have been derived from Glennies Creek and its associated alluvium (as distinct from the Permian), were both less than had been predicted for this stage of mining in the EIS.

Inflows through the eastern rib of TG1A were larger than subsequent inflows during longwall extraction from LW1. TG1A inflows were due to proximity to Glennies Creek and its associated alluvium, and an interpreted higher hydraulic conductivity of the Pikes Gully Seam close to outcrop. The PG seam subcrops very close to Glennies Creek, and the creek may in fact have been incised directly into PG seam over a limited section of the creek where it comes closest to the mine (150m east of LW1 at its closest point).

The seepage inflows to the TG1A heading were greater than had been anticipated in the 2001 EIS (as it had been expected that inflows would be highest during longwall extraction); however, as discussed below, very little additional inflow occurred from longwall extraction. A program of

in-seam injection grouting was undertaken during mining of TG1A in an effort to reduce the mine inflow, but was largely ineffectual.

Water levels were reduced on one alluvium bore (WML120B) and a number of Pikes Gully Seam bores between the creek and LW1, but nothing was impacted to the east of the creek. There was no detectable change in flow volumes in Glennies Creek, as well as partial drainage of saturated GC alluvium.

No impacts on Bowmans Creek or Hunter River and their associated alluvium at this stage of mining were expected and none was observed to occur.

4.2 LW1 to LW4 longwall panel extraction

Progressive mine water inflows during LW1-LW4 extraction were less than predicted in the EIS (HLA, 2001).

Surface cracking was observed to occur within the subsidence footprints, consistent with expectations, and open cracks were repaired soon after mining. There were some conflicting observations regarding connectivity between surface and goaf. Methane gas monitoring showed elevated concentrations above extracted longwall panels, suggesting direct connection between the surface and the goaf. However, during a major rainfall event on 15 February 2009, sheet runoff inundated an area of open surface cracking above LW1, which had not yet been rehabilitated. The sheet runoff led to water entering large open cracks, but water was observed to emerge from other open cracks downslope. Despite the limited cover depth (40 m to 92 m), there was no evidence that this influx actually reached the underground workings, as there was no noticeable increase in underground seepage volume or discolouration of underground water. This observation suggested that in this area there may have been less direct hydraulic connection between the surface and the goaf than was expected based on the limited depth of cover.

Mining the rest of LW1-LW4 caused full dewatering of the PG seam within the LW1-LW4 footprint, and depressurisation in the PG seam over a large area outside the footprint, which is consistent with conceptual and numerical model predictions (HLA, 2001 and Dundon, 2006).

Some of the monitoring piezometers in the overburden strata within the subsidence footprint survived the subsidence for a time. WML108, located above LW3, had piezometers at the Lemington 8-9, Lemington 10-12 and Lemington 15 levels that all survived being undermined by LW3 and were all still reporting positive pressures (indicating partial saturation at least down to Lemington 15) at the end of LW4 (see hydrostatic head profiles in Appendix B). WML109, located above LW4, had piezometers at the Lemington 7, Lemington 8-9, Lemington 11-12 and Lemington 15 levels. The Lemington 15 piezometer did not survive being undermined, but the higher piezometers all survived and continued reporting positive pressures (indicating partial saturation) until the end of LW4 extraction (see hydrostatic head profiles in Appendix B). Other piezometers inside the LW1-LW4 footprint reported full dewatering (WML189 and WML191).

Partial depressurisation of the overburden coal measures was observed in bores outside the LW1-LW4 footprint, but over a more restricted area. WML106 and WML107 located south of LW1 and LW2 respectively displayed only small partial depressurisation in the overburden down to the Lemington 19 seam, which is less than 20m above the Pikes Gully seam (see hydrostatic head profiles in Appendix B).

The observations of only partial depressurisation of the overburden suggested that the effects of subsidence fracturing from LW1 to LW4 did not result in connective cracking all the way to the top of the Permian. The hydrostatic head profiles (Appendix B) show that depressurisation was more complete below Lemington 15, and partial above Lemington 15, but minimal at the Lemington 15 seam itself. This suggests a possible hydraulic barrier beneath Lemington 15, possibly a stronger conglomerate layer.

The cross-section in Section 2.3 shows the region of total dewatering across the LW1-LW4 at the completion of LW4 extraction.

During extraction of LW1-LW4, TG1A seepage inflows slowly declined, and groundwater level drawdowns in alluvium and coal measures between LW1 and Glennies Creek underwent slow recovery over time accompanying the slow reduction in seepage inflows. These observations indicate no further impact on GC or GCA since the TG1A development heading, and also suggest progressive reduction in permeability of the Pikes Gully seam barrier between LW1 and Glennies Creek, possibly due to slow clogging of cleat fractures with sediment, or delayed response to in-seam injection grouting attempted during mining of TG1A.

No impacts were observed on Bowmans Creek or its alluvium, nor on Hunter River or its alluvium, during mining of LW1 to LW4.

4.3 LW5 to LW8 longwall panel extraction

LW5 to LW8 were mined between January 2010 and October 2013, and involved mining substantially beneath the Bowmans Creek alluvial floodplain, with increasing cover depths (overburden thickness ranged from 92 m at the northern end of LW5 to 170 m at the southern end of LW8).

The final panel mined was LW6B, after mining of panels LW7A and B and LW8 had been completed, and also after the first ULD panel LW101 had been extracted. LW6B was located beneath a section of the floodplain that included part of the former channel of Bowmans Creek prior to the creek diversion. The mining of LW6B had been deferred until the creek diversion works had been completed and the response to mining of the other panels beneath BCA had been monitored and evaluated. The extraction of LW6B was accompanied by a temporary increase in mine water inflows in excess of predictions, and is discussed below as a separate case.

Mine water inflows during the mining of LW5 to LW8 increased from 7 L/s to a maximum of 20 L/s. Then during the mining of LW6B, inflows increased markedly to 31.5 L/s. LW6B is discussed separately below. Total inflows through this period of mining are depicted graphically on Figure 4.1.

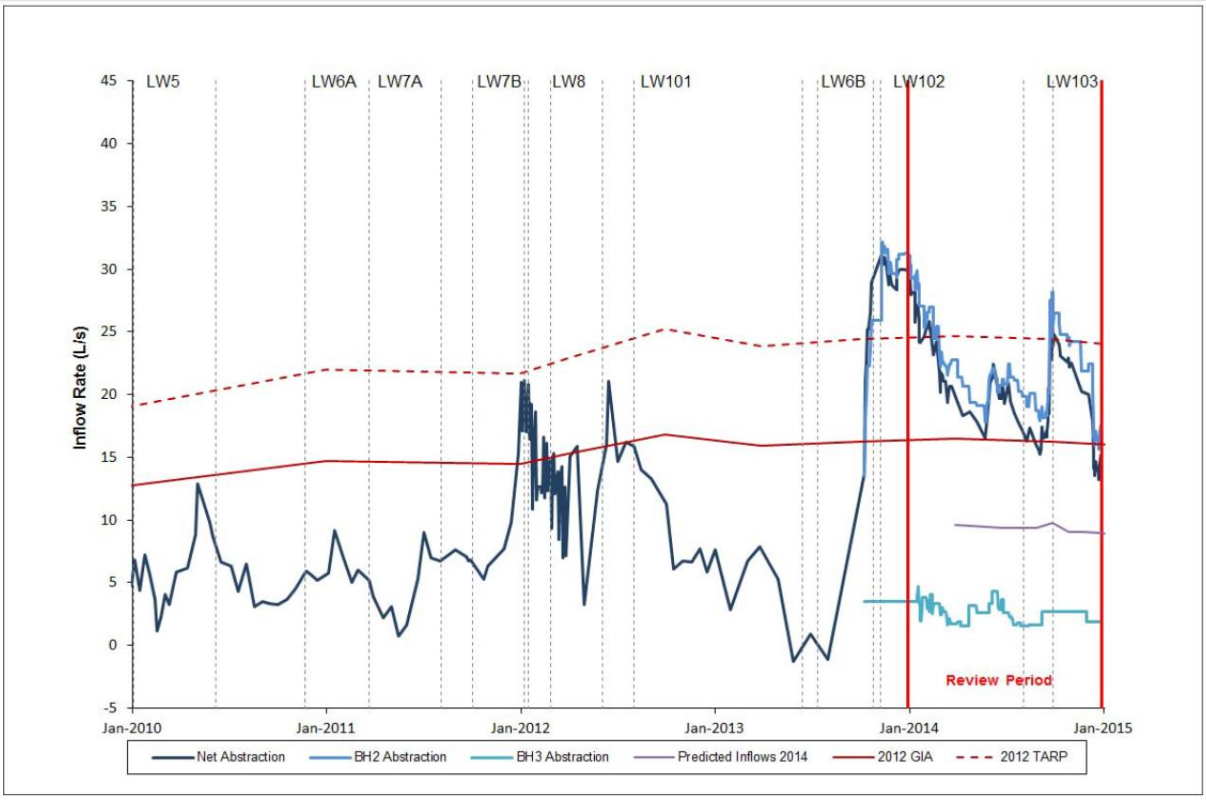


Figure 4.1 Mine inflow rates interpolated from pumping rates – to Jan 2015 (RPS 2014)

More widespread drawdown in the Pikes Gully Seam was observed during mining of LW5 to LW8. The PG seam was fully dewatered within the LW1 to LW8 footprint by the completion of LW5-8.

Likewise, more lateral spread of drawdowns was observed in overburden strata above the Pikes Gully, including various Lemington seams and interburdens. However, the overburden depressurisation was variable and not consistent with depth.

A number of multi-level vibrating wire piezometers within the LW5-LW8 footprint that were situated directly above a longwall panel (WML110, WML111, WML112, WML114 and WML115) were destroyed during the extraction of the underlying longwall. However, others within the LW5-LW8 footprint that were not located directly above a longwall panel, namely WMLP361, WMLP362 and WMLP363, which were installed during late 2013 and early 2014, after the mining of LW6B, showed that the overburden strata was not completely dewatered or even fully desaturated throughout the mine footprint. WMLP361 is located in the pillar between LW7 and LW7A; WMLP362 was drilled through the chain pillar between LW6A and LW7A; and WMLP363 through the chain pillar between LW6B and LW7B. WMLP361, WMLP362 and WMLP363 were installed with the intent of monitoring heads during future mining under the Bowmans Creek area.

All three showed that the strata down to at least the Lemington 8 seam level remained fully saturated and fully pressurised, indicated by the piezometric pressures for the piezometers in this interval plotting on the 45° trend line on the hydrostatic head profiles (Appendix B). This is compelling evidence that the connective cracking up from the goaf did not extend fully to the surface or to the base of the alluvium.

After the completion of LW6B, the final panel extracted from the Pikes Gully seam in this section of the mine, WMLP361 showed only minor depressurisation at the Lemington 15 seam, but almost full depressurisation at the Arties seam which lies just below the Pikes Gully seam, and partial depressurisation at the deeper ULD seam. Both WMLP362 and WMLP363 showed almost complete depressurisation at Lemington 15 by the completion of LW6B, and only partial saturation in the regions between Lemington 8 seam and the ULD seam. All three showed the Pikes Gully seam fully dewatered by this stage of mining.

Impacts on groundwater levels/pressures outside the LW5-LW8 footprint are illustrated by the progressive hydrostatic head profiles for bore WML213, which is a multi-level piezometer bore located to the southwest of the underground mine area (Appendix B). The WML213 hydrostatic head profile plot (Appendix B) shows that to the end of LW6B, the final longwall panel extracted from the Pikes gully seam, there had been progressively increasing depressurisation of the Pikes Gully seam, and to a lesser extent the Lemington 19 seam level, but very little depressurisation at the Lemington 15 level. Some depressurisation had also been noted at the underlying ULD and ULLD seams. Minor depressurisation was observed above the Lemington 15 seam level at the piezometer located at Lemington 8. No depressurisation had occurred at the Bayswater seam, nor at the Lower Barrett seam, and the heads at both of these levels remained on the 45° line of saturation on the hydrostatic head

The region of interpreted total dewatering at the completion of mining LW6B is depicted on a cross-section across the LW1-LW8 area (Figure 2.7). Contours of head depletion within the remaining saturated strata are also shown.

Limited temporary impacts on groundwater levels in Bowmans Creek alluvium, that were smaller in magnitude and duration, were observed, including:

- initial water level drops within the subsidence zones but without any reduction in saturated thickness (alluvium top, bottom and water table all dropped together);
- subsequent recovery in levels as water flowed into subsidence zones, leading to increase in saturated thickness as water levels returned to pre-subsidence levels; and
- localised partial dewatering of alluvium above LW6B (which is discussed as a separate case below).

The groundwater levels within the BCA during mining of LW5-LW8 are shown on Figure 2.7. 2 shows that the BCA remained saturated after mining of the PG seam had been completed across the LW5-LW8 area.

During mining of LW5-8, no further impacts on Glennies Creek or its alluvium were observed. The slow recovery (ie reduction in underground seepage to TG1A and recovery in water levels in alluvium and coal measures between LW1 and Glennies Creek) that had been observed during LW1-LW4 continued during LW5-LW8.

No impacts on Hunter River or its alluvium were detected.

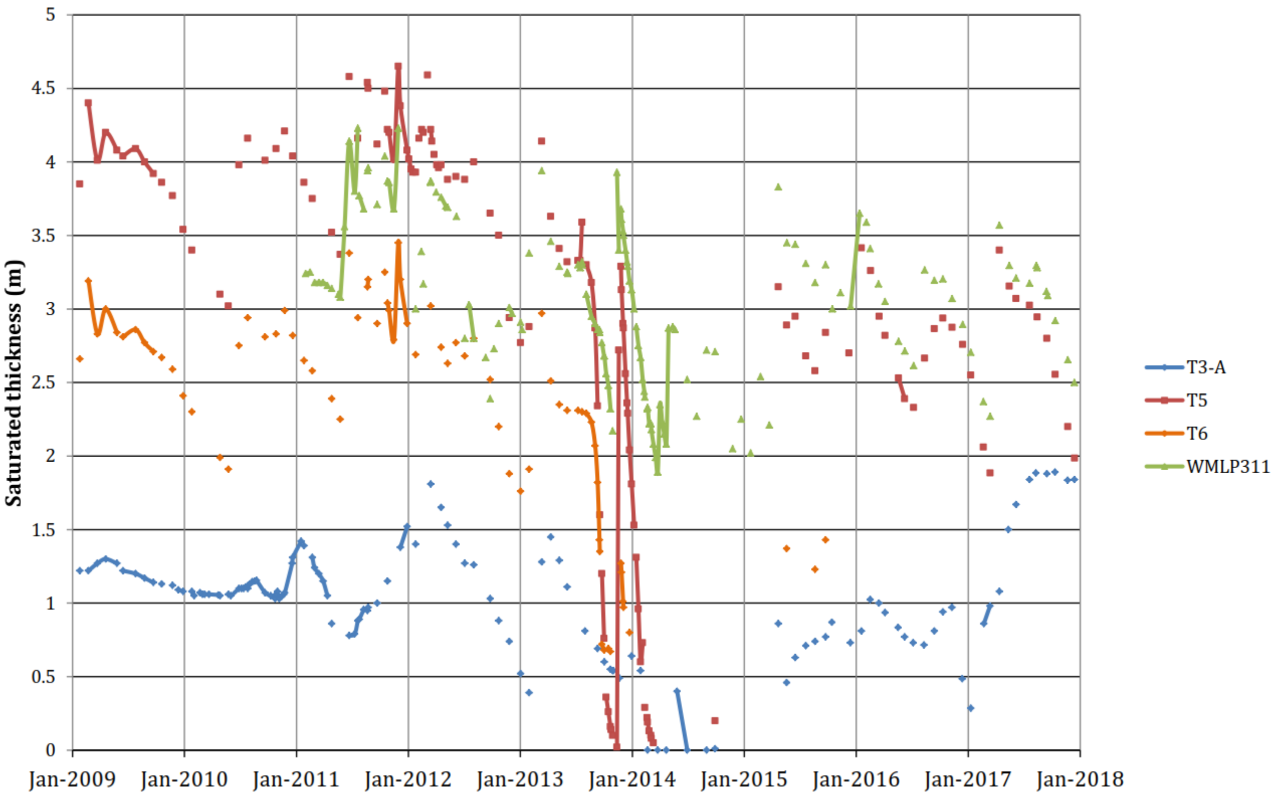


Figure 4.2 BCA water levels and saturation during underground mining

4.4 LW101 development headings

No significant water inflow was noted into the LW101 headings.

The LW101 development headings were started on approximately 4 August 2011. The only response to these headings was a drawdown of about 4m observed in the Upper Liddell piezometer at bore WMLC248, which is located 300m east of Glennies Creek, near the subcrop of the ULD seam beneath the Glennies Creek floodplain (refer Figure 2.5). No other bore showed a response to the passage of the development headings below the water table.

There was no measured change to water levels in the GCA or visible changes in GC baseflow.

At the time, longwall extraction was taking place in LW7A and the LW7B, beneath the Bowmans Creek floodplain.

4.5 LW6B longwall extraction

A large increase in mine water inflow (still within the predictions of the mod 6 EIS) occurred during the LW6B extraction. Total mine inflows were reported to have increased from less than 10 L/s at the start of LW6B to over 30 L/s by November 2013.

The largest increase occurred in October 2013, with inflows peaking at 31.2 L/s, and RPS (2014) proposed that this occurred during the passage of the longwall through a sheared zone which had been observed during geological mapping of the LW6B development headings. A similar zone of shearing had been recorded also in LW7B, and also in the NW Mains where seepage inflows had persisted long after the rest of the headings in that area had dried up. All three shear zones roughly line up with a persistent zone of face seepage that had been observed in the NW corner of the former Barrett pit (the main part of the NEOC).

Smaller increases in water inflow occurred towards the end of LW7B in late 2011, when inflows increased from less than 10 L/s to almost 20 L/s, before declining steadily; and again near the end of LW8 in mid-2012, when again inflows increased from less than 10 L/s to almost 20 L/s. Again inflows thereafter steadily declined to less than 5 L/s by mid-2013.

As with LW7B and LW8, after completion of LW6B, inflows steadily declined to around 15 L/s by May 2014. As the inflows declined after each occasion of major water inflow, it is considered that the increases in inflow are believed to be due to interception of an atypical water source of limited magnitude.

This water source has not been fully explained. Initially, the BCA was considered, but attempts to calibrate the groundwater model showed that there was insufficient groundwater available from the alluvium to fully explain the magnitude of the increases in inflows. It was also considered that relatively higher permeability in parts of the PG overburden may partly account for the increases in inflow, with water released from storage within and around the mine area once subsidence occurred and the resulting connective fracturing provided hydraulic connection with the goafs. It was recognised that a number of the larger Lemington seam plies were of similar thickness and properties to the four target coal seams, but the groundwater models had included all the overburden strata as aquitard with low hydraulic conductivity and storage. AGE incorporated a model layer of higher conductivity within the PG overburden, and called this layer the Lemington Conglomerate (later considered likely to be a coal seam). While the conglomerates in the overburden later proved to not be a potentially aquifer, some of the Lemington seam plies could be, and could account for at least part of the increased inflow.

Another possible source is water stored within the partly backfilled NEOC. Mining from the NEOC ceased in February 2011, and pumping of water from the open cut ceased at that time, and water was allowed to build up in the pit. After cessation of mining, the pit was used for deposition of coal wash plant tailings, and also collected any rainfall runoff from the mine and infrastructure areas.

Bore G1 has been monitored as part of the NEOC monitoring system since November 2003. It is a standpipe bore screened in the Lower Barrett seam at a depth of 201-203m (around -136 mAHD), and has shown a steadily declining water level during operation of the open cut, from an initial water level of around +59 mAHD to +44 mAHD by February 2011 (Figure 4.3). After closure of the NEOC, the water level in G1 recovered quickly, reaching +65 mAHD by June 2011. The water level then started a steady recession trend.

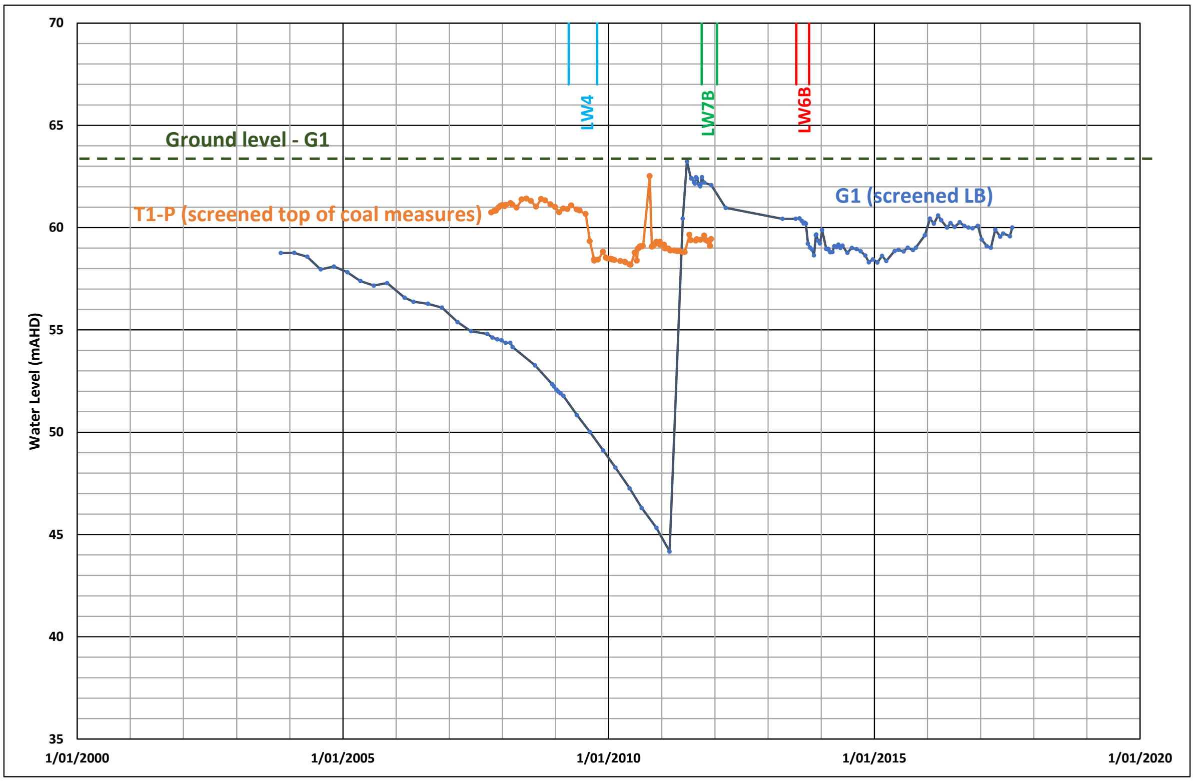


Figure 4.3 GM1 and T1-P hydrographs

Between December 2011 and March 2012, the G1 water level dropped by more than 1m relative to the recession trend. This coincides with the extraction of LW7B. G1 water then declined by 2 m between August 2013 and November 2013, which coincides with the mining of LW6B. These water level declines may be indicative of water being lost from the open cut. The coincidence of these two water level declines with the increased water inflows into the underground mine suggest that the water stored in the former open cut may be in part responsible for the increased water inflows to the underground, with the shear zone as a possible interconnection.

During the extraction of LW6B, there were some drawdowns observed in the groundwater levels in the BCA. However, although the water table dropped in a number of shallow alluvium bores (eg T5 – see 2), the alluvial aquifer remained saturated throughout the extraction of LW6B. The bores in which the water level declines were observed all showed complete recovery over time with subsequent recharge. This is compelling evidence that the connective cracking emanating up from the LW6B was not sufficient to allow direct hydraulic connection between the goaf and the base of the alluvium.

4.6 LW101 to LW104 longwall panel extraction

LW101 to LW104 involved coal mining from longwall panels in the second seam (ULD seam), lying under a previously subsided overburden sequence, and no alluvium.

LW101 was extracted immediately after LW8, and before LW6B, the final panel in the PG seam. LW102 then followed after the completion of LW6B.

Mine pumping rate measurement was automated at the start of 2013 and the 2013-2017 data is presented in Figure 4.4. Mine water inflows during the extraction LW101 to LW104 have varied from 10 L/s during LW101 to a median rate of 22 L/s during LW102 and LW103. Subsequently, the rate declined to between 5 and 15 L/s during the mining of LW104 and LW106A (see Figure 4.4).

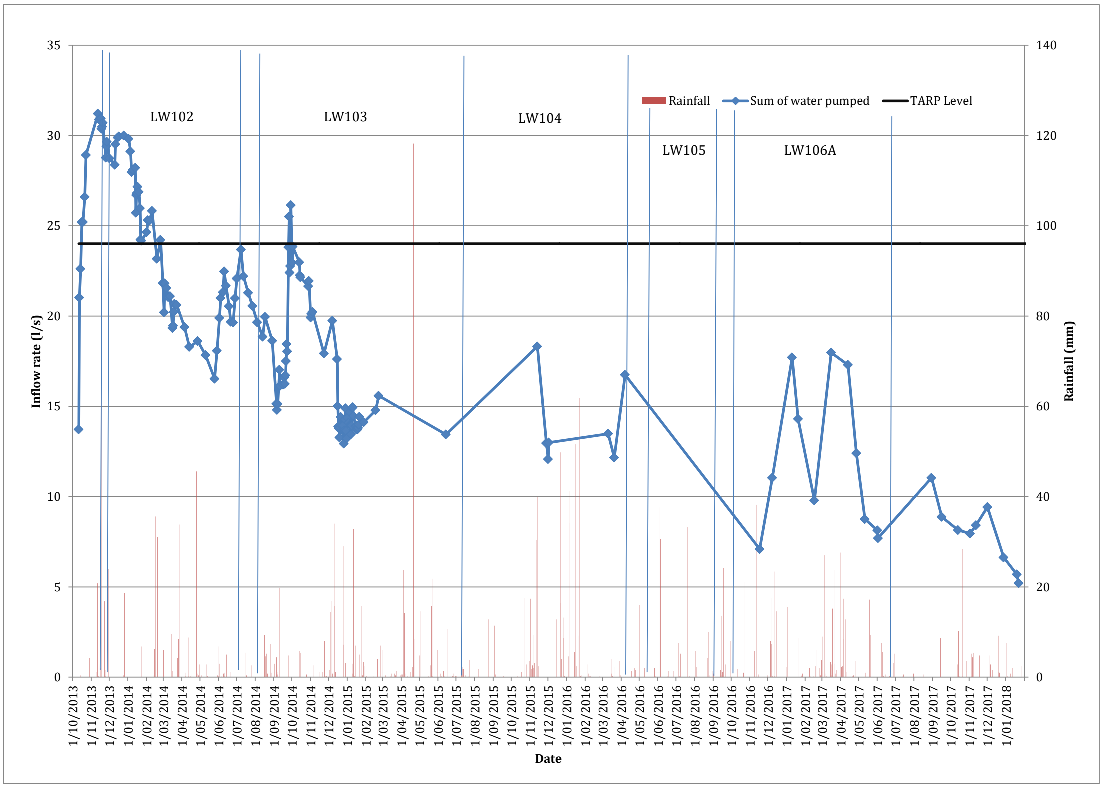


Figure 4.4 Mine inflow rates interpolated from pumping rates – 2013 to 2017

The ULD seam within the LW101-104 footprint is likely to have been fully dewatered by the end of LW104 to the floor of the ULD. Three piezometers within the area survived for part of this phase of mining, each until it was undermined by a longwall panel. These were WML189 (undermined by LW102), WML191 (undermined by LW102) and WMLC339 (undermined by LW103). The hydrostatic head profile for WML191 (Appendix B) shows that prior to the commencement of LW101, the PG overburden had been almost completely depressurised, and the ULD seam itself had only been slightly depressurised. During extraction of LW101 and LW102, until WML191 was undermined, the ULD became substantially depressurised, but there was only slight continuing depressurisation in the overlying and underlying strata. WML189 and WML339 did not extend to the ULD seam, but both showed that there was still partial saturation at the Arties seam level (ie below the PG seam) until those piezometers were undermined and lost.

Outside the footprint, steady depressurisation was observed.

WML213 southwest of the mine (Appendix B) showed very slow continuing depressurisation of the ULD seam and strata above and below. Almost no depressurisation has occurred at the Lemington 15 seam level, with slightly more at higher levels until the Bayswater seam which remained unaffected since underground mining began.

Piezometer WMLC361, located between LW107A and LW107B, revealed that the Lemington 15 seam, which had been fully pressurised at the end of mining from the PG seam (ie at the end of LW6B), finally started to depressurise during the mining of LW101-104. However, the overburden remained fully pressurised down to the Lemington 8 level.

WMLC363, located within the footprint of LW106B which has not yet been mined, showed depressurisation in the ULD seam starting during the LW101 development headings, then increasing significantly during longwall extraction of LW103, as well as almost complete depressurisation of the overburden between the PG seam and Lemington 8, which had remained partly saturated after completion of PG mining. In this part of the mine area, like at WMLC361, the overburden at Lemington 8 and above remained fully pressurised after completion of LW104.

Piezometers south of LW101, WMLC334 and WMLC335 (Appendix B) both showed partial depressurisation of the strata at the ULD level, and to a lesser extent at the deeper ULLD seam. No further depressurisation was observed east of Glennies Creek (WML245 and 248) since the LW101 development headings were mined.

4.7 LW105 and LW106A longwall panel extraction

Mining has not been completed across the full mine area in the ULD seam. The proposed longwalls LW6B, 7A and 7B have not yet been mined. Mining has meantime moved to the third seam the ULLD, and currently LW201 is being extracted.

Total mine inflows during mining of ULD LW105 and LW106A (May 2016 to May 2017) continued a declining trend pre-LW105, and were in the range 5 to 18 L/s (see Figure 4.4). This inflow rate was generally consistent with predictions from the latest version of the groundwater model, which were for a peak inflow of 13L/s during mining of the LW105 to LW106A. No unexpected increases in inflow were reported.

The hydrostatic head profile for WML213 showed no significant additional depressurisation of the coal measures strata between LW104A/B and LW106A. However, WML361 and WMLC363 (Appendix B) showed no further depressurisation at the ULD seam, no further change in the overburden up to Lemington 15, and the strata from Lemington 8 and above remained fully pressurised.

During the period of mining LW105 and LW106A, there was no adverse change in the alluvium groundwater levels, and the BCA remains saturated above the longwall panel area.

4.8 LW201 development headings and longwall extraction

Longwall extraction from LW201, the first longwall in the ULLD, commenced on 7 July 2017, and the time of commencing this report was still in progress.

Mine water inflows during this period have remained consistently below 10 L/s. No increase in inflows was predicted to occur during mining of LW201 to 204, compared with that during extraction of the ULD seam.

About 20m depressurisation in the ULLD seam was observed at WML248, east of Glennies Creek (Appendix B) during the mining of LW201 development headings and LW201 longwall extraction to October 2017. This bore is located close to the ULLD subcrop beneath regolith to the east of the GCA floodplain. Further depressurisation of about 10m was also observed to occur at WML213 during this stage, spread across all levels from the ULLD to PG seams.

No notable changes in alluvium groundwater levels were observed in either the GCA or BCA.

Throughout mining to date, no changes to water levels have been detected in the HRA.

5 Analysis

5.1 Summary of the Ashton groundwater models

There is a succession of increasingly comprehensive and complex numerical groundwater flow models for simulating the impact of the Ashton underground mine on key environmental receptors: surface watercourses, associated alluvium (including GDEs), and the Permian strata.

5.1.1 HLA Envirosciences (2001)

The initial groundwater model was developed by HLA Envirosciences (2001) for the mine approval EIS. This model was created using MODFLOW, and included 120 columns, 120 rows and 7 layers. The model of HLA Envirosciences (2001) predicted inflows to the mine, drawdowns in the alluvium and Permian strata, and surface water baseflow depletion.

The model was based on a conceptual model that recognised two aquifers, one in the shallow alluvium and one in the fractured Permian coal seams. There is, however, little or no documentation on the boundary conditions adopted, hydraulic parameters used and calibration for the HLA Envirosciences (2001) model.

At time of publication, the groundwater impacts assessment was fit for purpose and provided a prediction of impacts on the groundwater system due to mining as planned at the time.

5.1.2 Aquaterra (2008a)

An improved model was compiled for the groundwater impact assessment in support of the LW/MW 5-9 SMP. This was a significant change from the HLA EIS model. It was similar in structure to the model used for the Bowmans Creek Diversion EA which is described in more detail in Section 4.1.4 below, but as a simplification measure, layers below the PG seam were not activated in the model. It was developed as a temporary measure to assist in expediting an interim approval for a series of longwalls and miniwalls to allow mining beneath the Bowmans Creek floodplain under the 2002 consent.

It was superseded by the BC EA model (see Section 4.1.4).

5.1.3 Aquaterra (2009)

A modified version of the LW/MW 5-9 SMP model was used to predict impacts of the proposed SEOC mine. It included additional detail in the model domain east of the underground mine, and simplified some of the domain to the west.

5.1.4 Aquaterra (2009a)

The HLA Envirosciences (2001) model was updated by Aquaterra (2009a) for the BC diversion environmental assessment (EA). MODFLOW-SURFACT v4 was the code selected for the model. The seventeen (17) layer model by Aquaterra (2009a) included significant changes to the HLA Envirosciences (2001) model, namely the introduction of separate layers for coal seams and overburdens, and the division of the PG overburden so that caving and fracturing could be modelled within the numerical flow model. It also allowed for separate simulation of development headings and longwall panels, as the development headings for a particular panel precede the longwall extraction by up to a year or more.

The model was well documented to the extent that the reader can follow the model building process, the translation of the conceptual model to a numerical one, and calibration and predictive modelling.

The Aquaterra (2009a) model forces groundwater to flow horizontally, and vertical flow was artificially suppressed, to ensure consistency with the conceptual hydrogeology and the observed responses to early mining in the PG seam. This is achieved by setting horizontal to vertical hydraulic conductivity ratios in the model to be typically 100:1 for coal seams and interburden; and for the alluvium the ratio between horizontal to vertical hydraulic conductivity was between 10^5:1 and 10^7:1. These ratios were adopted to replicate the observed groundwater levels in the alluvium and Permian fractured rock aquifers at the site and the differences in lithology and hydrogeological nature of the units.

The Aquaterra (2009a) groundwater model was a complex numerical model that contained numerous layers replicating the geology/hydrogeology at the site. All available, site-specific, hydrogeological data was used in the model and assumptions used were conservative in nature. The model predicted impacts that were greater than the observed groundwater impacts.

5.1.5 RPS Aquaterra (2014b)

The groundwater model of Aquaterra (2009a) was updated by RPS Aquaterra (2014b). The updated model attempted to explain the increased mine inflows with the existence of a "*shear zone*" in the PG seam. The updated model used horizontal to vertical hydraulic conductivity ratios of 100:1 for most layers and zones, with the exception of a few zones:

"In general, the previously calibrated values for hydraulic conductivity were retained, with some minor alterations. As noted in Table 2.7, the vertical hydraulic conductivity of Hunter River, BC and Glennies Creek alluvium was corrected from a previous value of $5x10^{-6}$m/d, to a horizontal to vertical anisotropy of 100:1. In addition, in the Glennies Creek Alluvium (GCA), the distribution of hydraulic conductivity was simplified with localised pockets of high hydraulic conductivity incorporated into the general alluvium zone" (page 7 of RPS Aquaterra, 2014b).

Groundwater data gathered since the commencement of mining were used to update the Aquaterra groundwater model (RPS Aquaterra 2014b). The model was adjusted to incorporate an updated understanding of the site hydrogeological regime in an attempt to replicate site conditions, observations and underground inflows (including the underground in-flow event of October 2013). The reduction in horizontal to vertical conductivity ratios was made to try to force more water to leak downwards to the mine from the BCA, in an attempt to calibrate against the large increase in inflows encountered in October 2013 during the extraction of LW6B.

The updated model predictions remained conservative and within the approved impacts.

5.1.6 AGE (2016d)

The AGE (2016d) model objectives include the following:

- rebuild the groundwater model to include conceptual refinements and updated model structure;
- predict the loss and / or water take from the water bearing units on site;
- predict groundwater inflow into the underground mine based on a number of mine plan scenarios; and
- simulate and predict the extent and area of influence of mining on the water table.

The AGE (2016d) model used MODFLOW-USG (unstructured grid) that allows the use of polygons (instead of rectangles only in other finite differences codes), and layers no longer need to have the same number of nodes. This in turn allows improved simulation of layers that pinch out or sub-crop. Nodes from lower layers can also be in direct contact with the top layer of the model. This modelling approach is a significant improvement from the earlier model codes. The USG model was loosely based around the RPS Aquaterra (2014b) conceptual understanding and included monitoring data collected between 2014 and 2016. The conceptual hydrogeological model was reviewed and improved based on the data. The basis of the conceptual model is discussed further in the paragraphs below and in Sections 5.2 to 5.4.

The AGE (2016d) model was rebuilt and subsequently calibrated with a focus on the observed alluvium water levels (AGE, 2016c) for the purposes of assessing the potential regional impacts of the mine and mining of LW210-214. MODFLOW-USG is particularly suited to modelling the surface water/alluvium groundwater/fractured rock groundwater interaction due to layers being able to be "pinch out" beneath alluvium. The pinching of layers allows for a better representation of the interaction between aquifers. This increased focus on alluvium groundwater/fractured rock groundwater interaction was to replicate the mechanism that caused changes to water levels in alluvium bores and coal seam bores in the GC and BC areas during mining.

The number of model layers was increased in order to replicate a more complex conceptual hydrogeological model, including the inclusion of a unit of elevated storage and hydraulic conductivity. At the time of modelling, this unit was considered to be a sandstone/conglomerate (the Lemington Conglomerate – now considered a coal ply); however, subsequent assessment indicates that the elevated hydraulic conductivity unit may likely be a coal seam or other geological unit. Also, the fault modelled by RPS Aquaterra (2014b) was removed as there was insufficient clear evidence that demonstrated the presence of the fault.

The AGE (2016d) model represents mines with the DRAINS package and perennial watercourses with the RIVER package (similar to the previous models). AGE (2016d) also used an anisotropy ratio of 100:1 for all layers but for part of layer one: for less productive (finer grained) alluvium (Qa), GC the ratio was 1000:1. The development headings are not separately simulated in the AGE model.

The modelling of subsidence effects is based on the concepts of Kendorski (1993) who defined five zones in the goaf. These zones are summarised by AGE (2015). SCT reports related to assessment of changes to hydraulic conductivity post longwall mining were also reviewed during the initial phases of AGE (2016) in order to incorporate the predicted hydraulic conductivity changes in the longwall overburden. Tammetta (2015), a variation to Kendorski (1993), and SCT (2008a) were used to inform the changes to hydraulic conductivity through the subsidence profile based on site specific investigations and modelling. Further discussion of this understanding is presented in Section 5.1.7.

The AGE (2016d) model simulated the gradual changes to the hydrostratigraphic units in response to mining using the MODFLOW-USG TVM (time varying materials) package. The parameters within the coal seam and overlying strata were changed as the LW developed. This was achieved by applying a ramp function to vertical hydraulic conductivity (Kv), gradually decaying to the estimated maximum height of connective cracking (110 m above the LW roof). Changes to hydraulic parameters used a logarithmic stepping function across stress periods consistent with mining. Storage was changed in a step-wise manner above the mined seam to avoid creating water in partly saturated layers.

Changes to hydraulic properties post-subsidence were also simulated in a scenario in recognition of "*healing".* Over time, the fractures above mined LW panels caused by rock subsiding into the mined out areas can 'heal' through the infill of fines and through changes in stress in the rock mass following settlement.

Table B9 of AGE (2016d) shows the calibrated time varying material vertical hydraulic conductivities, reproduced here as Table 5.1 and Table 5.2. The AGE (2016d) model is an obvious and significant improvement on Aquaterra (2009a) because it introduces a smoothed vertical hydraulic conductivity profile in the goaf. However, similar to Aquaterra (2009a), it is calibrated to post-subsidence absolute values for vertical hydraulic conductivity, as opposed to relative changes. This means that in the Aquaterra (2009a) or AGE (2016d) models, the subsided vertical hydraulic conductivity has no relationship to the relevant pre-subsidence vertical hydraulic conductivity.

The AGE (2016d) subsidence modelling represents a significant improvement over Aquaterra (2009a). However, Aquaterra (2009), RPS Aquaterra (2014) and AGE (2016d) showed a clear understanding that a good understanding of subsidence impacts needed to be incorporated in to the numerical groundwater model. The most recent model (AGE 2016d) incorporated the cumulative understanding of the assessments and provided the most accurate and practical representation of the subsidence impacts on the overlying strata.

Table 5.1 Subsidence affected fractured parameters (after AGE, 2015 and 2016d)

Parameter	Fracture height (m)	Subsidence affected vertical hydraulic conductivity (m/d)*
Goaf	0	5.30×10^{-2}
Fracture	12.5	1.52×10^{-2}
Fracture	25	5.63×10^{-3}
Fracture	50	1.95×10^{-3}
Fracture	75	6.98×10^{-4}
Fracture	110	1.40×10^{-4}

Table 5.2 Subsidence affected layer parameters (after AGE, 2015 and 2016d)

AGE (2016d) model layer	Maximum Layer Vertical Hydraulic conductivity (m/d)**
1	**5×10^{-2}**
2	1×10^{-4}
3	**2.5×10^{-4}**
4	1×10^{-4}
5	**6.7×10^{-4}**
6	1×10^{-4}
7	1×10^{-4}

Note: *Bold values are in excess of the minimum 1.40×10^{-4} m/d vertical hydraulic conductivity *from AGE 2015 **from AGE (2016d)*

5.1.7 Comments on the modelling

The Aquaterra (2009a), RPS Aquaterra (2014c) and AGE (2016d) models simulate subsidence effects by changing the hydraulic conductivities of overburden layers to varying heights above the mined coal seam.

The subsidence impacts are based generally on the SCT (2008a) subsidence profile that distinguishes three zones above the coal seam: a caved zone, a tortuous cracking zone and a barrier zone. The PG seam overburden was divided to six layers so that caving and fracturing can be modelled.

At "lower subsidence" (during the mining of the PG seam) and at "higher subsidence" (ULD seam and below) the following arbitrary changes were made to hydraulic conductivities to simulate subsidence:

At "lower subsidence" (during the mining of the PG seam):

- Caved zone, 60 m to 70 m above the seam, layers six and seven, vertical hydraulic conductivity (Kv) was increased to 5 m/day (d) and the horizontal hydraulic conductivity (Kh) to 50 m/d.
- In the tortuous cracking zone, an additional 60 m to 80 m above the caved zone, both Kh and Kv were changed to 0.05 m/d.
- In the barrier zone, no change was implemented in hydraulic parameters.

For "higher subsidence" (ULD and below), the hydraulic parameters from SCT (2008a) were used as "guideline" only because they were known to overestimate the impacts.

- Caved zone: SCT (2008a) suggested Kv between 100 m/d and 1000 m/d, in the model 50 m/d was used for all Permian layers.
- In the tortuous cracking zone, the Kv was changed to 5 m/d.
- In the barrier zone, the Kv was changed to 5 m/d.

The AGE (2016d) model is based on the concepts of Kendorski (1993) and Tammetta (2015) that both discuss zones above the goaf which are summarised here after AGE (2015):

- <u>Caved Zone</u>: complete disruption of broken and rubble-sized strata extending from two to ten times (2 t to 10 t) the extracted seam thickness in height, above the mine roof.
- <u>Fractured Zone</u>: located above the caved zone to a height of 24 t to 30 t. The strata does not fall and detach, but cracks and settles. This results in fractures extending through individual beds, opening of bedding planes and shearing and dislocation of beds.

  The caved and fractured zones have increased vertical and horizontal transmissivity and storativity with both attributes decreasing exponentially with height above the seam roof.
- <u>Dilated Zone</u>: often referred to as the "Aquiclude Zone"; in which, the strata sag, allowing bed separations, but not connecting fracturing and drainage into the mine. Generally occurs at a height of 30 t to 60 t or greater. The water level of aquifers located in this zone may be lowered in response to the relatively rapid increases in void space laterally, that is, due to an increase in storage volume, but the water level generally recovers given sufficient time as voids are filled.
- <u>Constrained Zone</u>: occurs where the extracted seam is deeper than 60 t plus about 15 m, and is characterised by overall tensile strains of less than 1 mm/m. At this stress level, rock masses are not disrupted sufficiently to increase their hydraulic conductivity. Hence, there is no significant change in transmissivity or storativity and therefore aquifers in this zone are largely unaffected.

- Surface Fracture Zone: The surface fractures generally relate to panel and trough edges and extend to a depth of about 15 m from the topographic surface. If transmitted into soils, the soil properties may allow little or no crack development due to the plastic and non-brittle nature of many soils. If in rock, the natural pre-existing fracturing will be dilated, having little effect on continuity. The cracks are transmissive zones and the increased void space may result in a temporary lowering of shallow groundwater levels as the voids fill. The cracks will not provide pathways for deeper migration of groundwater unless extending into the "fracture zone". This may happen where the "dilated zone" is absent due to shallow mining, that is, shallow overburden thickness. Surface cracks also generally fill quickly with sediment or close due to spalling.

Combining the zones above with an SCT (2008b) study on the effect of panel width on subsidence, AGE (2015) concluded that a minimum overburden thickness of 300 m would have been required at Ashton to extension of subsidence impacts to the surface over a 205 m wide PG LW panel. The PG overburden at the northern end of LW6 is 106 m thick. Figure 5.1 illustrates the potential for surface cracking at WML115A, WMLC212 and WMLC236) hence the potential exists for the connective fracturing to extend from the goaf and connect with surface cracking. That said, the Bowmans Creek alluvium has not dewatered as predicted by HLA (2001) or partially dewatered as predicted by Aquaterra (2009).

At Ashton, theoretically there is potential for the dilated zone and the constrained zone to penetrate upwards to the ground surface and link up with the downward extending surface cracking. There is also potential for the fractured zone to penetrate the Lemington Conglomerate (later considered likely to be a coal seam) and numerous coal seams.

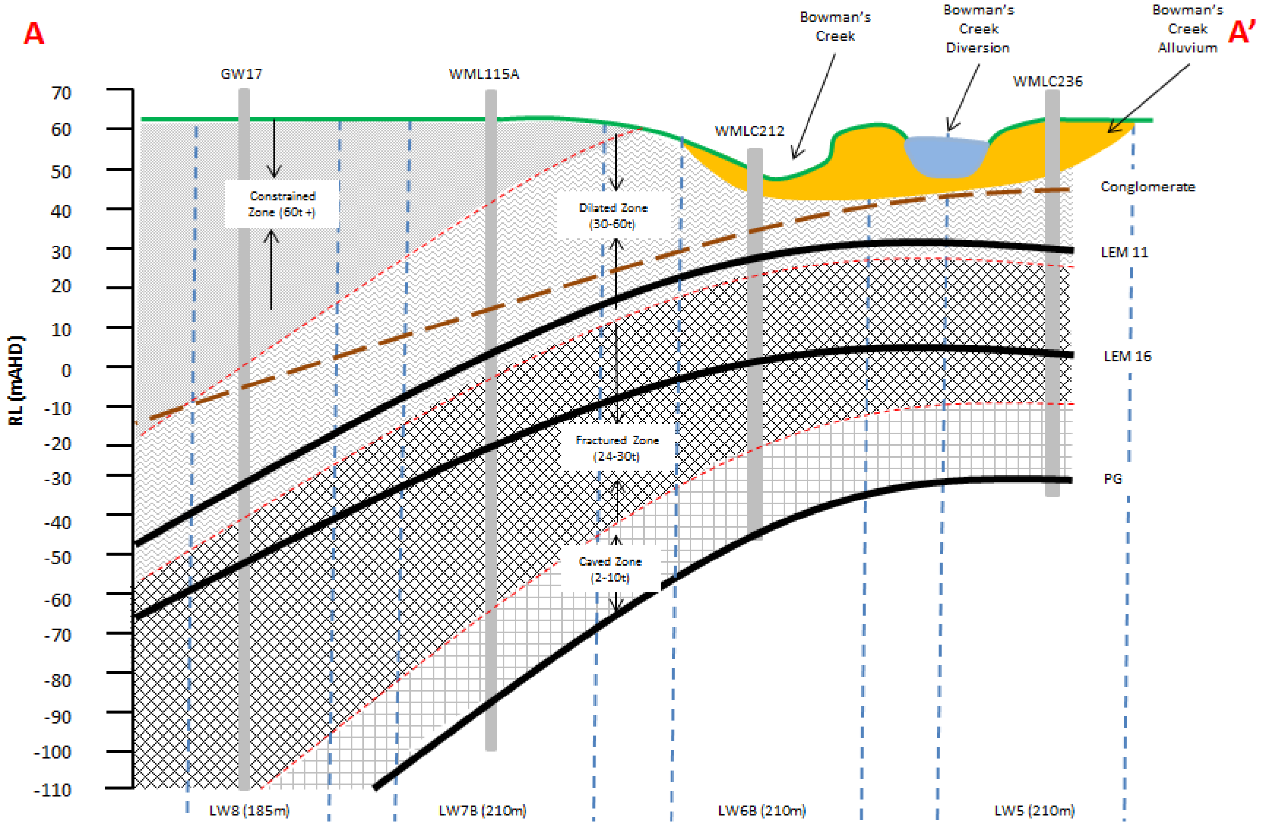


Figure 5.1 Schematic of subsidence induced fracture pattern – not to scale(from AGE 2015 and after SCT, 2008b)

5.1.8 Model predictions

Model predictions, where available, were presented in the individual tables accompanying the reviews of various reports in the sections above and in Appendix A. The model predictions are summarised based on AGE (2016c).

AGE (2016c) provides the most comprehensive comparison of the EIS (HLA Envirosciences, 2001), EA (Aquaterra, 2009a) and AGE (2016d) modelled and observed drawdowns. Table 5-3 of AGE (2016c) has been modified so that it now also includes completed mining impacts for all three models (Table 5.3).

The drawdown figures in Table 5.3 indicate that the AGE (2016d) model predicts more drawdown in the alluvium than the Aquaterra (2009a) or HLA Envirosciences (2001) models because the AGE (2016d) model represents the hydraulic conductivity in the alluvium by significantly higher values allowing better connectivity between the alluvium and underlying Permian strata.

The comparison of impacts summarised in Table 5.3 show a progressive and increased understanding of modelling techniques and groundwater system conceptualisation (based also on the increasing volume of data that became available over the years of investigation at Ashton). The greater volume of data allowed for the model assumptions to be refined, whilst still remaining conservative. The AGE (2016d) predictions were within the range of approved impacts and are based on more than 10 years of observation data that includes mining across the whole underground mine footprint at least once.

Table 5.3 Observed and modelled drawdowns and flows

Impact description	Location	Observed to time of modelling -March 2016 (to mid LW104 ULD)	2016 AGE model impact to end of LW204 - ULLD (March 2020)	2009 EA completed mine impact	2001 EIS completed mine impact
Drawdown	BCA	No drawdown observed in WMP bores (WMLP311, WMLP323, WMLP328, T2A)	<1 m (>1m - <2 m in a very small and localised area)	partly dewatered < 2 m	Partly dewatered
	GCA	No drawdown observed in WMP bores (WML120B, WML129, WML239)	<1 m (>1m - <2 m in a very small and localised area)	Generally <2 m	2.5 m
	HRA	No drawdown observed in WMP bores (WMLP279, WMLP280, WMLP337)	<1 m	Generally <1 m	No significant drawdown
Baseflow depletion	BC	-	0.06 ML/d	0.13 ML/d	0.4 ML/d
	GC	-	0.05 ML/d	0.23 ML/d	0.6 ML/d
	HR	-	0.02 ML/d	0.06 ML/d	0.3 ML/d
Mine Inflow		1.4 ML/d	1.6 ML/d	1.3 ML/d	1.6 ML/d

5.1.9 *Comparison between model predictions and licensing requirements over the life of the mine*

This summary is presented following AGE (2016c). Water licences held by ACOL are summarised in Table 5.4 based on Tables 1-1 and 7-4 of AGE (2016c). ACOL has a combined total surface water and groundwater entitlement of 2183 ML/yr (or 6.0 ML/d) assuming full allocation.

Table 5.4 ACOL water licences (after AGE, 2016c, Tables 1-1 and 7-4)

Licence No.	Reference	Category	Approved extraction (ML/yr)
Surface water			
WAL 872	20AL201030	Glennies Creek (General Security)	12
WAL 984	20AL201282	Glennies Creek (General Security)	9
WAL 15583	20AL204249	Glennies Creek (General Security)	354
WAL 997	20AL201311	Glennies Creek (High Security)	11
WAL 8404	20AL200491	Glennies Creek (High Security)	80
WAL 1358	20AL203056	Glennies Creek (Supplementary)	5
WAL 1121	20AL201625	Hunter River (General Security)	335
WAL 6346	20AL203106	Hunter River (Supplementary)	15.5
WAL 1120	20AL201624	Hunter River (High Security)	3
WAL 19510	20AL211015	Hunter River (High Security)	130
WAL 23912	20AL211423	BC (Unregulated River)	14
WAL 29565	20AL212286	BC (Unregulated River)	266
Groundwater			
WAL 29566	20AL212287	BC (Aquifer Access)	358
	20BL169508	Mining, Dewatering, Industrial	100
	20BL173716	Mining, Industrial	511
Source	**Current licence holding (ML/yr)**	**Predicted water inflow, Year 2016-2017 (ML/yr)**	**Predicted water inflow, end of mining 2031-2032 (ML/yr)**
HRA	0	15	18
HR	468	46	69
BCA	358	43	31
BC	280	73	103
GCA	0	32	24
GC	466	36	47
Permian	611	394	213
Total	2183	639	505

Figure 7-1 of AGE (2016c) indicates the predicted mine inflow will gradually decrease from 639 ML/yr (1.75 ML/d in 2017) to 505 ML/yr (1.38 ML/d in 2031-2032). Therefore, ACOL appears to have surplus of water from HR, BCA, BC and GC. The discrepancy of HRA and GCA licences is made up for by Ashton holding an excess of surface water licences for the surface water bodies of the respective alluvium and together Ashton holds adequate water licences for future mining activities.

5.2 Groundwater/surface water interaction

In general at site, the hydraulic connection between a surface watercourse, its alluvium, and the underlying Permian strata is complex and space and time dependent. Even adjoining reaches of a creek or river may be gaining / losing in the same time, and gaining reaches at certain times may become losing in other times. In addition, evaporation from the alluvium, if significant, has the potential to change the flow between river and alluvium.

The numerous groundwater investigation reports reviewed agree that most groundwater flow occurs in the alluvium, and in general, rely on a conceptual hydrogeological model that assumes groundwater in the alluvium recharges the relevant surface watercourse and in part the Permian strata. This is because the surface watercourses are perennial, and the groundwater heads indicate gradient/flow from the alluvium towards the watercourses (HR, BC and GC) most of the time. During flood events, and for limited periods following many larger runoff events, the water levels in the watercourses are above the groundwater levels, leading to a reversal of the normal flow gradient, and with surface water recharging the groundwater. Apart from the rare flood events, it is interpreted that the interchange between surface water and groundwater is generally limited to the regions close to the watercourse. Elsewhere within the alluvial floodplain areas, the normal pattern of groundwater discharge to the creek/river system prevails.

Observed groundwater level data also show that mining can cause increased groundwater inflow in areas where geological units sub-crop (namely, coal seams), which indicates that units at sub-crop are likely to have higher hydraulic conductivity than fresh (unweathered) units. This relationship also promotes recharge where coal seams sub-crop beneath saturated alluvium or regolith. When coal seams are depressurised, the depressurisation can extend to the sub-crop and potentially draw water from the saturated alluvium/regolith. However, groundwater levels within the alluvium have been observed to not be impacted significantly during mining and post mining, whilst the underlying Permian strata have been depressurised due to the effects of mining and subsidence.

Figure 4.2 shows the historic saturated thicknesses at a number of locations within the BCA. Figure 5.2 shows the historic water levels trend in BCA bores over LW6B and LW7B. Figure 5.3 shows the coal measures depressurising as a result of mining LW6B. The depressurisation extends above the PG Seam. The depressurisation effects are not seen in the Lemington 5-6 ply at 28 mBGL, nor in the Lemington 8 seam ply at the 50m level. However, depressurisation has occurred at all other piezometers below these two uppermost piezometers, although the hydrostatic head profile for WMLC361 indicates that only limited depressurisation of the Lemington 15 seam had occurred by completion of LW6B.

Apparent depressurisation below the PG may be due the effects on LW6B mining, although it is unclear whether this is an unloading effect of mining the overlying PG seam, or is a more regional effect from either the NEOC or other nearby coal mines.

The alluvium groundwater level trends match the cumulative rainfall departure (CRD) curve and are notably influenced by significant rainfall events. It is difficult to ascertain whether there are individual impacts associated with mining of individual LW panels; however, this may be explained by the storage available in the alluvium which would allow subsidence impacts to groundwater levels to be smoothed. Whilst the groundwater levels in the BCA are not significantly impacted to date, the water losses from the alluvium may be veiled by a loss of water from storage in the alluvium. The monitoring records reported that some alluvium bores in the BCA went dry during LW6B later recovered (e.g. T3-A, T5, T6 and WMLP311 – refer Section 4.3), but all later recovered when the alluvium re-saturated with the next recharge event. That said, the majority of the alluvium bore, even when subsided, maintained a constant saturated thickness indicating that dewatering of the BCA occurs in limited, localised extents.

AGE (2016d) groundwater impacts assessment of LW201-LW204 (ULD) replicated this mechanism adjusting the hydraulic parameters, kV/kH ratios and by weighting the calibration more toward the observed water levels in the alluvium. Standard automated calibration processes focus on the areas where large differences (or large residuals between observed and modelled heads) occur. For example, during calibration, more weight is given to large drawdowns observed within the Permian strata post mining and less to the minimal or no changes in alluvium calibration targets. The AGE model (2016d) is calibrated with a focus on the observed alluvium water levels. This provided a greater focus on impacts to alluvium, whilst remaining statistically calibrated to the hard rock aquifer. A satisfactory calibration was achieved with the AGE numerical groundwater model and steep head changes were adequately reproduced by the model.

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Figure 5.2 BCA water levels vs CRD

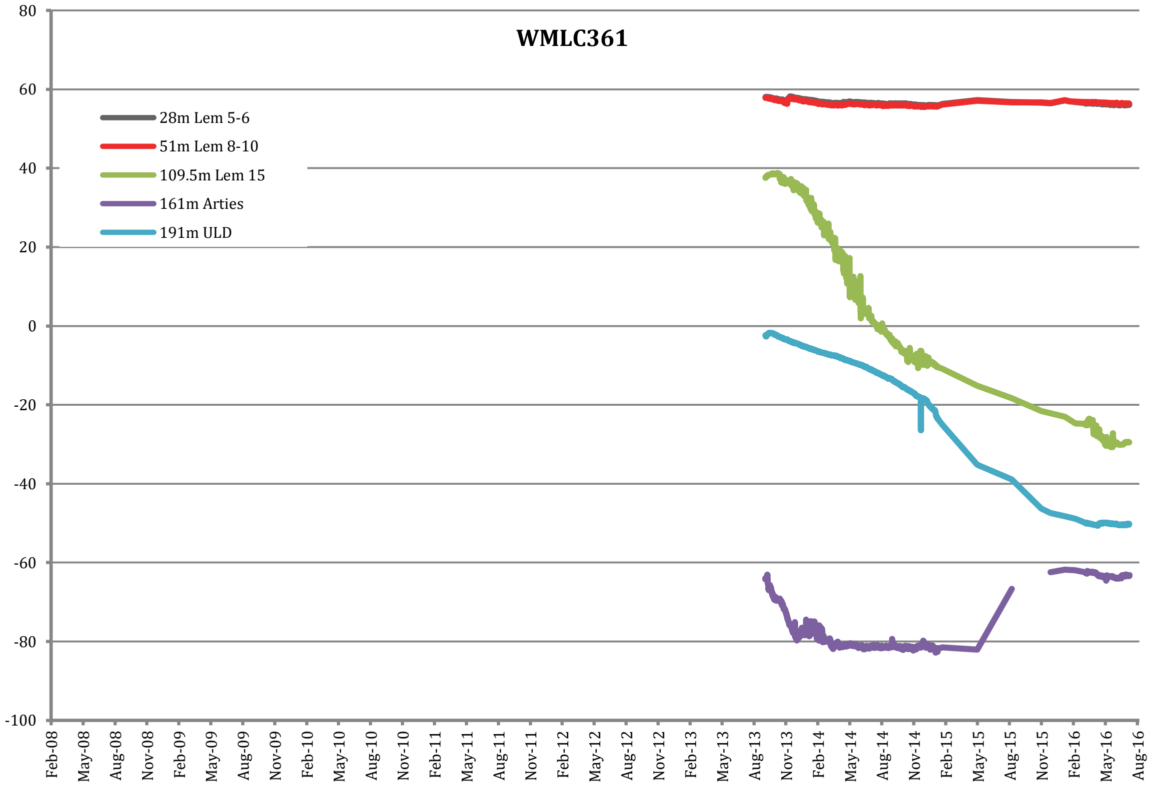

Figure 5.3 WML361 vibrating wire piezometer pressure head

5.3 Underground inflows

Progressive groundwater inflow into the underground workings is plotted on Figure 5.4, together with the inflows predicted by the three models of relevance to this review, viz:

- Bowmans Creek diversion EA model (Aquaterra, 2009) – which was the basis of the modification permitting longwall extraction beneath the Bowmans Creek alluvial floodplain.
- Ashton Coal Groundwater Model Update (RPS, 2014) – which was used to support a previous longwall extraction plan assessment.
- AGE (2016) model – which is in current use for prediction of impacts, and has been used to support the LW201-204 Extraction Plan.

Total and individual seam inflows are discretised, as are contributions from the various groundwater sources. These inflow predictions shows a peak in October 2013, which coincides with the inflow event of the same date. Whilst it does not replicate the exact inflow rate, a peak is replicated indicating that the conceptualisation is accurate.

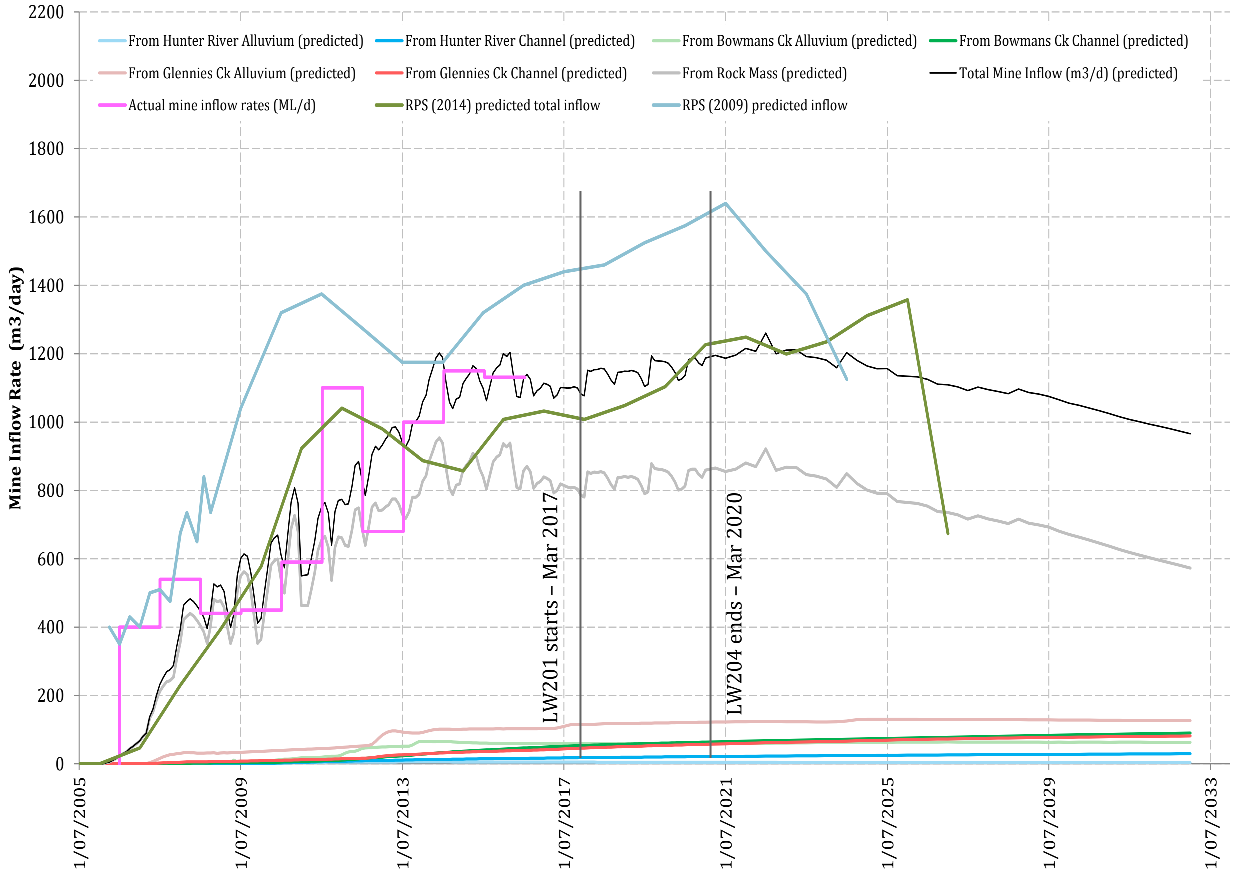

Figure 5.4 Predicted Ashton underground mine inflows

5.4 Impacts on alluvium

As discussed in Sections 4.1and 4.3, a small number of alluvium bores appear to have been impacted by mining over the years. These bores include WML120B screened in the BCA and T3A, T5, T6, and WMLP311 all screened in the BCA.

The water level in WML120B, located between BC and LW1, has not declined at all during underground mining at Ashton. The EC in the bore has varied with a decline from between 1,665 and 1,995 mg/L in early 2006 to between 438 and 865mg/L after November 2009. This bore is located close to the PG seam subcrop, which likely depressurised during LW1 tailgate. The depressurisation caused alluvium water to recharge the coal seam causing the decline in EC in the alluvium locally. The large difference in storage between the alluvium and the coal seam has allowed the alluvium to recharge the coal seam without causing a water level decrease in the alluvium.

T3A, T5, T6, and WMLP311 are located in the BCA area. The water levels in these bores have declined coincident to mining beneath those bores (refer Figure 4.2). Each of the bores are located close to the edges of longwall panels (refer Figure 2.5) which are the areas potentially most impacts by localised surface cracking after longwall mining. These surface cracks are shallow, generally do not extend to the subsidence profile and re-seal with fines and through spalling; however, they may potentially be a source of localised dewatering of alluvium. The water levels of each of the bores recovered to it previous level following the next recharge event. The impacts measured in these bores have been seen to be transitory and the BCA generally remains unimpacted by underground mining at Ashton.

6 Evaluation

AGE have been commissioned by Yancoal to prepare a concise report outlining how groundwater monitoring data at Ashton underground coal mine compares to impact assessments and models that have been relied upon for planning purposes throughout the mine's life. The request follows consultation with DPE and DPI Water on the LW201 to LW204 extraction plan. During consultation it was acknowledged that the groundwater environment at Ashton Coal is very complex, and vast amounts of monitoring data, impact assessment and modelling have been undertaken since the planning phases of the operation. It was agreed that this report would assist in the understanding of the site to date and could be useful in development and assessment of future impact assessments and approval processes.

Following an overview of mining and hydrogeology, a review of 23 publications, dated between 2001 and 2017, was completed. Analysis, based on the reviews (presented in Section5.1) shows the development of a robust and defendable understanding of the hydrogeological environment at Ashton Coal Mine.

Over the project life, a number of model refinements and improvements have been made, each making use of advances in modelling technique and software improvement, as well as the opportunity to calibrate the model against the growing dataset from the very extensive monitoring network. Each subsequent model has also taken advantages in improvements in modelling technology over this time. The reliability of model predictions is continually improved by having been able to calibrate the model against monitoring data over the full lateral extent of underground mining, which includes an eastern area with relatively shallow overburden and a western part beneath the Bowmans Creek floodplain, and through the mining of two seams and commencement of the third seam.

Each new model calibration constitutes an effective validation of the model due to increasing size of the calibration dataset, which is the monitoring data collected during the mining to date. Hence the current model is considered to have a higher level of reliability than typical longwall mining project models. Nevertheless the model is also considered to be adequately conservative.

The groundwater models (both current and historic) have predicted that the alluvium is likely to be impacted to some degree; however, no significant impacts to the alluvium have been recognised to date. This indicates that the groundwater model is a conservative tool for assessing potential impacts to the surface water systems and associated alluvium.

The analysis of monitoring against the modelled predictions (discussed in the relevant EIS's) demonstrates that Ashton's measured groundwater impacts are well within approved limits.

The various models throughout the life of mine have guided the surface and groundwater licences Ashton Coal holds and these are demonstrated to have been sufficient for operations to date. The latest model indicates adequate water licences are held for future mining activities.

Observed dewatering rates when corrected for water imported to the mine and changes in water stored in-mine, are a direct measure of groundwater inflow in the underground mine. The AGE (2016d) groundwater model was calibrated to these measured underground inflows, further increasing the model's representativeness of the natural hydrogeological environment. A significant, short term increase in the underground mine dewatering rate was measured in October 2013 and the AGE (2016d) model was able to replicate the timing and order of magnitude of this inflow event. This demonstrates that the model not only replicates the hard rock drawdown but also the groundwater flow into the underground mine.

The model was informed by site-specific and Hunter Valley-specific aquifer data, specifically hydraulic conductivity measurements. A formula was used to model the relationship of decreasing hydraulic conductivity of the geological units with increasing depth. This allowed the model to provide a realistic representation of the hydraulic parameters used in the model.

Extensive assessment has been undertaken on the potential impacts to the groundwater system caused by mining induced subsidence. Key aspects of the understanding of subsidence impacts to groundwater systems were extracted from Kendorski (1993), SCT (2009) and Tammetta (2015). The modelling undertaken by Aquaterra (2009), RPS Aquaterra (2014) and AGE (2016d) showed a clear understanding that longwall mining significantly impacts the overlying strata, and that this process needed to be incorporated into the numerical groundwater model. The most recent model (AGE, 2016d) incorporated the cumulative understanding of the assessments to provide a suitable representation of the subsidence impacts on the groundwater system.

Overall, the groundwater modelling undertaken for the LW201-LW204 extraction plan groundwater impact assessment utilised a model that was:

- informed by many years of observation data;
- based on a well-founded hydrogeological conceptual model;
- focussed on key risk areas, such as impacts to alluvium and surface water bodies;
- calibrated with a focus on observations in alluvium monitoring bores and underground inflows;
- based on aquifer data that was relevant and site/Hunter Valley specific; and
- incorporated a good understanding of the impact of mining induced subsidence on the groundwater system.

This has allowed for a robust and defendable representation of the groundwater system to be used to develop predictions of mining related impacts to groundwater at Ashton.

The review of this report by the DPE in March 2018 with additional information requested to fully address the DES requirements is provided in Appendix C.

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Appendix A Detailed review of historic reports

A1 Review of HLA Envirosciences (2001)

HLA-Envirosciences, 2001. "*Environmental Impact Statement, Ashton Coal Project: Appendix H – Groundwater Hydrology and Impact Report*" (Table A 1.1).

1. This original EIS impact assessment was presented as Appendix H of the EIS. However, figures and appendices were not available and therefore could not be sighted for the purposes of this report.
2. Modelling was implemented on the basis of a conceptual hydrogeology that recognised two aquifers, one in the shallow alluvium and one in the fractured Permian coal seams.
3. The hydraulic conductivity for modelling the BCA/GCA is 0.5 m/d and 45 m/d for the HRA.
4. The hydraulic conductivity for coal seams was considered as approximately five times that of the overburden, overall between 0.001 m/d and 0.4 m/d.
5. The model consists of seven layers, layer 1 being the alluvium and subsequent layers incorporating both the coal seams and the appropriate overburden.
6. Groundwater quality was summarised as:
    - Brackish, 6000 µS/cm to 16000 µS/cm in the Permian coals.
    - Slightly brackish to brackish in the BCA, near the creek 900 µS/cm to 1100 µS/cm increasing to 6000 µS/cm at alluvial margins.
7. Surface water quality was summarised as:
    - BC at 50% of flow ~ 1500 µS/cm, and
    - GC 50% of flow ~ 400 µS/cm.
8. Recharge was considered as approximately 0.5% to 1% of annual rainfall; groundwater discharge is upward from Permian (pre-mining) where it mixes with water in the alluvium.
9. Potentiometric surface for Permian was presented in Figure 8 (not sighted) and apparently indicates flow to the west and south.
10. Figures and appendices are not available for this report. Predictions are therefore summarised from the main report text of HLA Envirosciences (2001) as follows:
    - Groundwater inflow to the underground mine – Section 5.2 (page 17) referring to Figure 11 of the EIS Appendix H.
    - Seepage losses from the GC, BC and HR alluvial aquifer systems – Section 5.3 (pages 17-18) referring to Figure 13 of the EIS Appendix H.
    - Drawdowns – Section 5.4 (page 18) referring to Figures 14-16 of the EIS Appendix H.

Table A 1.1 Review of Impact Assessment Report, HLA, October 2001

Environment	Predicted impact (HLA, 2001)	Actual impact	Notes
Permian strata	Drawdown to the base of coal measures mined and steep drawdown cone on the sides	N/A	No detailed calibration statistics is provided for the model apart from a comparison between predicted and measured groundwater heads for three piezometers (page 17)
BCA	Partly dewatered		
GCA	< 2.5 m drawdown		
HRA	No significant drawdown		
BC Streamflow	reduction of 0.4 ML/d		
GC streamflow	reduction of 0.6 ML/d		
HR flow	reduction of 0.3 ML/d		
Mine Inflows	~1.6 ML/d		

A1.1 Review of Ashton Coal (2005)

Ashton Coal Operations Pty Limited, 2005. "*Annual Environmental Management Report, 2004 / 2005*", September 2005.

1. Page 63 reports that Ashton monitored 20 groundwater bores during the reporting period, primarily to collect background data for the proposed underground mine: standing water level, pH, electrical conductivity (EC), TSS, TDS, hardness, and oil and grease.

A1.2 Review of Ashton Coal (2006)

Ashton Coal Operations Pty Limited, 2006. "*Annual Environmental Management Report, 2005 / 2006*", September 2006.

1. As part of the Subsidence Management Plan process, a full review of the EIS modelling studies (HLA, 2001) was undertaken determine the likely groundwater inflows to LW1 to LW4 (page 88).
2. Groundwater inflows during the first 3 years of underground mining, which covers the PG seam extraction from LW1 to LW4, were predicted to reach a maximum of 3.5 L/s. Inflows in the development headings for LW1 already exceeded this rate suggesting that the model predictions may be under-estimating the potential inflow rates.
3. Ashton has established an Aquaclude Study Group, which combines input from experts in the fields of geology, groundwater, mine planning and subsidence (page 89).
4. Ashton monitored 19 groundwater bores during the reporting period, primarily to collect background data for the proposed underground mine: standing water level, pH, EC, TSS, TDS, hardness, and oil and grease were monitored. The data and time-series charts are presented.

A1.3 Review of Peter Dundon & Associates Pty Ltd (2008)

Peter Dundon & Associates Pty Ltd, 2008. "*Groundwater Report*", February 2008. Appendix 2 of Ashton Coal Operations Pty Limited, Annual Environmental Management Report, 2006/2007 (Table A 1.2).

1. This report covers the reporting period of 1 September 2006 to 1 September 2007 and accompanies the Ashton Coal Operations Pty Ltd 2006-2007 Annual Environmental Management Report.
2. The report details the monitoring and groundwater management activities for the project. The results of monitoring are presented, together with analysis of trends. The groundwater response to the mining operations has been compared with impacts predicted for this stage of mining in the EIS and the SMP for LW1 to LW4.
3. Up to 91 piezometers were monitored during the period.
4. Average total groundwater inflows to the underground mine during the reporting period were 0.4 ML/d compared with 0.45 ML/d predicted in the EIS for this stage of mining.
5. The average rate of seepage from the GCA calculated during the reporting period was under 0.16 ML/d, less than the rate of 0.17 ML/s predicted in the EIS for this stage of mining.
6. Large drawdown responses have been observed in restricted areas local to LW1 and LW2 in the PG seam and to a lesser extent in the overlying coal measures.
7. Drawdowns in the alluvium have been limited to the small area between the mine and GC. The magnitude of drawdown to date (0.5 m at WML120B) is smaller than the 1.3 m drawdown predicted for this location in the EIS at this stage of mining.
8. No mining related drawdown has been observed in either the HRA or BCA.
9. **In conclusion, impacts have in all aspects been at or below those predicted for this stage of mining in the EIS and the SMP for LW1 to LW4.**
10. Alluvium piezometers mostly show the influence of "*rainfall recharge*", in June and August 2007 (Figure 7). Prior to June 2007, groundwater levels in the BCA were at close to long-term lows, and BC itself had ceased to flow:

    "Flow ceased in BC during the drought, prior to the major rainfall event in June 2007. During the no-flow period, water in disconnected pools was sustained by baseflow seepages, which led to increases in salinity, to a high of 14,000 µS/cm in one instance" (page iii).

11. After the June 2007 event, the EC of BC at SM4 reduced to < 1000 µS/cm (from 14000 µS/cm; Figure 13).
12. Both WML119 and WML120A (both in PG) showed major water level rises (6 m and 4 m, respectively, Figure 3) in response to a "*large rainfall event*" of 8-10 June 2007, and a further smaller recharge event on 19-21 August 2007 (page 7). WML 120B and WML129 (at the southern end of LW1) show a 3 m and 7.5 m increase, respectively in the GCA (Figure 8).
13. Figure 7 also indicates significant rises (up to 2 m) in groundwater levels in the GCA and BCA following June 2007. It is likely that the rises shown in Figure 7 are less than those in reality because the manual weekly measurements mask the true size of individual events. For WML120B, both datasets are available and the rise is 1.5 m (Figure 7) based on manual measurements and 3 m based on a datalogger (Figure 8).
14. The hydrographs in Figures 3 and 8 appear to be similar to surface water hydrographs.
15. The June 2007 recharge event restored alluvium groundwater levels to close to long-term highs (page 7).

Table A 1.2 Review of Peter Dundon & Associates Pty Ltd (2008)

Environment	Predicted impact (HLA, 2001)	Actual impact	Notes
Permian Strata	Drawdown to the base of coal measures mined and steep drawdown cone on the sides	Up to 50 m drawdown in PG and up to 15 m drawdown in Lemington 19 seam (Fig.2)	The greatest changes occurred in the PG seam close to the underground mine, WML20, WML21, WML106-84m, WML115-VW144m and WML189-VW93m (Figure 2).
BCA	partly dewatered	no significant drawdown	
GCA	< 1.3 m drawdown	0.5 m in WML120B	
HRA	no significant change	no significant drawdown	
BC Streamflow	reduction of 0.4 ML/d	no significant impact	
GC streamflow	reduction of 0.17 ML/d	0.16 ML/d	Calculated from salt balance
HR flow	reduction of 0.3 ML/d	no significant impact	
Mine Inflows	0.45 ML/d	0.4 ML/d	

A1.4 Review of Aquaterra (2008)

Aquaterra Consulting Pty Ltd, 2008. "*Groundwater Report*", December 2008. Appendix 2 of Ashton Coal Operations Pty Limited, Annual Environmental Management Report, 2007/2008 (Table A 1.3).

1. This report covers the reporting period 1 September 2007 to 1 September 2008.
2. The report details the monitoring and groundwater management activities for the project. The results of monitoring are presented, together with analysis of trends. The groundwater response to the mining operations has been compared with impacts predicted for this stage of mining in the EIS and the SMP for LW1 to LW4.
3. Average total groundwater inflows to the underground mine during the reporting period were 0.5 ML/d compared with the 0.9 ML/d predicted in the EIS for this stage of mining.
4. The average rate of seepage from the GCA calculated during the reporting period was under 0.17 ML/d, less than the rate of 0.24 ML/d predicted in the EIS for this stage of mining.
5. Drawdown responses were observed in an area local to LW1 and LW2, in the PG seam and to a lesser extent in the overlying coal measures. Drawdowns in the alluvium have been limited to the small area between the mine and GC. **The magnitude of drawdown to date (1 m at WML120B) is less than the 1.3 m drawdown predicted for this location in the EIS at this stage of mining.**
6. No mining related drawdown was observed in either the HRA or the BCA, or in the GCA east of GC.
7. Groundwater levels in the BCA were generally stable, and show periodic influence of recharge, in November-December 2007, February 2008, June 2008 and September 2008 (Figure 3).
8. Similar responses were observed in the GCA (Figure 4). The continuous record from dataloggers in WML120B and WML129 (located between LW1 and GC) show a very slight upward trend overall, together with short-term sharp responses to rainfall recharge events (Figure 4). They appear to be similar to surface water hydrographs. The GCA bores show no additional impacts from mining of LW1 to LW3.

9. Piezometers completed into the upper weathered zone of the Permian coal measures in the BC floodplain area show no impact on groundwater levels from underground or open cut mining (Figure 6). Several of these bores show a direct response to rainfall recharge events, especially in May 2005 and June 2007.
10. Piezometers at deeper levels in the Permian only show recharge response where located close to outcrop adjacent to GC (e.g. WML119 and WML120A – see Figure 9).
11. The monitoring program has been carried out in accordance with the Groundwater Management Plan (GWMP) and the requirements detailed in the consent conditions. Impacts have in all respects been at or below those predicted for this stage of mining in the EIS and the SMP for LW1 to LW4.

Table A 1.3 Review of Aquaterra (2008)

Environment	Predicted impact (HLA, 2001)	Actual impact	Notes
Permian Strata	Drawdown to the base of coal measures mined and steep drawdown cone on the sides	Up to 75 m drawdown in PG and up to 30 m drawdown in Lemington seams (Fig.2)	The greatest change in the PG seam close to the underground mine, WML20, WML21, WML106-84m, WML115-VW144m and WML189-VW93m (Figure 2).
BCA	partly dewatered	no significant drawdown	
GCA	< 1.3 m drawdown	1 m at WML120B	
HRA	no significant change	no significant drawdown	
BC Streamflow	reduction of 0.4 ML/d	no significant impact	
GC streamflow	reduction of 0.24 ML/d	0.17 ML/d	
HR flow	reduction of 0.3 ML/d	no significant impact	
Mine Inflows	0.9 ML/d	0.5 ML/d	

A1.5 Review of Aquaterra (2009a)

Aquaterra Consulting Pty Ltd, 2009a. "*Bowmans Creek Diversion: Groundwater Impact Assessment Report*" (Table A 1.4).

1. A new model was created with 15 layers. Significant changes from HLA Envirosciences (2001) include the introduction of separate layers for coal seams and overburden and the division of the PG overburden so that caving and fracturing can be modelled.

2. The concepts are similar to HLA Envirosciences, 2001, i.e most groundwater flow is through a shallow granular aquifer system in the unconsolidated sediments of the alluvium associated with BC, GC and HR. Some groundwater flows through a fractured rock aquifer system in the coal measures (groundwater flow mainly in the coal seams).

3. Table 4.3 lists representative hydraulic conductivities, ranges and medians that were subsequently used in modelling:
   - BCA - 0.0002 m/d to 15 m/d, median 0.7 m/d;
   - GCA - 0.07 m/d to 180 (?) m/d, median 0.6 m/d;
   - HRA - 50 m/d;
   - PG Coal Seam - 0.01 m/d to 10 m/d, median 0.04 m/d;
   - Other coal seams – 2 x 10^{-3} m/d to 0.03 m/d, no median presented; and
   - Interburden/overburden - <1 x 10^{-6}m/d to 8 x 10^{-3} m/d, median 3 x 10^{-4} m/d.

4. The highest value of 10 m/d for the PG seam is from WML120a and is atypical for coal seams in the Hunter Valley. Bore WML120a is located close to outcrop, up-dip from the underground mine, and the result is believed to be more indicative of weathered PG close to outcrop, rather than the coal seam at depth below the base of weathering. Nearby drilling at other sites between the outcrop/subcrop and the eastern edge of LW1 indicates that the "*enhanced permeability*" is limited to much less than 100 m from outcrop (page 47). This point refers specifically to the potential coal seam/alluvium interaction at subcrop near GC.

5. On page 47 it is concluded that "*There is only limited hydraulic connection between alluvial deposits and shallow weathered Permian sediments. This is evidenced by distinctly different groundwater levels, differences in groundwater quality, and differing responses to recharge or mining activity. This is believed to be due to the presence of low permeability clays at the bottom of the alluvium that tend to block any vertical fractures that may be present within the underlying Permian strata.*" Whilst the statements presented in points 4 and 5 appear contradictory, the limited vertical connectivity (point 5) refers to the potential vertically interaction/connectivity of the alluvium with the underlying coal measures around BC and GC. interaction. The site specific data from BC appears to show that the BCA and underlying coal measures have differing water tables.

6. Pre-mining groundwater heads (page 48) were between 61 mAHD and 65 mAHD for the Permian strata; and between 55 mAHD and 60 mAHD for the alluvium, based on data from HLA (2001). Groundwater heads were generally higher in the Permian than those in the alluvium and there was a general trend of increasing potentiometric head with depth.

7. In the alluvium, groundwater flow generally follows the surface water flow and within the alluvium from the margins in towards the surface watercourse.

8. Page 83: "*A large recharge event in June 2007 during LW1 extraction, and several smaller rainfall recharge events in September 2008, February 2009 and April 2009 during the LW3 extraction, caused water levels in the alluvium to rise by up to 1 m or more in all bores monitored close to Glennies Creek. A similar recharge response was observed in coal measures bores close to outcrop (eg Pikes Gully bores WML119 and WML120A). However, bores distant from outcrop showed only limited or no response to these recharge events".* An alternative explanation is recharge from GC (bank recharge) that diminishes with increasing distance from the creek.

9. Although drawdown impacts on the PG seam are large, heads indicate that the drawdown effects are localised, with steep gradients around the mining perimeter. During mining, WML189 and WML191 show that there is significant and rapid depressurisation of Permian strata up to 50 m above the coal seam.
10. Figure 4-17 indicates that the ?actual mine inflows and EIS predictions diverge as early as 2007 and by 2009, predicted inflows are more than twice those observed.
11. Outside the mined area, large impacts are limited to the PG seam, and overlying seams show a muted, slow response.
12. Several piezometers have shown partial recovery of groundwater levels (page 49) after initial drawdown impacts from mining (WML107-98m set at the Lemington 19 Seam).
13. Table 6-1 shows the layer thicknesses and hydraulic parameters used in the model. The most transmissive layer is Layer 1 representing various alluviums and the weathered bedrock regolith. Coal seams typically have 0.0 x m/d horizontal hydraulic conductivity while overburden typically has 0.00 x m/d, about an order of magnitude less.
14. Horizontal to vertical hydraulic conductivity ratios in the model (Table 6-1) are typically 100:1 for coal seams and interburden, and 10^5:1 or even 9×10^6:1 for the alluvium.
15. The model simulates subsidence effects based on the SCT (2008a) report. SCT (2008a) distinguishes three zones above the coal seam: a caved zone, a tortuous cracking zone and a barrier zone.
16. The PG seam overburden was divided to six layers so that caving and fracturing to different heights can be modelled.
17. At “lower subsidence” (during the mining of the PG seam) the following changes were made to simulate subsidence:
    - Caved zone, 60 m to 70 m above the seam, Layers 6 and 7, vertical hydraulic conductivity (Kv) was increased to 5 m/d and the horizontal hydraulic conductivity (Kh) to 50 m/d.
    - In the tortuous cracking zone, an additional 60 m to 80 m above the caved zone, both Kh and Kv were changed to 0.05 m/d.
    - In the barrier zone, no change was implemented in hydraulic parameters.
18. For “higher subsidence” (ULD and below), the hydraulic parameters from SCT (2008a) were conservatively used as “guideline” even though they were known to overestimate the impacts based on attempting to calibrate the model to observed impacts during mining of the PG seam.
    - Caved zone, SCT (2008a) suggested Kv between 100 m/d and 1000 m/d, in the model 50 m/d was used for all Permian layers.
    - In the tortuous cracking zone, the Kv was changed to 5 m/d.
    - In the barrier zone, the Kv was changed to 5 m/d.
19. Table 6-2 indicates the hydraulic parameters used for subsidence modelling. The changes appear to leave sharp contrasts in hydraulic conductivity. There is a three-order-of-magnitude change between layers six and five (boundary between the caved and tortuous cracking zone) in Kh after the mining of the PG seam.
20. Figure 6-7 indicates that total mine inflows were matched by the Aquaterra (2009a) model much better than the EIS did. Figure 6-8 indicates predicted mine inflows up to approximately 1.6 ML/d in 2022/23.
21. Figure 6-15 shows modelled baseflows in the BC, GC and HR.
22. Overall, Aquaterra (2009a) predicts less impact (mine inflows, drawdown and baseflow reduction) than those predicted by HLA Envirosciences (2001).

Table A 1.4 Review of Aquaterra (2009a)

Environment	Predicted Impact (Aquaterra, 2009a)	Actual Impact	Notes
Permian strata	Target coal seams and overburden within the mine footprint are to be essentially dewatered. Outside of the mine footprint, the main impact to the south and south-east of the mine, drawdowns of 10 m or more could occur up to 2 km from the mine following mining to the LB seam.	Steady model calibration used 112 targets, 67 in the Permian and 45 in the alluvium. SRMS was 11.7%. Figure 6-6 shows the steady state calibration scattergraph.	Predicted impacts are cumulative, i.e. include mining the PG seam to the end of mining. Table ES1 compares predictions to those by HLA Envirosciences, 2001 (EIS).
BCA	Fig.7-1 and 7-2 show predicted drawdowns at the end of ULD and LB mining, respectively. Predicted impacts at the end of ULD mining on the BCA are limited to south of the New England Highway. The alluvium that is affected, between the highway and the HR, is predicted to be largely dewatered and saturated alluvium will only remain in the southern end of this reach, between the HR and the BC western diversion, and in a small area of alluvium around the section of creek that is left in place between the two proposed diversions. Drawdown impacts vary from around 0.5 m to 2 m in that area.		
GCA	Generally < 0.1 m drawdown, maximum 0.4 m in text but Fig.7-1 and 7-2 show up to 1 m drawdown.		
HRA	< 0.1 m drawdown		
BC Streamflow	Fig.6-15, a reduction of 0.1 ML/d		
GC streamflow	Fig.6-15, a reduction of 0.23 ML/d		
HR flow	Fig.6-15, a reduction of 0.06 ML/d		
Mine Inflows	Fig.6-8. Predicted to reach an initial peak of ~1.4 ML/d during the start of the mining of the ULD, inflow rates increase again once mining of the ULLD commences and connective cracking with the base of the BCA occurs. Maximum inflows of 1.6 ML/d are predicted to occur near the start of the LB seam mining.		

A1.6 Review of Aquaterra (2009b)

Aquaterra Consulting Pty Ltd, 2009b. *"Groundwater Report"* December 2009. Appendix 2 of Ashton Coal Mine, 2009 Annual Environmental Management Report (Table A 1.5).

1. This report covers the reporting period 1 September 2008 to 1 September 2009.

2. The report details the monitoring and groundwater management activities for the project. The results of monitoring are presented, together with analysis of trends. The groundwater response to the mining operations has been compared with impacts predicted for this stage of mining in the EIS and the SMP for LW1 to LW4.
3. Net groundwater inflows to the underground mine were averaging 0.4 ML/d over the 2008-2009 review period. The inflow rate predicted in the EIS for this stage of underground mining was between 1.2 to 1.4 ML/d; Figure 16.
4. The average rate of seepage from the GCA calculated during the reporting period was under 0.17 ML/d, less than the rate of 0.24 ML/d predicted in the EIS for this stage of mining.
5. During the reporting period, groundwater levels in the BCA were generally stable, and show the influence of rainfall recharge in September 2008, February 2009 and April 2009 (Figure 3). The long-term hydrographs of alluvium bores in the BC area do not show any evidence of mining-induced impacts.
6. Similar responses were observed in the GCA (Figure 4). The continuous records from WML120B and WML129 (located between LW1 and GC) show a very slight upward trend overall, together with short-term sharp responses to rainfall recharge events (Figure 4).
7. *"Piezometers in seams below the Pikes Gully seam (Upper Liddell Seam down to the Hebden Seam) have not shown any significant drawdown during LW1-4 extraction (Figure 11). However, several piezometers continue to show a slow but steady downward trend, which is considered to be unrelated to the Ashton underground mining and open cut mining, but is likely to be a regional response to general mining activity in the broader region" (*page 11).
8. In conclusion, the monitoring program has been carried out generally in accordance with the Ashton GWMP and the requirements detailed in the consent Conditions. All groundwater-related impacts from underground mining during the review period were below the levels predicted in the EIS (2001), and in the SMP for LW1 to LW4.

Table A 1.5 Review of Aquaterra (2009b)

Environment	*Predicted Impact (HLA, 2001)*	*Actual Impact*	*Notes*
Permian Strata	*Drawdown to the base of coal measures mined and steep drawdown cone on the sides*	*Up to 90 m drawdown in PG and up to 40 m drawdown in Lemington seams (Fig.8-10)*	-
BCA	*partly dewatered*	*no significant drawdown*	-
GCA	*< 1.3 m drawdown*	*not provided but appears to be 0.4 m at WML120B*	-
HRA	*no significant change*	*no significant drawdown*	-
BC Streamflow	*reduction of 0.4 ML/d*	*no significant impact*	-
GC streamflow	*reduction of 0.24 ML/d*	*0.12 ML/d*	-
HR flow	*reduction of 0.3 ML/d*	*no significant impact*	-
Mine Inflows	*1.2-1.4 ML/d*	*0.4 ML/d*	-

A1.7 Review of Aquaterra (2010)

Aquaterra Consulting Pty Ltd, 2010. "*Groundwater Report*", October 2010. Appendix 2 of Ashton Coal Operations Pty Limited, Annual Environmental Management Report, 2009/2010 (Table A 1.6).

1. This report covers the reporting period 1 September 2009 to 1 September 2010.

2. The report details the monitoring and groundwater management activities for the project. The results of monitoring are presented, together with analysis of trends. The groundwater response to the mining operations has been compared with EIS studies (HLA, 2001) and studies carried out in support of the LW1-4 SMP (Peter Dundon and Associates, 2006).
3. Apart from the initial drawdown observed in the GCA during the mining of LW1, no mining impacts have been observed in the GCA, BCA or HRA as a result of underground mining.
4. Large drawdown responses in the PG seam and Permian overburden units have been observed in the immediate LW1 to LW6 mining area. Piezometers located in the barrier between LW1 and GC have demonstrated that groundwater levels continue to show steady recovery of approximately 0.7 m/yr, approximately 80% of the initial 3.0 m drawdown has now been recovered. The partial recovery in water levels suggests a steady reduction in the hydraulic conductivity of the PG seam between LW1 and the subcrop line beneath the GC floodplain, possibly due to delayed response to the in-seam grouting carried out in 2007. The gradual recovery in water levels has been accompanied by a gradual reduction in the rate of underground seepage inflows to the tailgate 1 backroad weir.
5. Total groundwater inflows to the underground (0.35 ML/d to 0.86 ML/d) have been below inflow rates predicted in the EIS (1.4 ML/d).
6. Actual seepage inflow rates from the GCA (up to 0.086 ML/d), have been below the EIS predictions of 0.26 ML/d, and there were no seepage losses from BCA. The actual seepage rates have therefore continued to be less than the maximum rates contained in the EIS, LW1 to LW4 and LW5 to LW9 SMP predictions.
7. In conclusion, the monitoring program has been carried out in accordance with the Ashton GWMP and the requirements detailed in the consent conditions. **All groundwater-related impacts from underground mining during the review period were below the levels predicted in the EIS (HLA, 2001), and in the LW1 to LW4 SMP (Peter Dundon and Associates, 2006) and LW5 to LW9 (Aquaterra, 2008a) groundwater assessments.**
8. No additional drawdown occurred to the drawdown of 0.4 m, observed in alluvium monitoring bore WML120B between June 2006 and December 2006, coinciding with the advance of TG1A past the bore location (Figure 3). All drawdown impacts occurred during the development heading stage of LW1 and no further drawdown occurred in the alluvium bores during subsequent extractions of LW1 to LW6.
9. Water table responses in GCA to the east of GC are consistent with the rainfall controlled natural recharge and discharge responses also observed in the HR and BCA (Figure 4 and Figure 5).
10. Piezometers which monitor the BCA and HRA have not shown any response to mining. Figure 4 and Figure 5 show an upward trend in response to rainfall recharge, starting in June 2010. Prior to this a gradual recession following the previous, albeit small, recharge event in April 2009, was evident across all piezometers, which was concurrent to the breaking of the "millennial drought". The recession of the water table was associated with minimal rainfall recharge over the period April 2009 to June 2010, rather than underground mining, and there has been no discernible response to mining.
11. Figure 12 (EC in BC) show a much larger variation than Figure 13 (EC in GC).
12. All groundwater-related impacts from underground mining during the review period were below the levels predicted in the EIS (2001), and in the LW1 to LW4 SMP.

Table A 1.6 Review of Aquaterra (2010)

Environment	Predicted Impact (HLA, 2001)	Actual Impact	Notes
Permian Strata	Drawdown to the base of coal	Up to 130 m drawdown in PG	

Environment	Predicted Impact (HLA, 2001)	Actual Impact	Notes
	measures mined and steep drawdown cone on the sides	and up to 60 m drawdown in Lemington seams (Fig.7-8)	
BCA	partly dewatered	no significant drawdown	
GCA	< 1.3 m drawdown	0.4 m (WML120B)	Occurred between June 2006 and December 2006, coinciding with the advance of TG1A past the bore location. Modelling was not undertaken to such detail as to detect this type of localised drawdown.
HRA	no significant change	no significant drawdown	
BC Streamflow	reduction of 0.4 ML/d	no significant impact	
GC streamflow	reduction of 0.35 ML/d	0.07 ML/d	
HR flow	reduction of 0.3 ML/d	no significant impact	
Mine Inflows	1.4-1.6 ML/d	0.4 ML/d	

A1.8 Review of Aquaterra (2011)

Aquaterra Consulting Pty Ltd, 2011. "Ashton Coal Operations Limited: End of Panel 5 Groundwater Report". August 2011 (Table A 1.7).

1. Mining of LW5 from the PG seam began on 4 January 2010 and was completed on 4 June 2010. The thickness of the PG seam was between 2.3 m and 2.8 m along LW5. The overburden thickness above the PG seam along LW5 ranges from 153 m at the southern end to around 110 m at the northern end, as a consequence of the west-south-westerly dip on the coal measures strata.
2. Mining of LW5 stopped about 80 m to the south of the oxbow bend of BC and associated alluvium. The PG seam is more than 125 m below the BCA where it is closest to LW5.
3. Page 16: *Piezometers which monitor the BCA and HRA have not responded to mining. Instead the water table reflects the rainfall controlled natural recharge and discharge patterns (Figure 15).*
4. *All piezometers have shown a recent upward trend in response to rainfall recharge (Figure 15). Prior to this a gradual recession following a small recharge event in April 2009 was evident across all piezometers. The recession of the water table was associated with a reduction in rainfall recharge over the period, rather than underground mining, and there has been no discernible response to mining.*
5. *As discussed above, the absence of any mining related response in the alluvium at any of the paired sites (T1-T4), while all sites show some impact in the Permian from longwall extraction, indicates a clear lack of hydraulic connection between the alluvium and the underlying Permian coal measures.*"
6. *Water table responses in Glennies Creek alluvium to the east of Glennies Creek are consistent with the rainfall controlled natural recharge and discharge responses also observed in the Hunter River and Bowmans Creek alluvium (Figure 16)*. The hydrographs in Figure 16 resemble surface water and the magnitude of changes may suggest bank recharge from surface water may be a contributing factor besides rainfall recharge.
7. *"In the absence of any fracturing beneath the alluvium, either horizontal or vertical, the permeability of the overburden beneath Bowmans Creek cannot have undergone any significant*

change, and therefore no increase in seepage losses from Bowmans Creek alluvium is anticipated as a result of LW5 mining (page 5).

8. **All groundwater related impacts from underground mining up to the completion of LW5 in June 2010 were at, or below, the levels predicted in both the EIS (HLA Envirosciences, 2001), and the LW1 to LW4 SMP and LW5 to LW9 SMP and BC EA predictions (Peter Dundon and Associates, 2006; Aquaterra, 2008b) groundwater assessments for this stage of mining (page 29).**

Table A 1.7 Review of Aquaterra (2011)

Environment	Predicted Impact (Aquaterra, 2009a)	Actual Impact	Notes
Permian Strata	Drawdown to the base of coal measures and steep drawdown cone on the sides.	Drawdown in PG up to 130 m (Figure 6). Heads in PG between -100 mAHD and 0 mAHD	
BCA	Partially dewatered , elsewhere drawdown impacts vary from around 0.5 m to 2 m.	No significant drawdown	
GCA	Generally < 0.1 m drawdown, maximum 0.4 m in text but Fig.7-1 and 7-2 show up to 1 m drawdown.	0.4 m drawdown	
HRA	< 0.1 m drawdown	No significant drawdown	
BC Streamflow	Fig.6-15, a reduction of 0.1 ML/d	negligible	
GC streamflow	a reduction of 0.23 ML/d	0.1 ML/d	
HR flow	Fig.6-15, a reduction of 0.06 ML/d	negligible	
Mine Inflows	1.5 ML/d	Between 0 and 0.9 ML/d, average around 0.5 ML/d	

A1.9 Review of RPS Aquaterra (2011)

RPS Aquaterra Consulting Pty Ltd, 2011. "*Ashton Underground Mine LW6a end of Panel Groundwater Report*". August 2011 (Table A 1.8).

1. Mining of LW6A in the PG seam began on 9 July 2010 and was completed on 22 November 2010.
2. The south-western corner of LW6A underlies saturated BCA. **Unsaturated alluvium occurs over about half of the panel length, while the northern half of the panel lies outside the BC floodplain. The PG seam is more than 150 m below the BCA where LW6A underlies the floodplain.**
3. **All groundwater-related impacts from underground mining up to the completion of LW6A (November 2010) were at, or below the levels predicted in the EIS and in the LW1 to LW4 SMP and LW5 to LW9 SMP groundwater assessments (page 32). In particular, there was no drawdown observed in the Bowmans Creek alluvium, even though saturated alluvium had been undermined by LW6A.**
4. *Most of the impacts relating to Glennies Creek alluvium had stabilised prior to the end of LW1, and no significant incremental impact or influence from mining of LW2 to LW6A has been observed. Impacts on inflows and groundwater levels in alluvium associated with Glennies Creek have generally continued to decline over time. There have been no observed impacts to date in relation to BC or its alluvium, either in terms of drawdown or mine inflow rates* (page 32).

Table A 1.8 Review of RPS Aquaterra (2011)

Environment	Prediction (Aquaterra, 2009a)	Actual Impact	Notes
Permian Strata	Drawdown to the base of coal measures and steep drawdown cone on the sides.	Drawdown up to 130 m. Heads in PG between -80 mAHD and 40 mAHD	
BCA	Partially dewatered , elsewhere drawdown impacts vary from around 0.5 m to 2 m.	No significant drawdown	
GCA	Generally < 0.1 m drawdown, maximum 0.4 m in text but Fig.7-1 and 7-2 show up to 1 m drawdown.	0.4 m drawdown	
HRA	< 0.1 m drawdown	No significant drawdown	
BC Streamflow	A reduction of 0.1 ML/d	negligible	
GC streamflow	a reduction of 0.23 ML/d	0.08 ML/d	
HR flow	a reduction of 0.06 ML/d	negligible	
Mine Inflows	~1.55 ML/d	Between 0.25 and 0.5 ML/d, average around 0.35 ML/d	

A1.10 Review of RPS Aquaterra (2012)

RPS Aquaterra Consulting Pty Ltd, 2012. "*Ashton Coal: 2010-11 Annual Groundwater Management Report*". March 2012 (Table A 1.9).

1. This report covers the reporting period 1 September 2010 to 1 September 2011.
2. This report details the monitoring and other work carried out as part of the groundwater management activities for the project. The results of all groundwater monitoring are presented, together with analysis of trends.
3. Over the review period, the actual groundwater related impacts, derived from the analysis of data were below the levels predicted in the groundwater assessment reports for the EIS (HLA Envirosciences, 2001) and the BC Diversion Environmental Assessment (EA) (Aquaterra, 2009a).
4. Apart from the initial drawdown observed in the GCA during the mining of LW1, no mining impacts have been observed in the GC, BC or HRA as a result of underground mining. There were no additional baseflow impacts to GC. Actual seepage inflow rates from the GCA were about 0.06 ML/d, and therefore continued to be below the EIS and EA predictions of 0.28 ML/d and 0.21 ML/d, respectively. **Statement is consistent with previous reports.**
5. Mining of LW6A and LW7A occurred beneath parts of the BCA and no reduction in alluvium storage was evident, hence no baseflow impacts on BC have been observed to date. The actual seepage rates have continued to be less than the rates contained in the EIS (0.38 ML/d), EA (0.03 ML/d) predictions.
6. There were no baseflow impacts to the HR and therefore no impacts to the small stands of River Red Gums near the HR, which is consistent with the EA predictions, and lower than the EIS prediction of 0.27 ML/d for this stage of mining.
7. Large drawdown responses in the PG seam and Permian overburden units have been observed in the immediate LW1 to LW7A mining area, which is in line with modelled predictions.
8. Piezometers located in the barrier between LW1 and GC have demonstrated that groundwater levels continue to show steady recovery so that most of the initial 3 m drawdown at Glennies

Creek has now recovered. The recovery in water levels suggests a steady reduction in the hydraulic conductivity of the PG seam between LW1 and the subcrop line beneath the GC floodplain, possibly due to delayed response to the in-seam grouting carried out in 2007 or progressive infilling/clogging of cleat fractures with fines. The gradual recovery in water levels has been accompanied by a gradual reduction in the rate of underground seepage inflows to the tailgate 1 backroad weir. No additional responses to underground mining were observed.

9. As reported in the LW1 End of Panel Report (Aquaterra, 2008b), a small drawdown of 0.4 m was observed in alluvium monitoring bore WML120B, between June 2006 and December 2006, coinciding with the advance of TG1A past the bore location, which has since recovered (Figure 4). **In fact, Figure 4 indicates that the groundwater head in WML120B seems to return to 52 mAHD together with WML120A (Figure 10).**
10. The development headings of ULD LW101 have been in progress over the review period. However, there have been no additional drawdown impacts observed to date. All drawdown impacts occurred during the development heading stage of PG LW1 and no further drawdown occurred during subsequent extractions of LW1 to LW7A, and the development headings of ULD LW101 that has progressed to date.
11. Groundwater level drawdown in the GCA has been significantly less than predicted in the EIS. Groundwater levels in bore WML120B indicated an initial drawdown of about 0.4 m, which has now recovered. Statement is consistent with previous reports.
12. Water table responses in the GCA to the east of GC are consistent with the rainfall controlled natural recharge and discharge responses also observed in the Hunter River and BCA (Figure 4).
13. Overall, the BCA was not significantly impacted by LW6A to LW7B extraction, however, some piezometers (WML112C, T10, T3-A and RA14) which were located around the goaf edge of LW7A, revealed a temporary groundwater response that coincided with the passage of LW7A (Figure 5). T10, T3-A and RA14 became dry for a short period of time. However, following a recharge event, all piezometers have recovered and retained a saturated thickness that is slightly greater than pre-LW7A conditions.
14. The piezometers which responded to LW7A are located near to the goaf edge of LW7A where subsidence cracking was observed at the surface. The temporary drawdown was considered to be due to groundwater flowing laterally into the subsided 'alluvium trough' above the LW7A goaf. This drawdown response was previously observed in RA8 (which is located near the LW5 goaf edge) during the extraction of LW5.
15. Piezometers located outside of areas where surface cracking was observed (T2-A and RA18) did not respond to LW extractions (Figure 5). Instead the water level trends are due to natural recharge and discharge processes and are not related to mining. The trends are also consistent with pre-mining trends and groundwater trends observed in piezometers outside the goaf areas (i.e. WML275 and RA15). It is unclear what pre-mining trends are/were.
16. The EIS, EA and SMP for LW7A predicted groundwater drawdowns of 0.5 m to 2.0 m for this stage of mining. However, no reduction in alluvium storage occurred during LW6A or LW7A extraction, and hence there was no seepage loss from the BCA. The impact on BCA has therefore been less than the EIS and EA predictions.
17. Piezometers which monitor the HRA have shown no response to mining. (Figure 6). All piezometers have shown a recent upward trend in response to above average rainfall recharge. Prior to this, a gradual recession following a small recharge event in April 2009 was evident across all piezometers. The recession of the water table was associated with a reduction in rainfall recharge over the period, rather than underground mining, and there has been no discernible response to mining.
18. Accordingly, there is no impact to the HRA, which is consistent with the EA and SMP predictions, and is lower than the EIS prediction of <0.5 m.

19. East of LW1, PG groundwater levels in WML120A and WML184 to WML186 have continued to show steady recovery of approximately 0.7 m per year, so that nearly all of the initial 3.0 m drawdown has recovered (Figure 10). The recovery in water levels suggests a steady reduction in the hydraulic conductivity of the PG seam between LW1 and the subcrop line beneath the GC floodplain, possibly due to delayed response to the in-seam grouting carried out in 2007. The gradual recovery in water levels has been accompanied by a gradual reduction in the rate of underground seepage inflows.
20. All groundwater-related impacts from underground mining during the review period were below the levels predicted in the groundwater impact reports for the EIS and EA.

Table A 1.9 Review of RPS Aquaterra (2012)

Environment	Predicted Impact (Aquaterra, 2009a)	Actual Impact	Notes
Permian Strata	Drawdown to the base of coal measures and steep drawdown cone on the sides.	Up to 140 m drawdown in PG and up to 110 m drawdown in Lemington seams	
BCA	Partially dewatered, elsewhere drawdown impacts vary from around 0.5 m to 2m.	no significant drawdown	
GCA	Generally < 0.1 m drawdown, maximum 0.4 m in text but Fig.7-1 and 7-2 show up to 1 m drawdown.	no significant drawdown	0.4 m (WML120B) occurred between June 2006 and December 2006, coinciding with the advance of TG1A past the bore location but has since recovered
HRA	< 0.1 m drawdown	no significant drawdown	
BC Streamflow	a reduction of 0.03 ML/d	no significant impact	
GC streamflow	a reduction of 0.21 ML/d	0.06 ML/d	
HR flow	a reduction of 0.06 ML/d	no significant impact	
Mine Inflows	1.4 ML	7.44 L/d	

A1.11 Review of Ashton Coal (2012)

Ashton Coal, 2012. "*Ashton Longwall 7A – end of panel summary report*". May 2012 (Table A 1.10).

1. LW7A was extracted between the 22 March 2011 and 5 August 2011. LW7A was 793 m long and 187 m wide and was **mined without any unexpected impact to the surface environment or infrastructure above it.**
2. All groundwater related impacts from underground mining during the review period were below the levels predicted in the groundwater impact reports for the 2001 EIS, 2009 EA and 2010 SMP for LW7A.
3. The groundwater monitoring network was expanded which included three nested monitoring sites, installed in the BCA and the Permian overburden units. An additional six standpipe piezometers were also installed in the BCA.
4. Apart from the initial drawdown observed in the GCA during the mining of LW1, no mining impacts have been observed in the GC, BC or HRA as a result of underground mining.
5. There were no additional baseflow impacts to GC. Actual seepage inflow rates from the GCA were about 0.06 ML/d, and continued to be below the EIS and EA predictions of 0.28 ML/d and 0.21 ML/d, respectively.
6. Mining of LW6A and LW7A occurred beneath parts of the BCA and no reduction in alluvium storage was evident, and no baseflow impacts on BC have been observed to date. The actual seepage rates continued to be less than the rates predicted by the EIS (0.38 ML/d), EA and SMP (0.03 ML/d) predictions.
7. There were no baseflow impacts to the HR, consistent with the EA and SMP predictions, and lower than the EIS prediction of 0.27 ML/d for this stage of mining.

Table A 1.10 Review of Ashton Coal (2012)

Environment	Predicted Impact (Aquaterra, 2009a)	Actual Impact	Notes
Permian Strata	Drawdown to the base of coal measures and steep drawdown cone on the sides.	Up to 140 m drawdown in PG and up to 110 m drawdown in Lemington seams (from AEMR)	
BCA	Partially dewatered, elsewhere drawdown impacts vary from around 0.5 m to 2m.	no significant drawdown	
GCA	Generally < 0.1 m drawdown, maximum 0.4 m in text but Fig.7-1 and 7-2 show up to 1 m drawdown.	no significant drawdown	0.4 m (WML120B) occurred between June 2006 and December 2006, coinciding with the advance of TG1A past the bore location but has since recovered
HRA	< 0.1 m drawdown	no significant drawdown	
BC Streamflow	a reduction of 0.03 ML/d	no significant impact	
GC streamflow	a reduction of 0.21 ML/d	0.06 ML/d	
HR flow	a reduction of 0.06 ML/d	no significant impact	
Mine Inflows	1.4 ML	0.44 ML/d (from AEMR)	

A1.12 Review of RPS Aquaterra (2013a)

RPS Aquaterra Consulting Pty Ltd, 2013a. "*Groundwater Management Report*", May 2013. Appendix 1 of Ashton Coal Operations Pty Limited, Annual Environmental Management Report, 2011/2012 (Table A 1.11).

1. This report covers the reporting period 1 September 2011 to 31 December 2012.
2. This report details the monitoring and other work carried out as part of the groundwater management activities for the project.
3. The results of all groundwater monitoring are presented, together with analysis of trends. Over the review period, the actual groundwater related impacts, derived from the analysis of this data were below the levels predicted in the groundwater assessment reports for the ULD seam extraction plan groundwater impact assessment.
4. Over the review period underground coal extraction was completed for the PG seam at LW7B and LW8. The development headings for ULD LW101 were driven and completed with partial extraction of LW101.
5. No impacts have been observed in the GC, BC or HRA as a result of underground mining.
6. Mining of LW7B and LW8 occurred beneath sections of the BCA. No reduction in alluvium storage of groundwater was observed.
7. A gradual trend of declining groundwater levels was observed in the northern and southern sections of the BCA over the reporting period. This trend is attributed to a recovery following above average water levels associated with above average rainfall in late 2011 and early 2012. It is unclear what the recovery is from. Sounds like a recession following high groundwater levels.
8. Underground inflows increased significantly and above predictions in January 2012 and again in July 2012. However, both events were short lived with the average groundwater inflows over the reporting period below both the 2001 EIS and current model predictions.

Table A 1.11 Review of RPS Aquaterra (2013a)

Environment	Predicted Impact (Aquaterra, 2009a)	Actual Impact	Notes
Permian Strata	Drawdown to the base of coal measures and steep drawdown cone on the sides.	Up to 150 m drawdown in PG and up to 120 m drawdown in Lemington seams	The report displays hydrographs from 2010 only while the text refers to incremental drawdowns making it difficult to assess total drawdowns.
BCA	Partially de-watered, elsewhere drawdown impacts vary from around 0.5 m to 2 m.	no significant drawdown	
GCA	Generally < 0.1 m drawdown, maximum 0.4 m in text but Fig.7-1 and 7-2 show up to 1 m drawdown.	no significant drawdown	
HRA	< 0.1 m drawdown	no significant drawdown	
BC Streamflow	a reduction of 0.03 ML/d	no significant impact	
GC streamflow	a reduction of 0.21 ML/d	no significant impact	
HR flow	a reduction of 0.006 ML/d	no significant impact	
Mine Inflows	1.6 ML	1.1 ML/d	

A1.13 Review of RPS Aquaterra (2013b)

RPS Aquaterra Consulting Pty Ltd, 2013b. "*Ashton Coal: End of Panel 8 Groundwater Report*". August 2013 (Table A 1.12).

1. Mining of LW8 began on 27 February 2012 and was completed on 5 June 2012. LW8 accessed coal from the PG seam and is located in the north-west of the approved underground mine plan.
2. The BCA is located, at its closest point, east of the southern half of LW8.
3. Subsidence monitoring during coal extraction at LW8 has shown the lowering of the base of the BCA by approximately 1 m. The groundwater level within the aquifer is also shown to reduce following subsidence. **The net result does not equate to a reduction in the saturated thickness across the BCA**, in some areas the saturated thickness was observed to increase.
4. Groundwater in the HRA and the GCA do not show impacts attributable to coal extraction at LW8, owing to the distance separating LW8 and the HRA and GCA.
5. The impacts associated with coal extraction at LW8 are within the approved predictions documented in the EIS (2001) and the BC Diversion Environmental Impact Assessment (2009 EA).
6. *Page 5: Groundwater levels in the Permian coal measures may have been influenced by historical mining in the area. It is considered likely that the groundwater levels in the Permian were higher than in both the alluvium and in the creeks/streams prior to commencement of mining at Ashton. Higher potentiometric surfaces in the Permian suggest that under natural conditions, groundwater is discharged from the Permian to the alluvium and to the surface streams. This is reflected in relatively higher salinities in areas in the alluvium and in the constant stream flow during periods of low rainfall and runoff.*
7. *At multi-level piezometer sites, potentiometric surfaces are commonly higher in the deeper piezometers in the Permian than in the shallow alluvium and the near-surface parts of the Permian sequence, unless affected by mining activity. Historically in some locations, potentiometric surfaces in the Permian sequences have been observed to be above the ground level elevation (artesian - positive pressure). Typically across the ACP, there is an upward hydraulic gradient with depth below surface under natural conditions*.
8. *In areas where mining impacts have lowered the potentiometric surface elevation in the Permian, the hydraulic gradients may have been reversed. In this case so the potential for water to flow from the alluvium directly into the underlying Permian exists. However, groundwater studies utilizing data collected from the ongoing monitoring program have indicated that there is generally very poor hydraulic connection between the alluvium and the underlying Permian coal measures. Vertical flow between the formations is therefore limited under the low pressure gradients.*
9. The Permian water level (WML120A in Fig.19) shows a steady recovery following the passing of LW1 up to 2011 after which it closely mirrors the alluvium water levels. The alluvium water level (WML120B) has remained relatively constant with no impacts post LW1 from the time series profile with occasional peaks in groundwater levels that are likely associated with elevated, episodic rainfall and creek levels.

Table A 1.12 Review of RPS Aquaterra (2013b)

Environment	Predicted Impact (Aquaterra, 2009a)	Actual Impact	Notes
Permian Strata	Drawdown to the base of coal measures and steep drawdown cone on the sides.	Drawdown in PG up to 110 m (Fig.8). Figure 10 shows a tight cone of depression which emanates from LW1 to LW8. Steep gradients occur around the mining perimeter.	Fig.10 shows heads down to -80 mAHD in PG.
BCA	Partially de-watered , elsewhere drawdown impacts vary from around 0.5 m to 2 m.	No significant drawdown	
GCA	Generally < 0.1 m drawdown, maximum 0.4 m in text but Fig.7-1 and 7-2 show up to 1 m drawdown.	No significant drawdown	
HRA	No significant drawdown	No significant drawdown	
BC Streamflow	a reduction of 0.03 ML/d	Negligible	
GC streamflow	a reduction of 0.23 ML/d	Up to 0.05 ML/d	
HR flow	a reduction of 0.06 ML/d	Negligible	
Mine Inflows	1.5 ML/d	Between 0.3 ML/d and 1.2 ML/d, average 1 ML/d	

A1.14 Review of RPS Aquaterra (2014a)

RPS Aquaterra Consulting Pty Ltd, 2014a. "*Ashton Coal Underground Mine End of Panel Groundwater Review Longwall 6B*". February 2014 (Table A 1.13).

1. Mining of LW6B began on 14 July 2013 and was completed on 27 October 2013.
2. The overburden thickness above the LW6B varies as a consequence of the west-south-westerly dip on the coal measures strata. Thickness of the overburden ranged from 100 m at the northern end to approximately 140 m at the south-western extent of LW6B.
3. LW6B lies adjacent to the eastern creek diversion channel and undermines the excised section of BC. **The LW6B panel is largely overlain by saturated alluvial sediments associated with BC**.
4. Groundwater inflows to the underground mine increased in October 2013 and plateaued at approximately 2.6 ML/d. In comparison, predicted groundwater inflows were approximately 1.3 ML/d. Prior to October 2013, mine inflows were considerably less than those predicted by Aquaterra (2009). That predicted inflows prior to October 2013 were above the actual inflows does not alter the significance of the large inflow event in October 2013. This inflow event was likely caused by a unmapped mechanism not replicated by the conceptual and numerical model; also, the stress periods of the model were not suitable to replicate an inflow event of that took place over this time frame. Nonetheless, it should be noted that the total annual inflow for the year in question was not exceeded.
5. During the course of LW6B extraction, a moderate decline in the groundwater level in a limited area of the BCA was also observed. This decline has been attributed to LW extraction. **The BCA**

has, however, remained saturated in areas above LW6B as well as retaining substantial saturated thickness to the east and south of LW6B.

6. Figures 8 and 9 show a decline in BCA groundwater levels from August 2013 for a period of approximately two months. The most pronounced decline was at piezometer T5 (BCA monitoring bore), located above the LW6B/LW7B chain pillar, with a drawdown of over 3 m. T5 bore logs show that there is approximately 4 m of saturated alluvium at this location and even with 3 m of drawdown the alluvium still maintained at least 1 m of saturated alluvium at its base.
7. Over the LW6B extraction period, groundwater recharge was minimal with below average rainfall experienced. This is thought to have contributed to the observed water level decline. **The low rainfall/low stream stage may have been the dominant factor in those drawdowns.**
8. The groundwater modelling completed for the 2009 GIA predicted complete dewatering of portions of the BCA overlying the LW panels (Aquaterra, 2009). Therefore **the observed decline is expected and within the approved predicted impacts in the 2009 GIA**.
9. Following the completion of LW6B in October 2013, water levels within the BCA fully recovered following a large rainfall event in November 2013.
10. A rainfall event in excess of 150 mm of rain occurred on 18 November 2013 (following LW6B extraction). The rainfall caused minor flooding and high streamflow rates through the ACP area and resulted in a significant aquifer recharge event. The recharge was observed to completely reset groundwater levels in the BCA, and partial recovery was observed in the CMOB with up to 3.5 m recovery at WMLP325 (Figure 13).

Table A 1.13 Review of RPS Aquaterra (2014a)

Environment	Predicted Impact (Aquaterra, 2009a)	Actual Impact	Notes
Permian Strata	Drawdown to the base of coal measures and steep drawdown cone on the sides.	Drawdown in PG up to 140 m. Heads in PG between -100 mAHD and 0 mAHD.	
BCA	Partially de-watered, elsewhere drawdown impacts vary from around 0.5 m to 2 m.	Up to 3 m short-term drawdown but the BCA has, however, remained saturated in areas above LW6B as well as retaining substantial saturated thickness to the east and south of LW6B.	
GCA	Generally < 0.1 m drawdown, maximum 0.4 m in text but Fig.7-1 and 7-2 show up to 1 m drawdown.	No significant drawdown	
HRA	< 0.1 m drawdown	No significant drawdown	
BC Streamflow	a reduction of 0.1 ML/d	Not reported	
GC streamflow	a reduction of 0.23 ML/d	Not reported	
HR flow	a reduction of 0.06 ML/d	Not reported	
Mine Inflows	1.4 ML/d	Up to 2.6 ML/d but overall between 0.25 ML/d and 0.5 ML/d, average around 0.35 ML/d	Groundwater inflows increased in October 2013 and plateaued at approximately 2.6 ML/d

A1.15 Review of RPS Aquaterra (2014b)

RPS Aquaterra Consulting Pty Ltd, 2014b. "*Groundwater Management Report*", May 2014. Appendix 2 of Ashton Coal Operations Pty Limited, Annual Environmental Management Report, 2013 (Table A 1.14).

1. This report covers the reporting period 1 January 2013 to 31 December 2013.
2. Over the review period the following relevant activities took place:
   - 3 August 2012 to 16 June 2013 – LW101 extraction in the ULD seam
   - 14 July 2013 to 27 October 2013 – LW6B extraction in the PG seam
   - 10 November 2013 to 31 December 2013 – LW102 extraction in the ULD seam (partially complete).
3. In the northern BCA (page 13) the report appears to indicate that mining related drawdown occurred from either August or September 2013.
4. Groundwater level rises due to rainfall in January/February, and a recession to November 2013. In mid-November 2013 groundwater levels rose rapidly following a large rainfall event (73 mm) on 18 November. Aquaterra (2014a) refers to 153 mm rain.
5. WML182 and to a lesser extent, WML183 in PG, (Figure 20) show water level fluctuations in response to rainfall/recharge events, possibly indicating a hydraulic connection with the GCA or recharge at outcrop/subcrop.
6. Figures 6 to 13 indicate significant, ~2 m increases in groundwater head in the BCA, and up to 1 m increases in the GCA and HRA (based on manual measurements that probably underestimate the changes).
7. Page 17 states: "*The 2009 GIA specifically references monitoring points to the north-east and the south-east of LW6B (paired sites WMLP323/324 and WMLP311/325) to be used to determine if connective cracking from the goaf to the BCA has occurred. At these sites, an accelerated drop in water levels within the coal measures overburden (CMOB)* [underlying the alluvium] *is observed and relatively gradual declines within the BCA (Figure 28). This is consistent with a response from disconnective cracking and increased permeability with the gradual decline demonstrating that direct connective cracking from the goaf has not occurred.*"
8. On 10 October 2013, an increase in pumping rate was observed at BH2. Although the inflow rate increased above model predictions, the total inflow volume for the year is within model predictions.
9. As the rate of inflow (approximately 26 L/s to 30 L/s) exceeded predictions, ACOL committed to updating and re-calibrating the current groundwater model using monitoring data collected to date, including the increased inflow rate. This model update is scheduled to commence in January 2014 and will be reported in the 2014 AEMR.

Table A 1.14 Review of RPS Aquaterra (2014b)

Environment	Predicted Impact (Aquaterra, 2009a)	Actual Impact	Notes
Permian Strata	Drawdown to the base of coal measures and steep drawdown cone on the sides.	Up to 150 m drawdown in PG and up to 120 m drawdown in Lemington seams.	The report displays hydrographs from 2011 only making it difficult to assess total drawdowns.
BCA	Partially de-watered,	Up to short-term 3 m	

Environment	Predicted Impact (Aquaterra, 2009a)	Actual Impact	Notes
	elsewhere drawdown impacts vary from around 0.5 m to 2 m.	drawdown above LW6A and LW7A	
GCA	Generally < 0.1 m drawdown, maximum 0.4 m in text but Fig.7-1 and 7-2 show up to 1 m drawdown.	no significant drawdown	
HRA	< 0.1 m drawdown	no significant drawdown	
BC Streamflow	a reduction of 0.05 ML/d	no significant impact	
GC streamflow	a reduction of 0.25 ML/d	no significant impact	
HR flow	a reduction of 0.01 ML/d	no significant impact	
Mine Inflows	1.6 ML	1.1 ML/d	Fig.33 indicates considerable variations between 0 ML/d and 2.6 ML/d.

A1.16 Review of RPS Aquaterra (2014c)

RPS Aquaterra Consulting Pty Ltd, 2014c. "*Ashton Coal Groundwater Model Update, RPS May 2014*".

1. This model update was initiated to address the increased mine inflows during and after October 2013. Mine inflows reporting to the BH02 underground dewatering pump increased, coincident with completion of PG LW6B, with an average of approximately 5 L/s to over 19 L/s on 10 October 2013. Between November 2013 and February 2014, the pumping rate was maintained at approximately 26 L/s to 30 L/s and eventually decreased to 21 L/s by May 2014.
2. There was an observed decline and recovery of groundwater levels in shallow standpipe piezometers in the BCA, but there was no observed decrease in surface water flow within BC itself. This was interpreted by RPS (2014) as "*consistent with predicted impacts that lining of BC will minimise potential impact to streamflows*" (page 1).
3. The updated model matches the observed drawdown and short-term recovery in response to large episodic rainfall of groundwater levels in the shallow alluvium in the vicinity of LW6B and a conclusion is that inflow from alluvium to the mine is not sufficient to account for the magnitude of the observed inflow event.
4. The model calibration SRMS error was 14.1% (all layers) and 9.1% for Layer One (alluvium) only.
5. The increased mine flows are interpreted by RPS (2014) to come from trapped water in a shear zone: "*Figure 12 presents detailed model output in the vicinity of LW06B. Observation data at VWP WMP115_144m and WML21 indicates that the PG seam is fully depressurised. Modelled groundwater levels match general trend of depressurisation of PG seam, however, it is apparent that the models representation of the 'shear zone', the yellow zone (Zone 39) of high hydraulic conductivity in Layer 8* (PG seam) *of Figure 12, is providing a source of water*".
6. A conclusion of this investigation is "*that there is a large but finite source of 'trapped' groundwater, with a salinity that is closer to surface water than groundwater, inferring (at least*

potentially) connectivity to a surface water source, currently or in the past. Modelling indicates the proposed connection to a lower salinity stored water source is not the same process of mining-induced depressurisation and drawdown and short term increase in response to rainfall of groundwater levels in the alluvium. If this was the case, then there would be a continuous inflow since natural hydrologic processes are observed to recharge the alluvium".

A1.17 Review of RPS Aquaterra (2015)

RPS Aquaterra Consulting Pty Ltd, 2015. "*Groundwater Management Report*", February 2015. Appendix 1 of Ashton Coal Operations Pty Limited, Annual Environmental Management Report, 2014 (Table A 1.15).

1. This report covers the reporting period 1 January 2014 to 31 December 2014.
2. Over the review period the following relevant activities took place:
    - 8 August 2014 – Completion of LW102 extraction in the ULD seam
    - 21 August 2014 – Commencement of LW103 extraction in the ULD seam

Table A 1.15 Review of RPS Aquaterra (2015)

Environment	Predicted Impact (RPS, 2014c)	Actual Impact	Notes
Permian Strata	Drawdown to the base of coal measures and steep drawdown cone on the sides.	Up to 120 m drawdown in PG and up to 80 m drawdown in Lemington seams	
BCA	Partially de-watered , elsewhere drawdown impacts vary up to 3.5 m. BCA may not completely desaturated as per the previous predictions by Aquaterra (2009).	Up to 1 m drawdown Above LW6A and LW7A	
GCA	< 2 m drawdown (Fig.21)	no significant drawdown	
HRA	< 2 m drawdown (Fig.21)	no significant drawdown	
BC Streamflow	a reduction of 0.13 ML/d	0.05 ML/d	
GC streamflow	a reduction of 0.076 ML/d	no significant impact	
HR flow	a reduction of 0.087 ML/d	no significant impact	
Mine Inflows	up to 1.4 ML/d	1.75 ML/d	

A1.18 Review of AGE (2016a)

Australian Groundwater and Environmental Consultants (AGE), 2016a. "*Report on Ashton Coal Project Groundwater Monitoring Review for AEMR 2015*". Document reference G1758H.

1. This report covers the reporting period 1 January 2015 to 31 December 2015.
2. The Water Management Plan (WMP) was reviewed and updated by Gilbert & Associates Pty Ltd and AGE on behalf of ACOL and approved by the NSW Department of Planning &

Environment (DPE) on 27 October 2015. The GMP was changed and came into force the 1 November 2015.

3. Triggers for groundwater level and water quality have been developed for monitoring bores in the BCA, GCA and the HRA. These triggers have been included in the last WMP in May 2015 and have been updated in November 2015 based on the current observations.
4. Groundwater level triggers were established based on the predicted mining related drawdowns at the alluvial monitoring bores and on the observed natural variations. Since the validation of the WMP in May 2015 and until the end of mining in the ULD, a recorded water level below the defined trigger level at a monitoring bore, sustained for three consecutive months, would trigger a response under the WMP. Groundwater elevation trigger levels are summarised in Table 3-1.
5. Mining of LW103 in the ULD commenced on 22 August 2014 and was completed mid-July 2015. ACP was, at the time of the report completion, mining LW105.
6. No groundwater level within the alluvium was recorded below the trigger values; neither did observations exceed pH and EC trigger values.
7. Direct rainfall recharge within the alluvium is observed at all the sites, also in the overburden on the north east and the PG and Arties seams east of the underground.
8. The high level of inferred hydraulic connection between the GCA and PG seam on the eastern part of the underground mine does not translate as observed inflows into the underground mine.
9. Groundwater to the east of LW1 have recovered from the impacts of underground mining. The stabilisation of the groundwater pressures between the GCA and the PG seam indicates that the groundwater gradient has returned to a pre-mining state. It is important to note that pre-mining state may include a low GC flow/stage –upward hydraulic gradient sub-state as well as a high GC flow/stage – downward hydraulic gradient sub-state.
10. Groundwater level variations related to mining from Lemington 19 to ULD seams on the south side of the underground working area.
11. Groundwater level variations related to mining of the ULD seam on the whole area.
12. The impact of the pumping and ground subsidence related to mining in the ULD extends to the Lemington seam plies in the south part of the mine.
13. Hydrographs are presented in five groups shown in Figure 4-1.
14. For group 1, east of the mine and adjacent to GC, groundwater elevations in all of the target formations are similar, potentially indicating a similar water source. No mining related impacts are evident from the water level data.
15. Group 2 bores are in similar position to group 1, east of the mine footprint and adjacent to GC, but some 700 m further south. In general bores in the GCA and down to PG seam react to recharge rapidly, bores in the Arties seam react with delay and bores in the ULD seam react to mining by depressurisation. Figure 5-2 indicates a significant rise in the PG seam bore in April 2015, the GCA bore does not capture this event because of infrequent measurements.
16. Group 3 bores are in the HRA down to Lemington 17 seam and show no mining related impacts.
17. Group 4 bores are located in the southern end of LW104 to LW106 and adjacent to the HR. The HRA, BCA and CMOB bores do not appear to be impacted by mining.
18. Bores in the Group 5 area are screened in the BCA and the CMOB above the northern part of LW105. The three bores react to significant recharge events (April 2014 and April 2015), and are not impacted by mining.
19. Estimated groundwater inflow, 1 ML/d, is below the modelled inflow, 1.12 ML/d.

20. In conclusion, during the year 2015, there was no groundwater impact related to mining exceeding the predicted impacts from the Bowman's Creek Diversion Environmental Assessment.

A1.19 Review of AGE (2016b)

Australian Groundwater and Environmental Consultants (AGE), 2016b. "*Report on Yancoal Australia - Ashton Coal Project - End of Panel Report - LW104".* Document reference G1758L.

1. Mining of LW104 in the ULD commenced on 1 August 2015 and was completed 23 April 2016. LW104 is the fourth panel to recover coal from the ULD. LW104 underlies the previously mined PG LW4.
2. Historically, monitoring of the alluvium has found that groundwater levels have not been significantly impacted by mining activity; whereas, groundwater pressures in the rock units overlying the PG have been significantly depressurised by LW mining and related goafing.
3. The depressurisation extends above the PG seam (Lemington 5-6 ply at 28 mbgl [metres below ground level]) and below the PG seam.
4. The BCA water trends are interpreted to match the cumulative rainfall departure (CRD) and are notably influenced by significant rainfall events. It is difficult to ascertain whether there are individual impacts associated to mining of individual LW panels; however, this may be explained by the storage available in the alluvium allowing subsidence impacts to groundwater levels from water losses to be smoothed.
5. The site trigger values for the GCA, BCA and HRA are shown in Table 5-1.
6. Hydrographs are presented in five groups shown in Figure 6-1.
7. For group 1, east of the mine and adjacent to GC, groundwater elevations in all of the target formations are similar, potentially indicating a similar water source. This water source is most likely to be the surface waters of GC (page 24). This is the first report that refers directly to recharge from GC. No mining related impacts are evident from the water level data.
8. Group 2 bores are in similar situation to Group 1 bores, east of the mine footprint and adjacent to GC, but some 700 m further south. In general, bores in the GCA and down to the PG seam react to recharge rapidly, bores in the Arties seam react with delay and bores in the ULD seam react to mining by depressurisation. The EC of the groundwater in both group 1 and 2 bores is typical of surface water. The seam subcrop of both the PG and Arties seams is close to the surface in this area. It is likely that there is good hydraulic connection between the aquifer and the recharge source (pages 35-36). This concept is consistent with strong alluvium-surface water interaction.
9. Group 3 bores are in the HRA or beneath it and show no mining related impacts in the HRA.
10. Group 4 bores are located in the southern end of LW104 to LW106 and adjacent to the HR. RA27 (HRA), WMLP326 (BCA) and WMLP327 (CMOB) do not appear to be impacted by mining.
11. Pressures measured at VWP monitoring location WMLP333 at the depths of 124 mBGL (Lem15) and 144 mBGL (Lem19) are notably impacted by mining. The measurements recorded by WMLP333 VWP sensor at 124 mBGL and 144 mBGL are variable indicating that the seam was not completely depressurised until impacted by mining in LW104.
12. Bores in the Group 5 area are screened in the BCA and the CMOB above the northern part of LW105. The Ashton well (BCA), WMLP311 (BCA) and WMLP325 (CMOB) respond and stabilise quickly after significant recharge events (April 2014 and April 2015), and are not impacted by mining.
13. Alluvium compliance bores show that the BCA monitoring bores respond quickly to rainfall events. The GCA and HRA alluvium monitoring bores respond only to significant rainfall

events. The BCA and GCA groundwater levels show a slight increase over the monitoring period. This is likely due to long-term above average rainfall in the area in the latter part of 2015. **None of the compliance bores show responses to mining impacts** and groundwater levels have not changed significantly over the period of mining in LW104.

14. Groundwater levels in LW specific compliance alluvium monitoring bores (RA27, Ashton Well, RM03, WMLP301 and WMLP302) do not appear to be impacted by mining activity.
15. There are no obvious impacts to the groundwater levels, EC and pH measured in site monitoring bores which can be directly attributed to the extraction of LW104;
16. There are no observable impacts to groundwater levels in the BCA, GCA and HRA from the extraction of LW104; and no reportable exceedances of WMP trigger values occurred during the extraction of LW104.
17. Historical extraction of the PG seam and associated subsidence has caused depressurisation of overlying coal seams, namely Lemington 19 and the overlying Lemington 15. Lemington 10 has also been impacted in some areas.
18. Extraction of the ULD seam and associated subsidence has caused the depressurisation of overlying Arties seams. This depressurisation is on-going and the seam has not been completely depressurised.
19. All of the coal seams between the Lemington seams and the currently mined ULD seam are undergoing depressurisation at a constant rate. This depressurisation is a site wide response which is more related to general mining at the site rather than the extraction of individual LW panels.
20. **The observed impacts to the groundwater regime at Ashton at the end of mining in LW104 are in line with approved impacts as outlined in the 2001 EIS and the 2009 BC environmental assessment.**

A1.20 Review of AGE (2016c)

Australian Groundwater and Environmental Consultants (AGE), 2016c. "*Report on Yancoal - Ashton Coal Longwalls LW201 to LW204, Groundwater Impact Assessment*", Document reference G1758N (Table A 1.16).

1. This report (August 2016) uses and relies on the 18 layer model developed earlier and reported subsequently by AGE (2016d). The difference between the models used for this report and AGE (2016d) is the calibration process. The automated calibration of AGE (2016d) focussed mostly on minimising the large differences between observed and modelled heads that normally occur in the Permian strata by allocating more weight to Permian observations than for those in the alluvium. The AGE (2016c) model was recalibrated with a focus on the observed alluvium water levels **providing an overall greater focus in the model on the alluvium.**
2. Predicted groundwater impacts (presented as drawdown) immediately prior to the commencement of LW201, upon completion of mining of LW204 and the drawdown attributable only to the mining of LW201 to LW204 are presented in Figures 5-1 to 5-4.
3. LW201 to LW204 drawdown in the majority of the BCA and GCA is less than 1 m. Areas of drawdown greater than 1 m are localised and limited to the very edges of the alluvium boundaries. The area of low hydraulic conductivity alluvium in the GCA/regolith over the southern portion of LW1 shows a potential for greater drawdown.
4. Drawdown in the HRA is expected to be low and drawdown greater than 1 m is limited to small areas south of LW204.
5. Drawdown in the PG and ULD will be steep within the mine area as the seams will be depressurised and continue to be actively dewatered during the life of the mine.
6. Approximately 30 m to 50 m drawdown is predicted to occur within the ULLD prior to the extraction of LW201. After completion of LW204, drawdown is predicted to be in the order of 100 m.
7. **The predicted impacts are in line with approved impacts as outlined in the 2001 EIS and the 2009 BC environmental assessment.**

Table A 1.16 Review of AGE (2016c)

Environment	Predicted impact	Actual impact	Notes
Permian Strata	Fig.5-2 predicts up to 10 m drawdown in PG due to LW201-204. Fig.5-3 predicts up to 20 m drawdown in ULD due to LW201-204. Fig.5-4 predicts up to 100 m drawdown in ULLD due to LW201-204.	n/a	
BCA	Fig.5-1 predicts indiscernible drawdown in BC due to LW201-204. Table 5-3 predicts < 1 m (< 2 m in localised area).	No significant drawdown	
GCA	Fig.5-1 predicts up to 5 m drawdown in GC due to LW201-204. Table 5-3 predicts < 2 m (< 10 m in localised area).	No significant drawdown	
HRA	Fig.5-1 predicts indiscernible drawdown in HR due to LW201-204. Table 5-3 predicts < 1 m (< 7 m in localised area).	No significant drawdown	
BC Streamflow	0.02 ML/d baseflow reduction (page 18) Table 5-3 predicts 0.06 ML/d	None observed	Page 18 refers to impact due to LW201-204, Table 5-3 refers to cumulative impacts
GC streamflow	0.01 ML/d baseflow reduction (page 18) Table 5-3 predicts 0.05 ML/d	None observed	Page 18 refers to impact due to LW201-204, Table 5-3 probably refers to cumulative impacts
HR flow	No change (page 18) Table 5-3 predicts 0.02 ML/d	None observed	Page 18 refers to impact due to LW201-204, Table 5-3 probably refers to cumulative impacts
Mine Inflows	1.1 ML/d to 1.15 ML/d	~ 1 ML/d	

A1.21 Review of AGE (2016d)

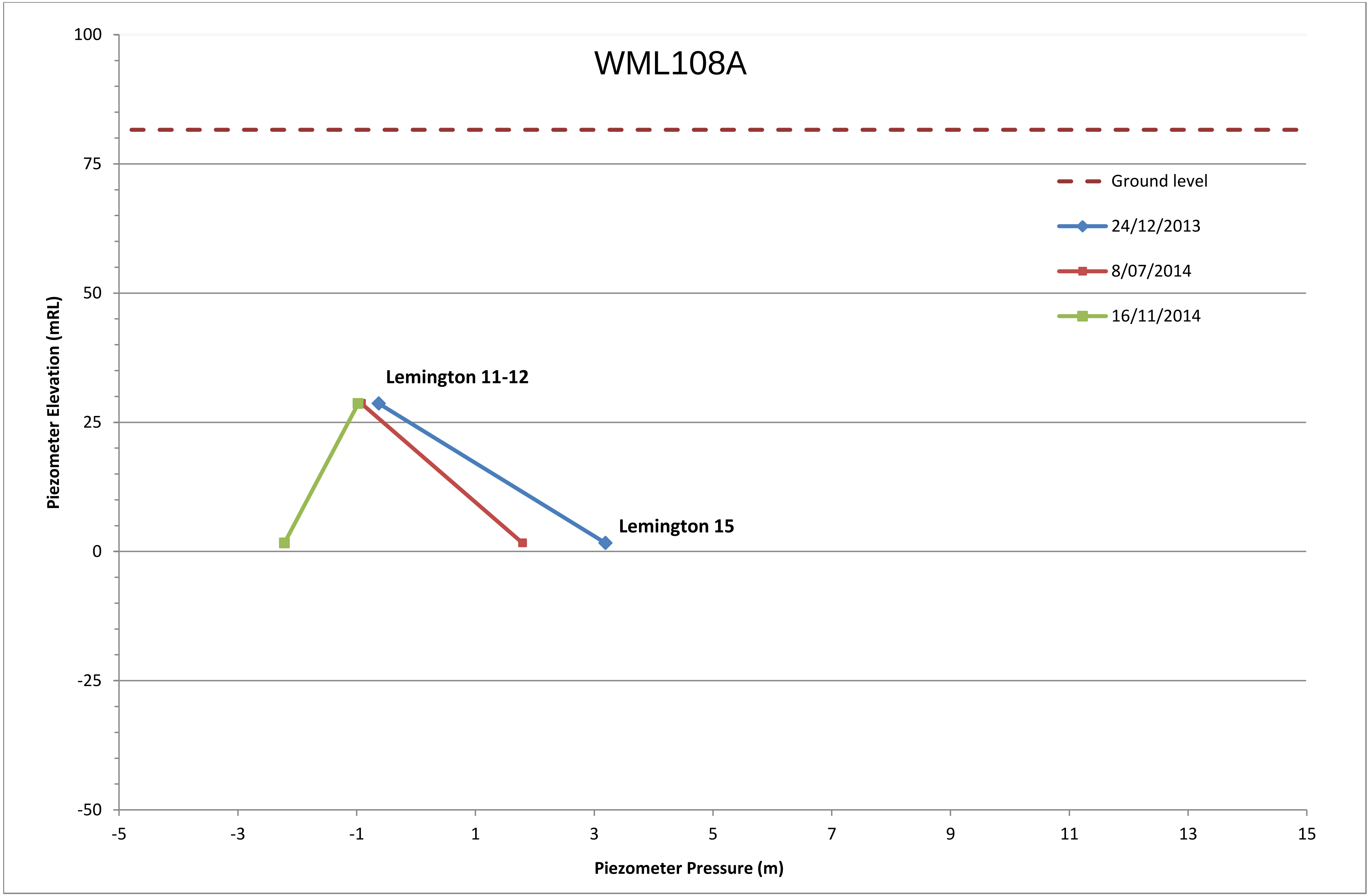
Australian Groundwater and Environmental Consultants (AGE), 2016d. "*Report on Yancoal - Ashton Coal - Groundwater Model Rebuild".* Document reference G1758G_001_v01.02 (Table A 1.17).

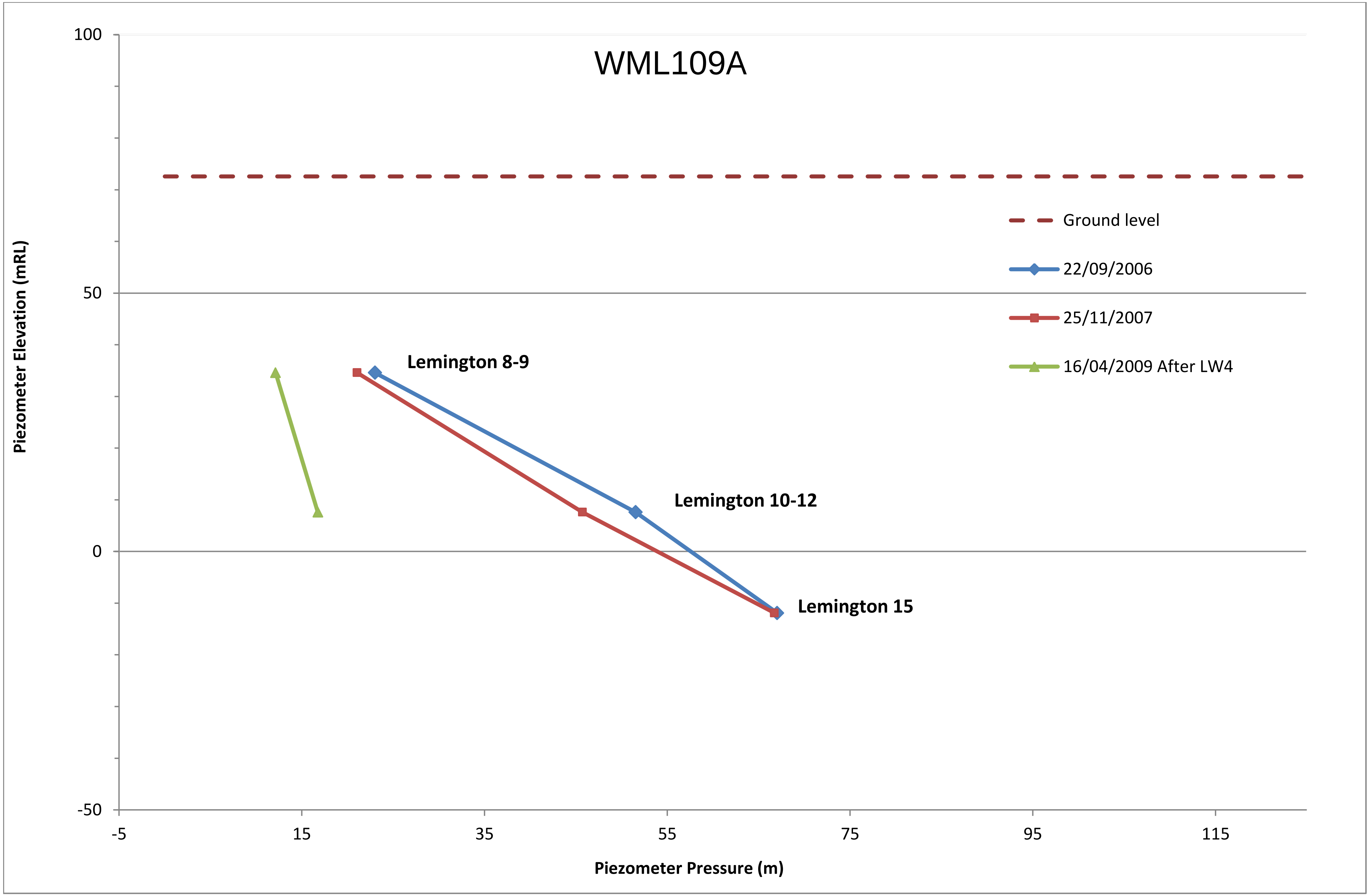
1. An 18 layer model was constructed, with the notable conceptual change of including the Lemington Conglomerate and the use of an unstructured grid.
2. MODFLOW-USG (unstructured grid) was used that allows the use polygons (instead of rectangles) and layers no longer need to have the same number of nodes which in turn allows the improved simulation of layers pinching out or sub-cropping. Nodes from lower layers can also be in direct contact with the top layer of the model. These features make groundwater models more transparent and recreate conceptual models in a much improved way. **This code lends itself to the hydrostratigraphy at Ashton, especially for layers that pinch out.**
3. The main transmissive units are in layers 1 and 5 (Lemington Conglomerate), a significant change from the RPS Aquaterra (2014c) model where only Layer 1 had a significant transmissivity.
4. Hydraulic conductivity was considered as a function of depth for Layers 2-18 and post-mining fractured zones that extend up to 110 m above the LW panel.
5. Pre-mining water budget for the model indicates 4 ML/d rainfall recharge of which half feeds evaporation (2 ML/d) and somewhat less than half is baseflow (1.7 ML/d) to surface waters.
6. The average transient water budget indicates most groundwater is from storage (5.8 ML/d) and rainfall recharge (4.0 ML/d), and some from river recharge (1.0 ML/d). Outflows include increased evapotranspiration (7.4 ML/d), baseflow to surface water (2.0 ML/d), and minor storage (0.5 ML/d) and to drain cells (0.4 ML/d).
7. The model incorporates the historic and more recent understanding of the potential impact to groundwater systems by mining induced subsidence. References to the strata collapse process associated with longwall coal mining and its impact to impact regional groundwater flow systems include Kendorski (1993), SCT (2008a) and Tammetta (2015). Tammetta (2015) is a variation to Kendorski (1993) and SCT (2008a) was used to inform the changes to hydraulic conductivity through the subsidence profile based on site specific investigation and modelling.
8. The model replicates the timing of the October 2013 inflow event as a result of mining LW106B (ULD) but not the magnitude (model 14 L/s, actual inflow rate in the order of 30 L/s+). The model is not able to exactly replicate the subsidence conditions that may have caused the LW6B inflow event. **However, it would be unrealistic to expect the model to re-create the timing and magnitude of the October 2013 event.**
9. Figure 7-8 presents the groundwater sources for the mine inflow. Inflows from the GCA increase markedly at the start of LW mining in each seam – LW1, LW101, LW201 and LW301. Total inflow rate is predicted to increase slightly between 2021 and 2023. This period coincides with the start of mining in the ULLD and completion of mining in the ULD under the BCA.
10. Mine inflows are in the order of 400 ML/yr (1.1 ML/d). In general, over 70% of the inflows are predicted from Permian groundwater ("rock mass" in Table 7-3). About 10% and 5% are predicted from the GCA and BCA, respectively, and around 5% each from the BC and GC and a minor contribution, ~ 2% from the HR. The predicted baseflow depletion is around 24 ML/yr for the BC and GC each. In comparison, the annual average discharge from BC is ~ 18000 ML/yr and from GC is 66335 ML/yr.

Table A 1.17 Review of AGE (2016d)

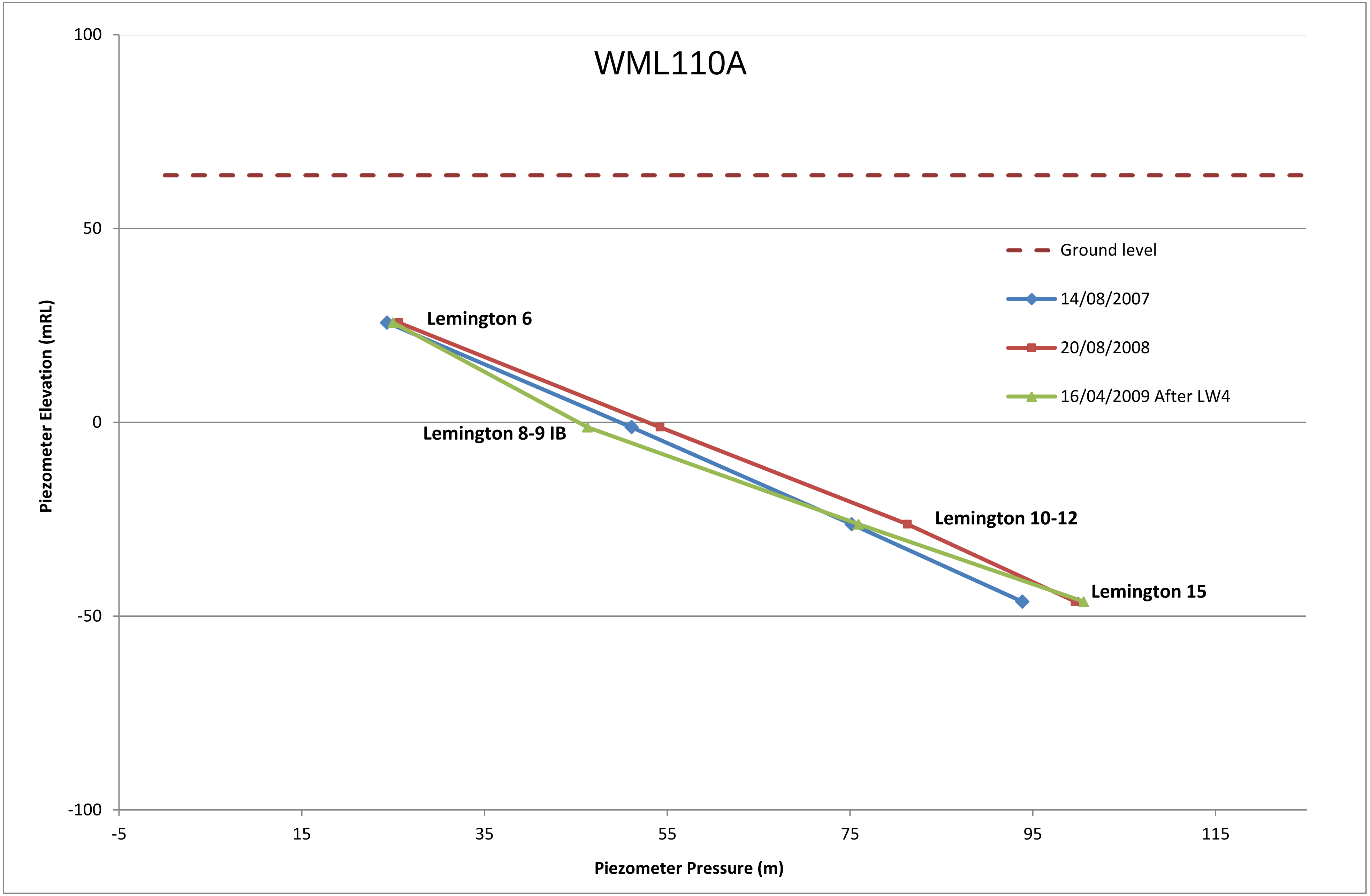
Environment	Predicted Impact	Actual impact	Notes
Permian Strata	Fig.7-2 predicts up to ~ 100 m drawdown in PG by the end of mining in PG, Oct.2013. Up to 100 m drawdown in ULD (Fig.7-3) by the end of mining in ULD, Nov.2023. Fig7-5 predicts up to 200 m drawdown in the ULLD by the end of mining in ULLD, Sept.2029. The predicted drawdown cones are elongated along a NNW-SSE axis and decay rapidly (in ~ 3km) to the west of the underground mine.		
BCA	Fig.7-2 and 7-3 predict indiscernible drawdown in BC by the end of mining the PG and ULD near the BC diversions. Up to 1 m drawdown appears to be predicted in the BC by the end of mining the ULLD (Fig.7-4) and in LB (Fig7-5). The predicted drawdown in Fig.7-6 appears to be up to 2 m drawdown near the northern diversion in the BCA but no date is specified.		
GCA	Fig.7-2 and 7-3 predict no drawdown in GC by the end of mining in PG and UL, respectively. Up to 1 m drawdown appears to be predicted by the end of mining the ULLD (Fig.7-4) and LB (Fig7-5). The predicted drawdown in Fig.7-6 appears to be up to 2 m drawdown near the SE corner of the underground mine (no date).		
HRA	Fig.7-2 to 7-6 predict indiscernible drawdown in the HRA.		
BC Streamflow	Fig.7-8 and Table 7-2 show predicted streamflow and alluvium contributions to mine inflows. In 2013/14 (end of PG mining) a 10 ML/yr contribution is predicted from BC and 23 from BCA. In 2021/22 (end of UL mining) a 24 ML/yr contribution is predicted from BC and 22 from BCA.		
GC streamflow	Fig.7-8 and Table 7-2 show predicted streamflow and alluvium contributions to mine inflows. In 2013/14 (end of PG mining) an 11 ML/yr contribution is predicted from GC and 35 from GCA. In 2021/22 (end of UL mining) a 23 ML/yr contribution is predicted from GC and 45 from GCA.		
HR flow	Fig.7-8 and Table 7-2 show predicted streamflow and alluvium contributions to mine inflows. In 2013/14 (end of PG mining) a 4 ML/yr contribution is predicted from HR and 2 from HRA. In 2021/22 (end of UL mining) an 8 ML/yr contribution is predicted from HR and 1.5 from HRA.		
Mine Inflows	Fig.7-8 and Table 7-2 show predicted mine inflows. In 2013/14 (end of PG mining) 390 ML/yr (1.07 ML/d) is predicted. In 2021/22 (end of UL mining) a 445 ML/yr (1.22ML/d) contribution is predicted.		

Appendix B Hydrostatic head profiles and piezometer water level/pressure hydrographs.

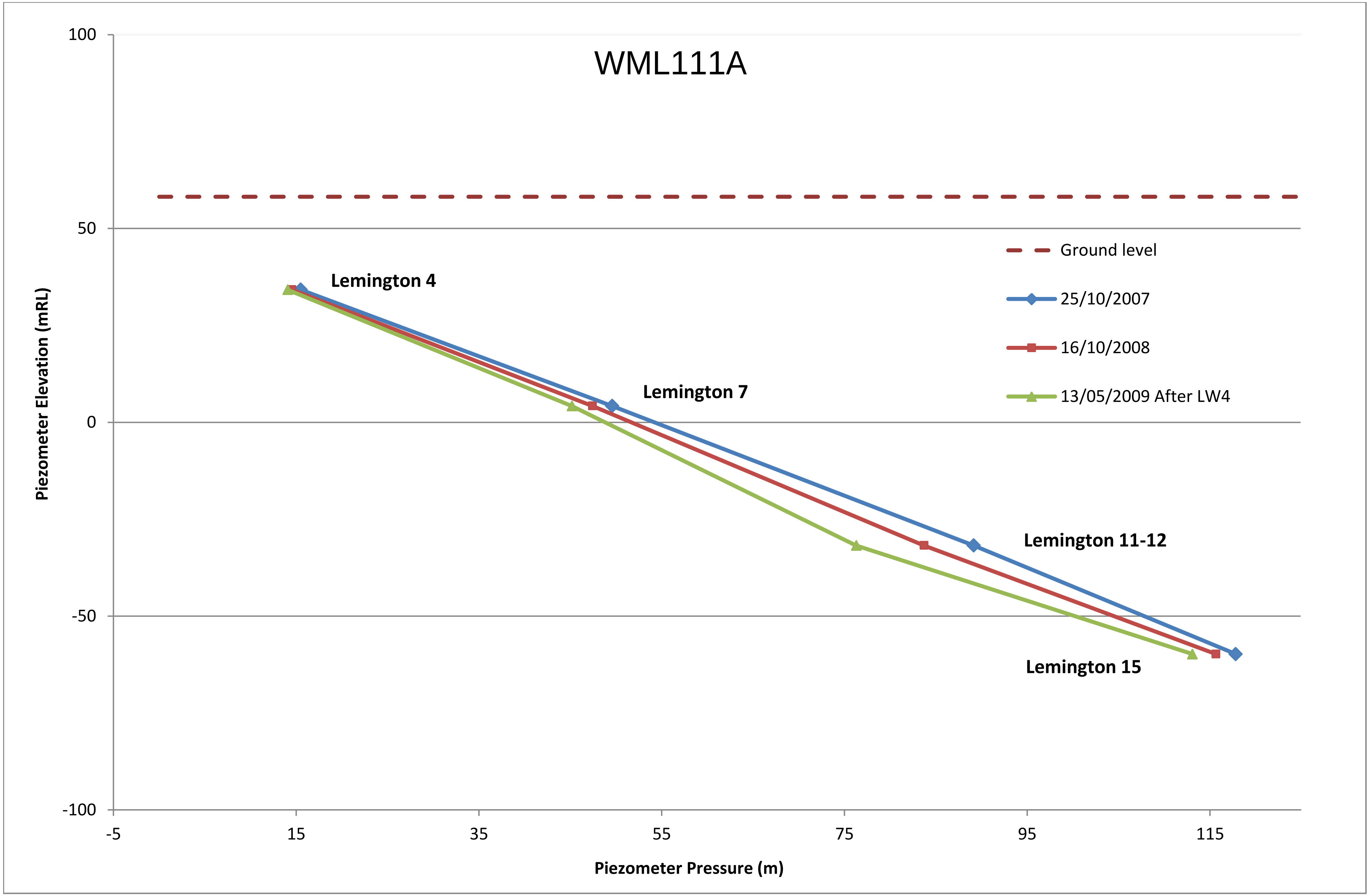

WML108A
Piezometer Elevation (mRL)
100
75
50
25
0
-25
-50
Ground level
24/12/2013
8/07/2014
16/11/2014
Lemington 11-12
Lemington 15
-5
-3
-1
1
3
5
7
9
11
13
15
Piezometer Pressure (m)



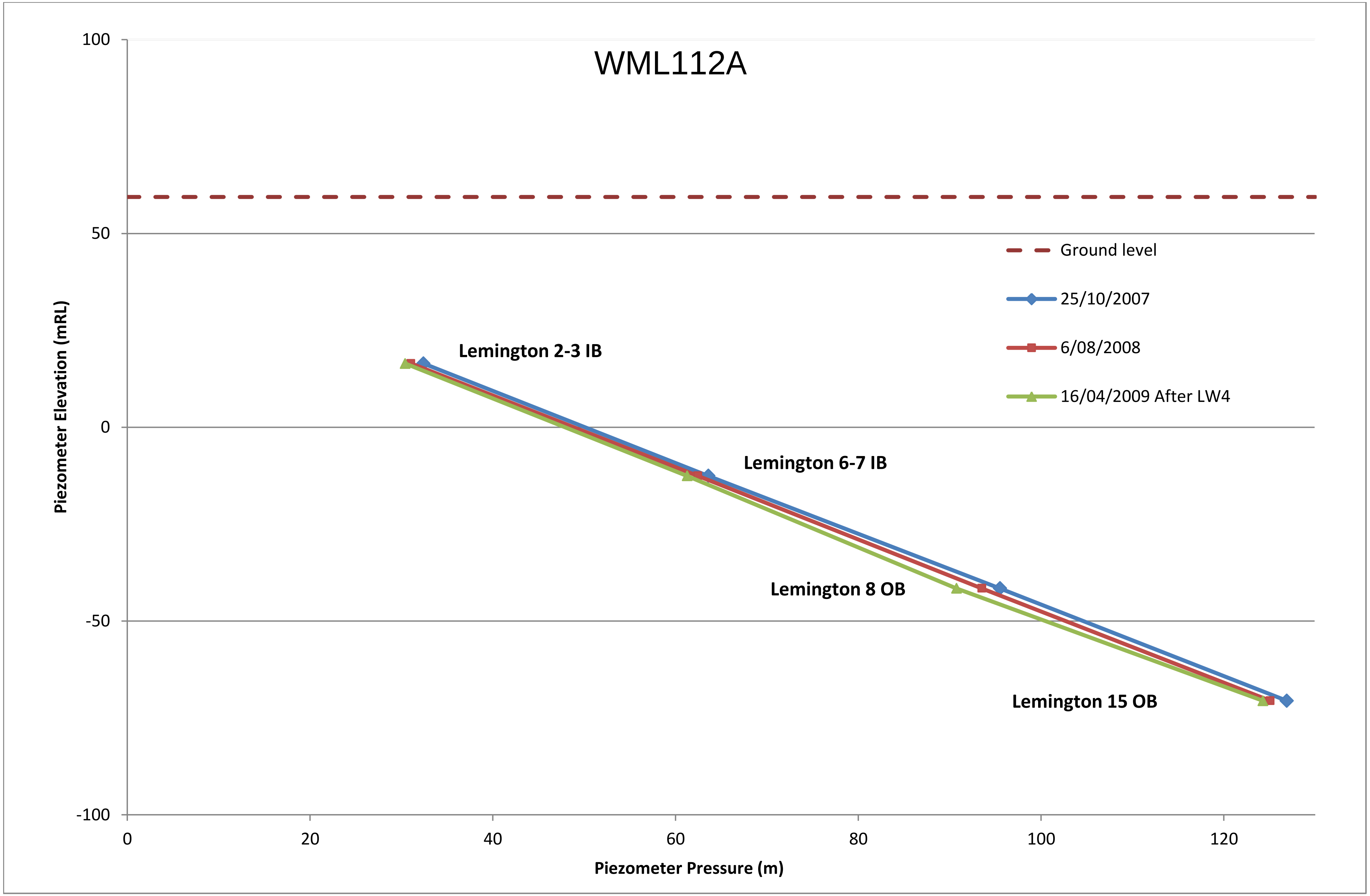
WML109A
Piezometer Elevation (mRL)
100
50
0
-50
-5
15
35
55
75
95
115
Piezometer Pressure (m)
Ground level
22/09/2006
25/11/2007
16/04/2009 After LW4
Lemington 8-9
Lemington 10-12
Lemington 15



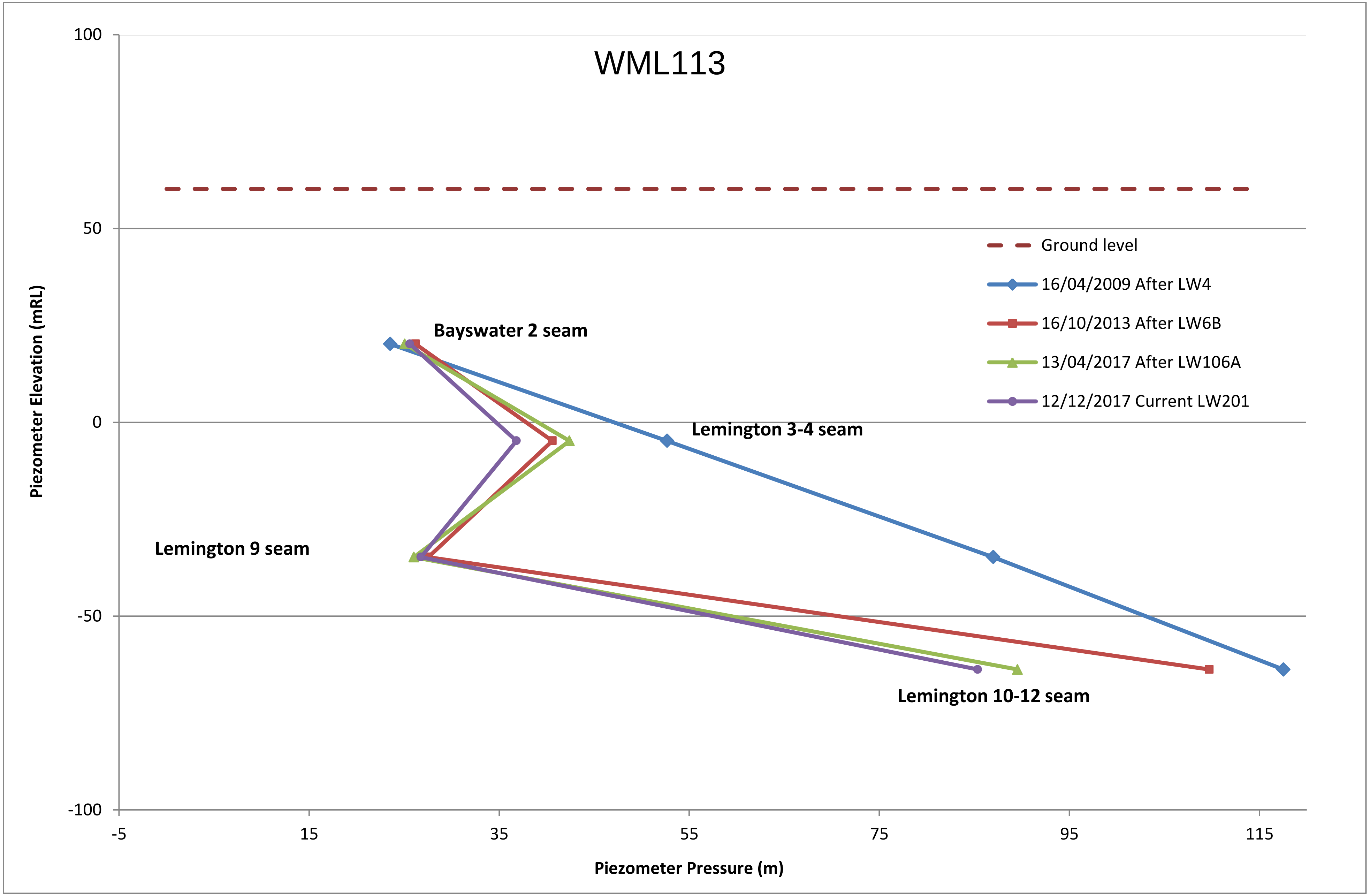
WML110A
100
50
0
-50
-100
-5
15
35
55
75
95
115
Piezometer Elevation (mRL)
Piezometer Pressure (m)
Ground level
14/08/2007
20/08/2008
16/04/2009 After LW4
Lemington 6
Lemington 8-9 IB
Lemington 10-12
Lemington 15



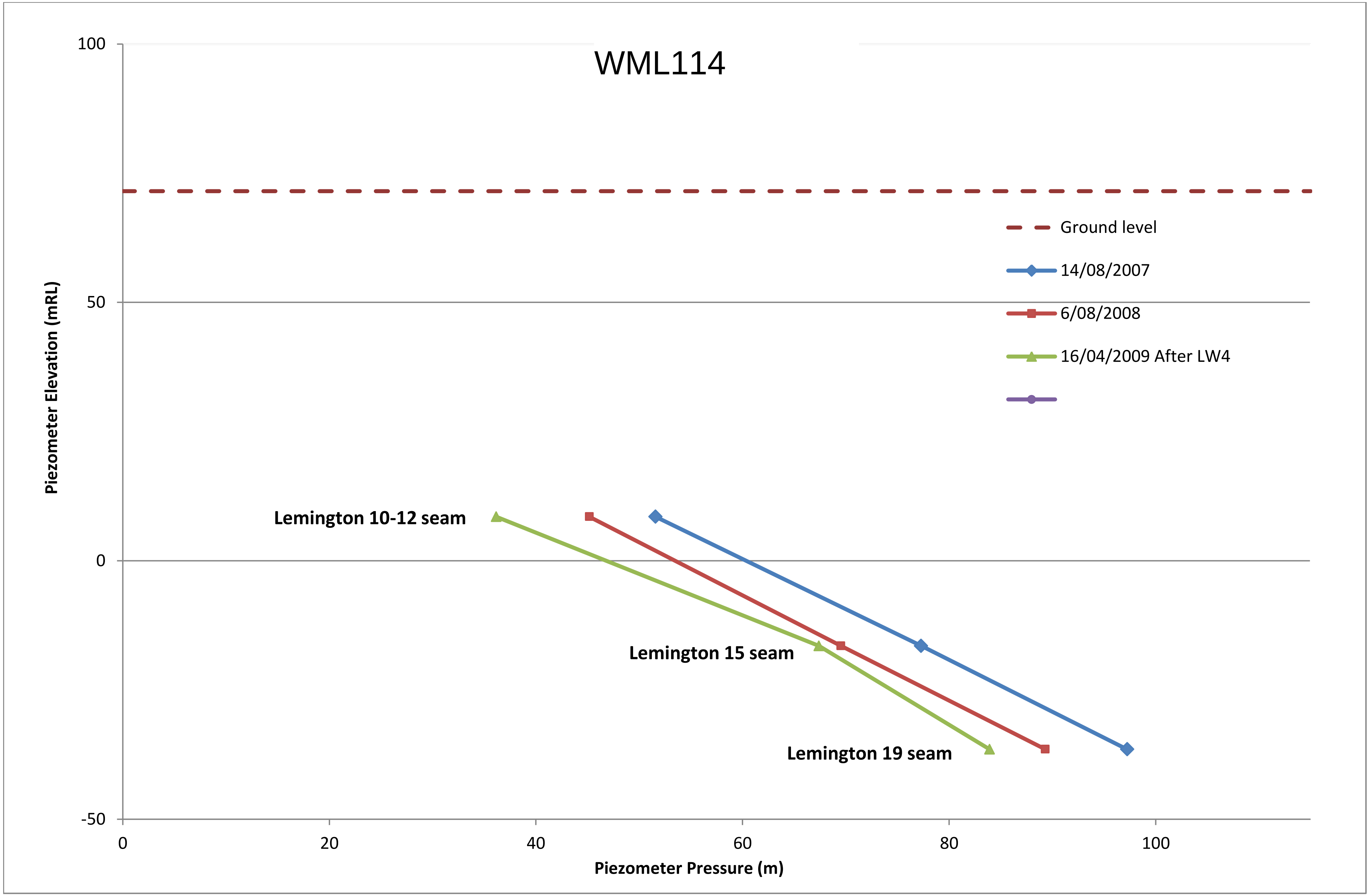
WML111A
100
50
0
-50
-100
-5
15
35
55
75
95
115
Piezometer Elevation (mRL)
Piezometer Pressure (m)
Ground level
25/10/2007
16/10/2008
13/05/2009 After LW4
Lemington 4
Lemington 7
Lemington 11-12
Lemington 15

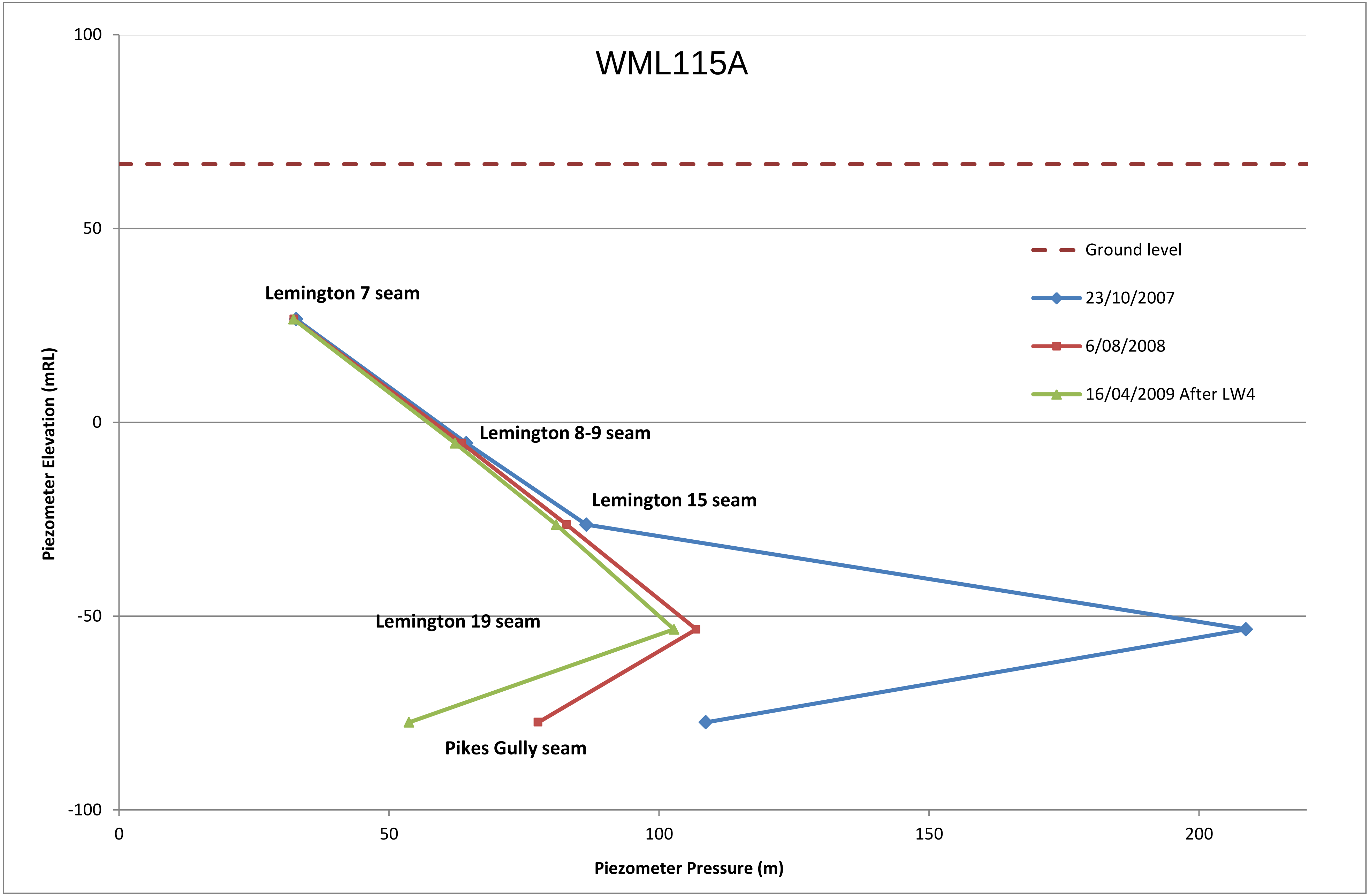


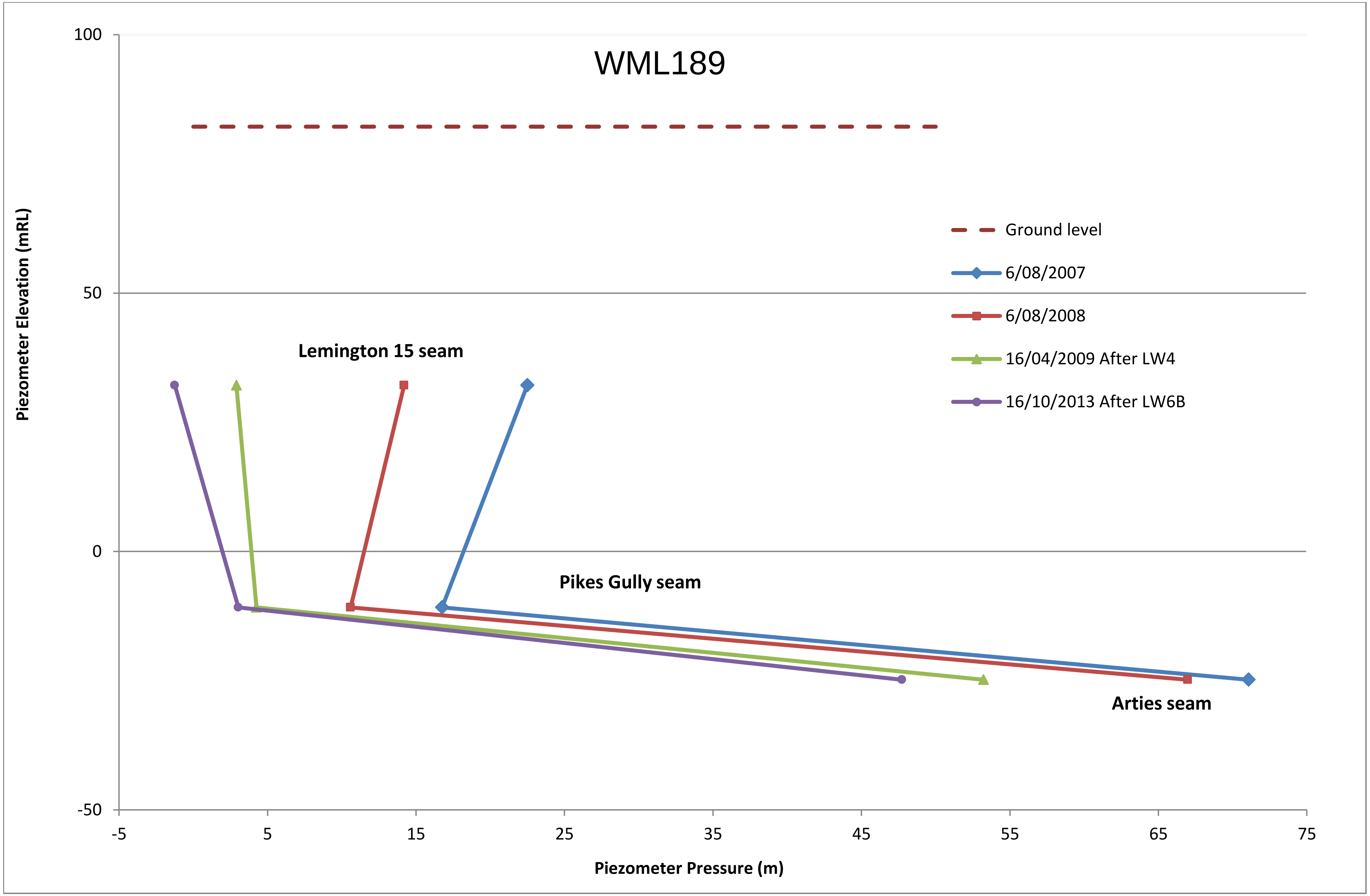
WML112A
100
50
0
-50
-100
0
20
40
60
80
100
120
Piezometer Elevation (mRL)
Piezometer Pressure (m)
Ground level
25/10/2007
6/08/2008
16/04/2009 After LW4
Lemington 2-3 IB
Lemington 6-7 IB
Lemington 8 OB
Lemington 15 OB

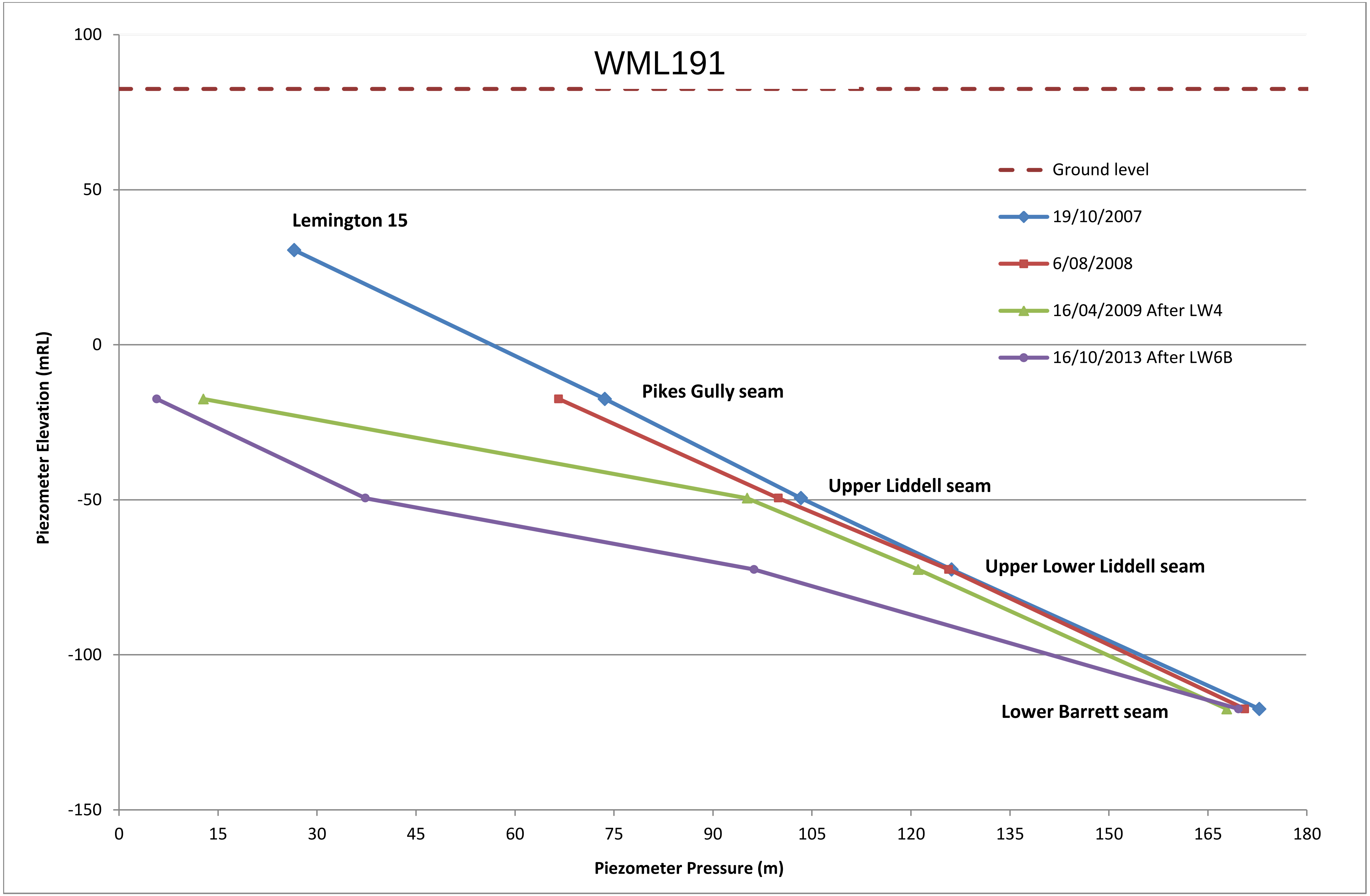


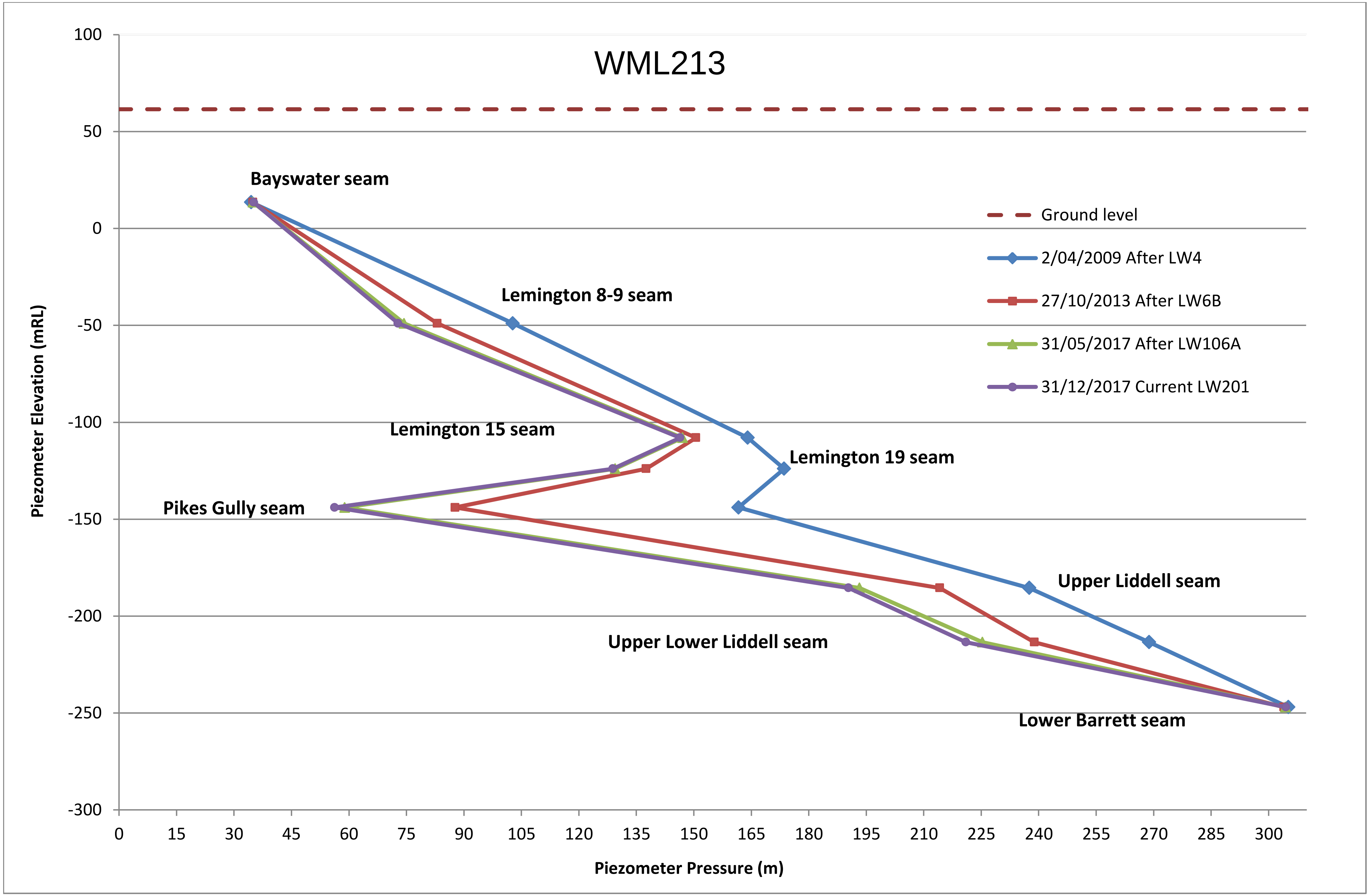
WML113
100
50
0
-50
-100
Piezometer Elevation (mRL)
-5
15
35
55
75
95
115
Piezometer Pressure (m)
Ground level
16/04/2009 After LW4
16/10/2013 After LW6B
13/04/2017 After LW106A
12/12/2017 Current LW201
Bayswater 2 seam
Lemington 3-4 seam
Lemington 9 seam
Lemington 10-12 seam


WML114
100
50
0
-50
0
20
40
60
80
100
Piezometer Elevation (mRL)
Piezometer Pressure (m)
Ground level
14/08/2007
6/08/2008
16/04/2009 After LW4
Lemington 10-12 seam
Lemington 15 seam
Lemington 19 seam

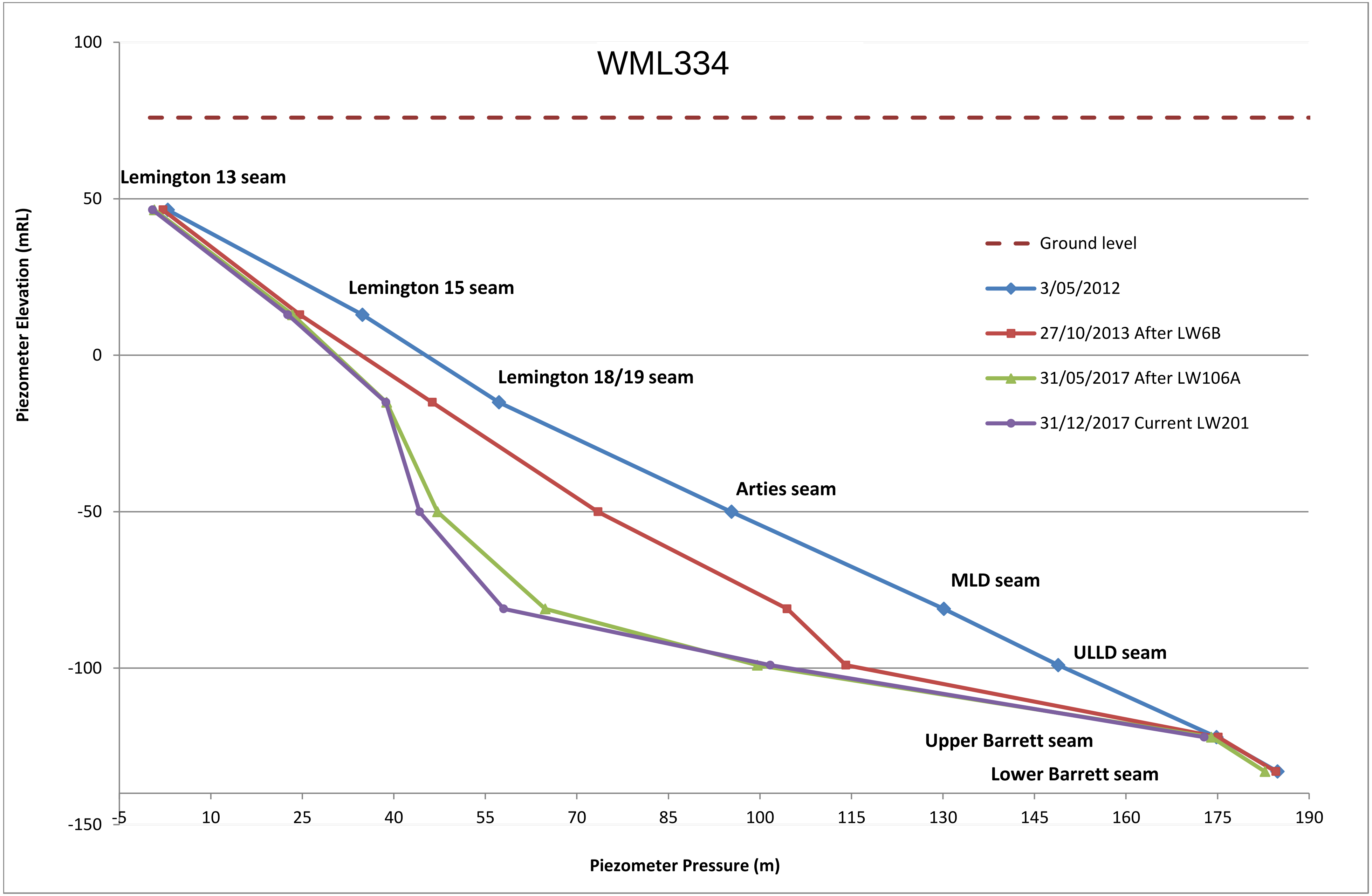

WML115A
Piezometer Elevation (mRL)
100
50
0
-50
-100
Piezometer Pressure (m)
0
50
100
150
200
Ground level
23/10/2007
6/08/2008
16/04/2009 After LW4
Lemington 7 seam
Lemington 8-9 seam
Lemington 15 seam
Lemington 19 seam
Pikes Gully seam

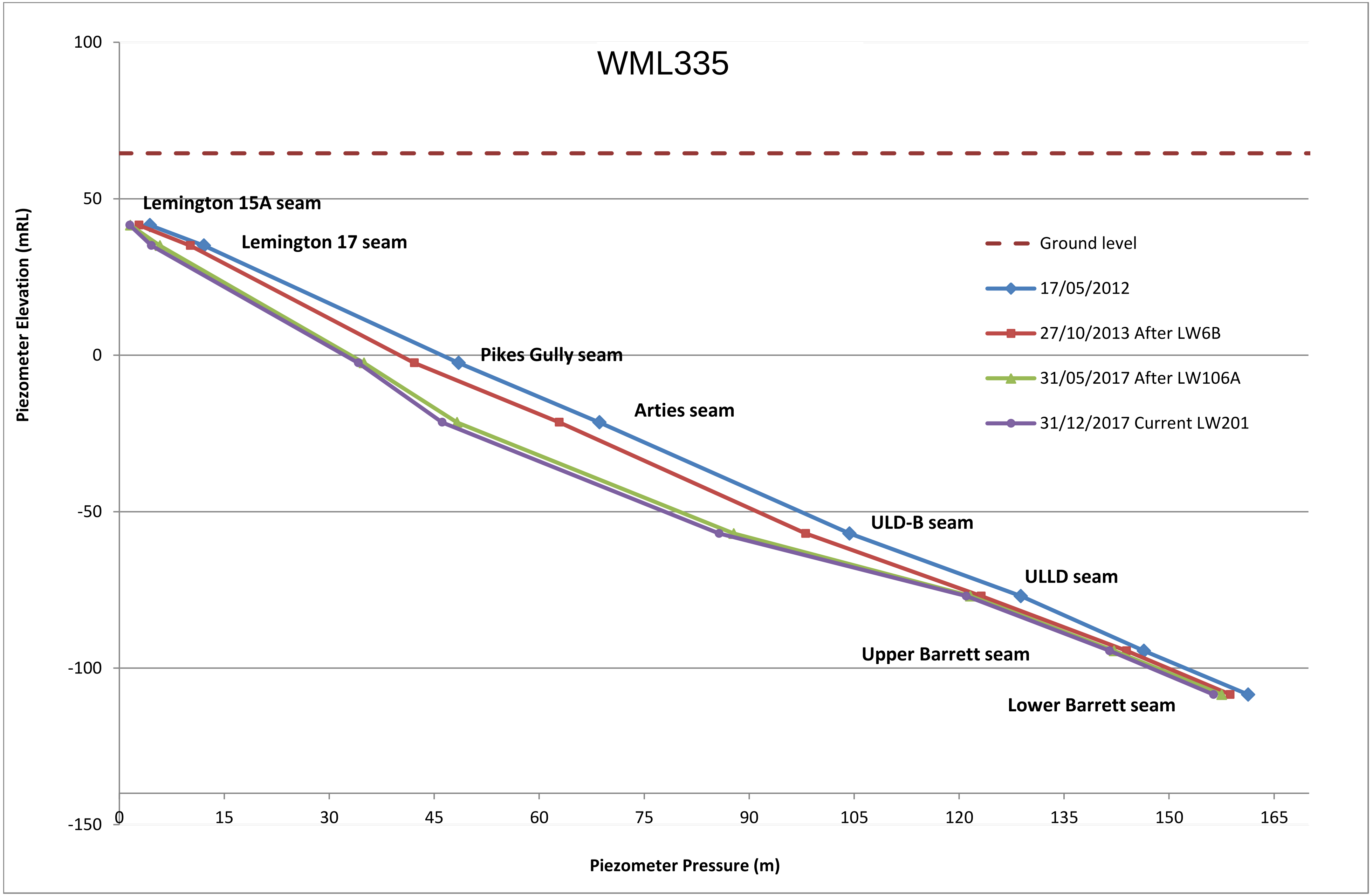

WML189
Ground level
6/08/2007
6/08/2008
16/04/2009 After LW4
16/10/2013 After LW6B
Lemington 15 seam
Pikes Gully seam
Arties seam
Piezometer Elevation (mRL)
100
50
0
-50
-5
5
15
25
35
45
55
65
75
Piezometer Pressure (m)


WML191
Piezometer Elevation (mRL)
Piezometer Pressure (m)
100
50
0
-50
-100
-150
0
15
30
45
60
75
90
105
120
135
150
165
180
Ground level
19/10/2007
6/08/2008
16/04/2009 After LW4
16/10/2013 After LW6B
Lemington 15
Pikes Gully seam
Upper Liddell seam
Upper Lower Liddell seam
Lower Barrett seam

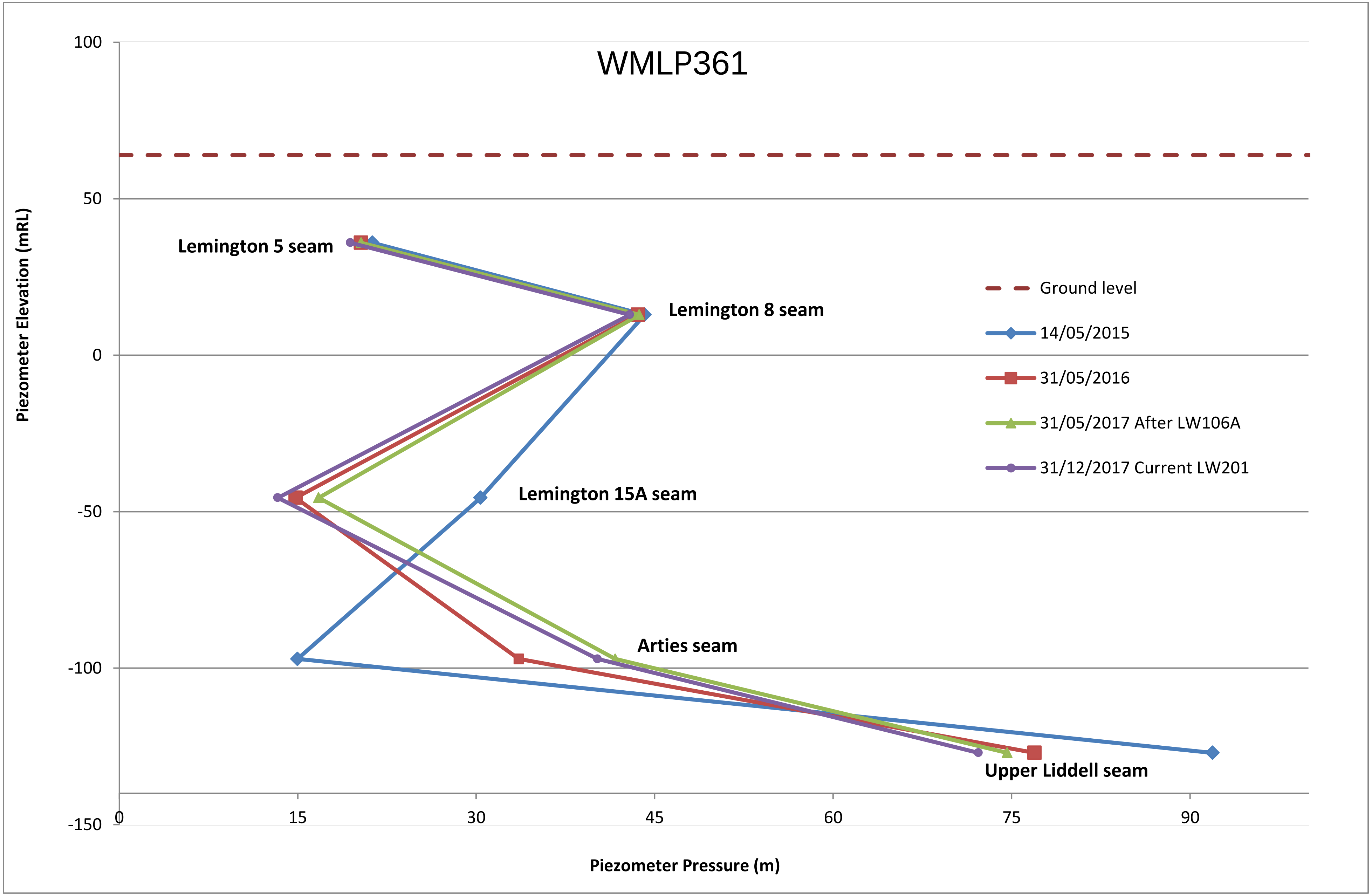


WML213
Bayswater seam
Lemington 8-9 seam
Lemington 15 seam
Lemington 19 seam
Pikes Gully seam
Upper Liddell seam
Upper Lower Liddell seam
Lower Barrett seam
Ground level
2/04/2009 After LW4
27/10/2013 After LW6B
31/05/2017 After LW106A
31/12/2017 Current LW201
Piezometer Elevation (mRL)
Piezometer Pressure (m)
100
50
0
-50
-100
-150
-200
-250
-300
0
15
30
45
60
75
90
105
120
135
150
165
180
195
210
225
240
255
270
285
300

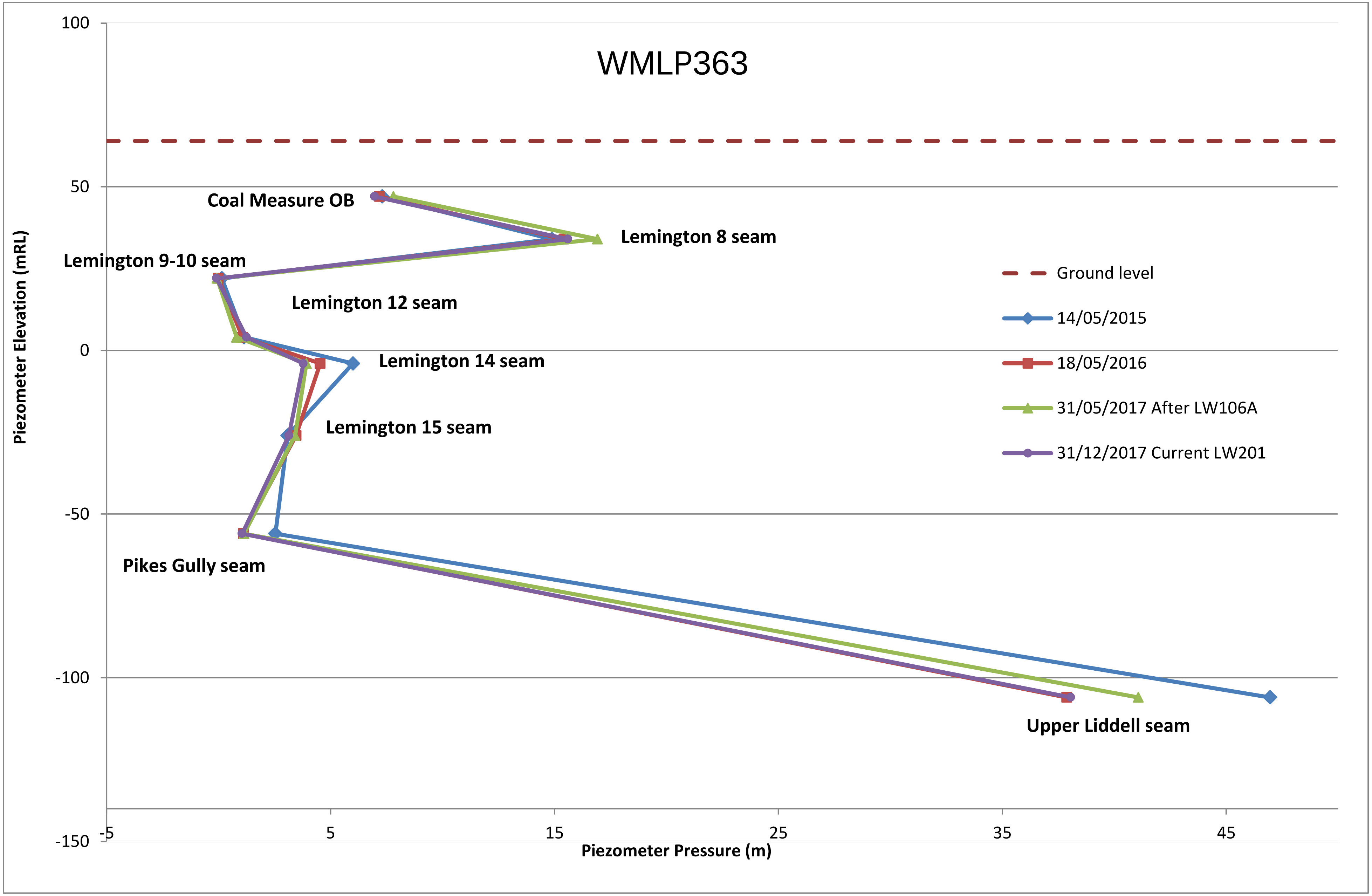

WML334
Piezometer Elevation (mRL)
Piezometer Pressure (m)
Lemington 13 seam
Lemington 15 seam
Lemington 18/19 seam
Arties seam
MLD seam
ULLD seam
Upper Barrett seam
Lower Barrett seam
Ground level
3/05/2012
27/10/2013 After LW6B
31/05/2017 After LW106A
31/12/2017 Current LW201
100
50
0
-50
-100
-150
-5
10
25
40
55
70
85
100
115
130
145
160
175
190



WML335
Piezometer Elevation (mRL)
Piezometer Pressure (m)
100
50
0
-50
-100
-150
0
15
30
45
60
75
90
105
120
135
150
165
Lemington 15A seam
Lemington 17 seam
Pikes Gully seam
Arties seam
ULD-B seam
ULLD seam
Upper Barrett seam
Lower Barrett seam
Ground level
17/05/2012
27/10/2013 After LW6B
31/05/2017 After LW106A
31/12/2017 Current LW201



WMLP361
Piezometer Elevation (mRL)
100
50
0
-50
-100
-150
0
15
30
45
60
75
90
Piezometer Pressure (m)
Lemington 5 seam
Lemington 8 seam
Lemington 15A seam
Arties seam
Upper Liddell seam
Ground level
14/05/2015
31/05/2016
31/05/2017 After LW106A
31/12/2017 Current LW201



WMLP363
Piezometer Elevation (mRL)
100
50
0
-50
-100
-150
-5
5
15
25
35
45
Piezometer Pressure (m)
Coal Measure OB
Lemington 8 seam
Lemington 9-10 seam
Lemington 12 seam
Lemington 14 seam
Lemington 15 seam
Pikes Gully seam
Upper Liddell seam
Ground level
14/05/2015
18/05/2016
31/05/2017 After LW106A
31/12/2017 Current LW201

Appendix C DPE Letter (21 March 2018), HEC Letter (19 August 2019) and AGE Letter Addendum Report (22 August 2019)

Planning Services
Resource Assessments

Contact: Megan Dawson
Phone: 9274 6391
Email: megan.dawson@planning.nsw.gov.au

Mr Phillip Brown
Environment and Community Manager
Ashton Coal Operations Pty Limited
PO Box 699
SINGLETON NSW 2330

Dear ~~Mr Brown~~ Phil

Ashton Coal Project (DA 309-11-2001-i)
Historical Groundwater Review and Assessment

I refer to the Historical Groundwater Review and Assessment (dated February 2018), prepared in response to the Department's conditional approval of the Extraction Plan for Longwalls 201-204 of the Ashton Coal Project (dated 16 May 2017).

The Department's conditional approval required Ashton Coal Operations Pty Limited (ACOL) to prepare a technical review of historical water impacts at Ashton mine which "*should ultimately demonstrate ACOL's understanding of the hydrogeological regime to support its view that additional monitoring to validate the model predictions is unnecessary*".

The Department has completed a thorough and careful review of the assessment and is satisfied that it provides:

- an adequate overview of the historical and current mining operations;
- an adequate description of the conceptual hydrogeology in the area of the Ashton Mine;
- three large-scale hydrogeological cross-sectional figures illustrating the pre-mining and post-mining (ie. post LW6b and post LW106A) impacts of underground mining on alluvial groundwater levels and coal measure groundwater heads;
- a description of the historic groundwater models and assessments prepared for the Ashton Mine dating from 2001 to 2016; and
- a summary of the predicted impacts of underground mining from each groundwater model and assessment against actual impacts recorded from monitoring data.

However, in order to fully address the Department's requirements, it is requested that ACOL amend the report to also include:

- a summary of the existing surface and groundwater monitoring program addressing drawdown, baseflow and mine inflow;
- comment on the adequacy or otherwise of this monitoring program to a full understanding the hydrogeological regime and mining impacts in the area of the Ashton Mine; and
- comment on whether additional monitoring could lead to an increased understanding of the hydrogeological regime and more accurate model predictions.

If you require any more information, please contact Megan Dawson on 9274 6391.

Yours sincerely

Howard Reed 21·3·18

Howard Reed
Director Resource Assessments
as nominee for the Secretary

HYDRO ENGINEERING
& CONSULTING PTY LTD

19 August 2019

Environment & Community Manager
Ashton Coal Operations Pty Ltd
via Email
Attention: Phil Brown

Dear Phil,

Re: Ashton Coal Mine – Groundwater Review and Assessment

Further to your email today, we understand that the NSW Department of Planning & Environment (DPE) have requested amendments to the Historical Groundwater Review and Assessment Report prepared in response to the DPE's conditional approval of the Extraction Plan for Longwalls 201-204 of the Ashton Coal Mine (ACM). One of the requested amendments is for the inclusion of "a summary of the existing surface and groundwater monitoring program addressing drawdown, baseflow and mine inflow". The following provides a summary of current surface water monitoring that is undertaken at the ACM that would contribute to addressing baseflow and mine inflow.

Streamflow Monitoring

Streamflow is monitored on Bowmans Creek at GS210310 located between the Eastern and Western reaches of the Bowmans Creek Diversion (BCD). This gauging station is operated by WaterNSW and continuous flow data is available on line. Another streamflow gauging station is maintained by Ashton Coal Operations Pty Limited at a location downstream of the BCD. Assessment of the recorded data from these two stations would allow partitioning of the recorded flow hydrograph in order to estimate the baseflow component. Analysis of baseflow response with time in response to catchment rainfall would allow any mine-induced impacts on baseflow to be assessed.

Mine Inflow

Routine monitoring of water supplied to and withdrawn from the ACM underground operations is undertaken using flow meters and is typically recorded on a monthly basis. In addition, the volume of water stored in goafed underground areas is periodically assessed from monitored water levels. Assessment of the underground water balance (i.e. pumped inflows minus pumped outflows minus the change in storage) allows for estimation of groundwater inflow rates to the underground mine. This is undertaken each month and reported as part of the Annual Review.

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Similarly water balance calculations undertaken as part of an annual water balance review for the north-east open cut (NEOC) use monitored flow rates into and out of the NEOC, monitored water levels and modelled estimates of rainfall runoff (based on recorded site rainfall and a calibrated runoff model), to estimate groundwater inflows to the NEOC.

We trust that this provides the information required by the DPE in relation to surface water. Please contact the undersigned if you have any queries.

Yours faithfully,

Tony Marszalek
Director

Australasian Groundwater
and Environmental Consultants Pty Ltd
Level 2 / 15 Mallon Street
Bowen Hills, QLD 4006 Australia

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brisbane@ageconsultants.com.au
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CC/DWI:kc
G1858H.Ashton_EP_Monitoring Letter_v01.03.docx
22 August 2019

Attention: Phillip Brown
Ashton Coal Operations Pty Ltd
PO Box 699
SINGLETON NSW 2330

via email

Dear Phil,

RE: Ashton Coal Mine – Letter Addendum Historical Groundwater Review and Assessment

1 Introduction

On 15 February 2018, Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) provided a report to Yancoal Australia Ltd (Yancoal) that assessed groundwater conditions from historic monitoring data (AGE, 2018[1]). The report was prepared to address correspondence from the NSW Department of Planning and Environment (DPE) and the NSW Department of Primary Industries–Water (DPI Water) which requested that a "*technical review of historical water impacts*" at the Ashton Coal Mine (ACM) be carried out. DPE and DPI Water suggested that a technical review would demonstrate Yancoal's understanding of the hydrogeological regime, and support the suitability of the existing monitoring network and WMP, and justify that additional monitoring is unnecessary.

The Historical Groundwater Review and Assessment was provided to DPE and DPI Water for consideration. The report was reviewed by both government departments and a letter response from DPE was provided to Ashton Coal Operations Pty Ltd (ACOL) on the 21st of March 2018.

The letter from DPE expressed a general satisfaction that the assessment had addressed the majority of concerns and issues initially expressed by DPE. However, the letter also requested that ACOL amend the report to also include:

- *A summary of the existing surface and groundwater monitoring program addressing drawdown, baseflow and mine inflow;*
- *Comment on the adequacy or otherwise of this monitoring program to a full understanding of the hydrogeological regime and mining impacts in the area of the Ashton Mine; and*
- *Comment on whether additional monitoring could lead to an increased understanding of the hydrogeological regime and more accurate model predictions.*

[1] *AGE. 2018. Historical Groundwater Review and Assessment - Ashton Coal Mine. Prepared for Yancoal Australia Ltd. Project No. G1858H. February 2018.*

With the exception on the surface water monitoring program (to assess baseflow), which is to be completed by others, this letter report presents commentary on the above additional items and is intended to be included as an addendum to the February 2018 report (AGE, 2018[2]).

2 Summary of existing groundwater monitoring program

The Ashton Water Management Plan (WMP) was updated in March 2018 and included the addition of 15 groundwater monitoring locations into the existing Ashton WMP groundwater monitoring network. These additional sites included bores targeting key hydrogeological units, primarily the Glennies Creek alluvium (GCA) and the Bowmans Creek alluvium (BCA). The current and approved WMP groundwater monitoring network now consists of 64 monitoring bores and vibrating wire piezometer (VWP) installations that monitor both the alluvial and fractured rock aquifers on site. The VWP installations typically have multiple (up to six) VWP gauges / sensors at each site that monitor from the regolith zone to the Barrett (BAR) seam. The monitoring network is shown in Figure 1 along with the general alignment of the underground longwall panels.

The groundwater monitoring program includes the monitoring of:

- water levels;
- piezometric pressure;
- field water quality parameters – pH and electrical conductivity (EC);
- groundwater sampling for a minor chemical analysis suite, comprising laboratory pH, laboratory EC and cation / anions (Na, K, Ca, Mg, F, Cl, SO_4 HCO_3).
- groundwater sampling for comprehensive chemical analysis, comprising the minor analytical suite and laboratory NO_3, Total N, Total P, Cu, Pb, Zn, Ni, Fe, Mn, As, Se, Cd, Cr, Total Alkalinity, Total Cyanide;
- monitoring of water level and EC required by environmental protection licence 11879 (EPL 11879)^; and
- dewatering bore pumped volumes.

The monitoring frequency of the groundwater monitoring network is as follows:

- Monthly campaigns:
    - All WMP monitoring bores are gauged for water level. Bores equipped with pressure transducers are be downloaded monthly.
    - monitoring at selected alluvium and fractured rock aquifer piezometers for field water quality.
    - Monitoring of piezometric pressure at selected VWPs.
- Quarterly campaigns. In addition to the monthly monitoring campaign, the quarterly campaign also include:
    - Monitoring at additional monitoring bores for water level and field water quality (EC and pH).
    - Sampling at selected monitoring bores for minor suite of chemical analysis (laboratory analysis of pH, EC and cation / anions).
    - Six-monthly monitoring at EPL 11879 monitoring bores for field EC only.

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[2] *AGE. 2018. Historical Groundwater Review and Assessment - Ashton Coal Mine. Prepared for Yancoal Australia Ltd. Project No. G1858H. February 2018.*

- Annual campaign. In addition to the quarterly monitoring campaign, the annual campaign also include:
    - Annual sampling at additional monitoring bores for minor suite of chemical analysis (laboratory analysis of pH, EC and cation / anions [Na, K, Ca, Mg, F, Cl, SO_4 HCO_3]).
    - Annual sampling at selected monitoring bores for comprehensive chemical analysis (laboratory analysis of lab pH, lab EC, temperature, TDS, Turbidity, NO_3, Total N, Total P, Cu, Pb, Zn, Ni, Fe, Mn, As, Se, Cd, Cr, Total Alkalinity, Total Cyanide).

The WMP was updated in March 2018 to include a number of GCA bores (east of Glennies Creek) to provide additional monitoring for potential impacts to the GCA. The nine GCA bores are shown in Figure 1 as light blue dots and are located on the eastern and western side of Glennies Creek.

The Hunter River Alluvium (HRA) bores are shown in Figure 1 as dark blue dots and it can be seen that there is a spatial distribution of eight monitoring bores along the southern boundary of the mine along the northern side of the Hunter River. ACOL does not have land access to the southern side of the Hunter River.

The BCA bores are shown in Figure 1 as green dots with a distribution of 21 monitoring bores along the western boundary of the mine along Bowmans Creek. The BCA monitoring bores are located on both the east and west sides of Bowmans Creek and are installed above three longwall panels of the mine.

In addition to this, a number of fractured rock bores and VWP installations have been added to the monitoring program following a recent bore census carried out on site. This brings the total number of fractured rock (Permian coal seam and overburden) bores within the WMP up to 26. As discussed above, the VWP installations typically have multiple VWP gauges / sensors at each site and monitor several coal seams at the one location. The location of the fractured rock monitoring bores and VWPs are shown in Figure 1.

A network of flowmeters at Ashton is monitored monthly to enable the site water balance to be updated on a regular basis. These flowmeters are located both underground and at the various site infrastructure. By updating this water balance, an estimate of groundwater inflows is able to be back calculated and this is partitioned for the three alluvial water sources and the Permian coal measures. This monthly estimate of groundwater inflow is then used to compare and correlate against model predictions.

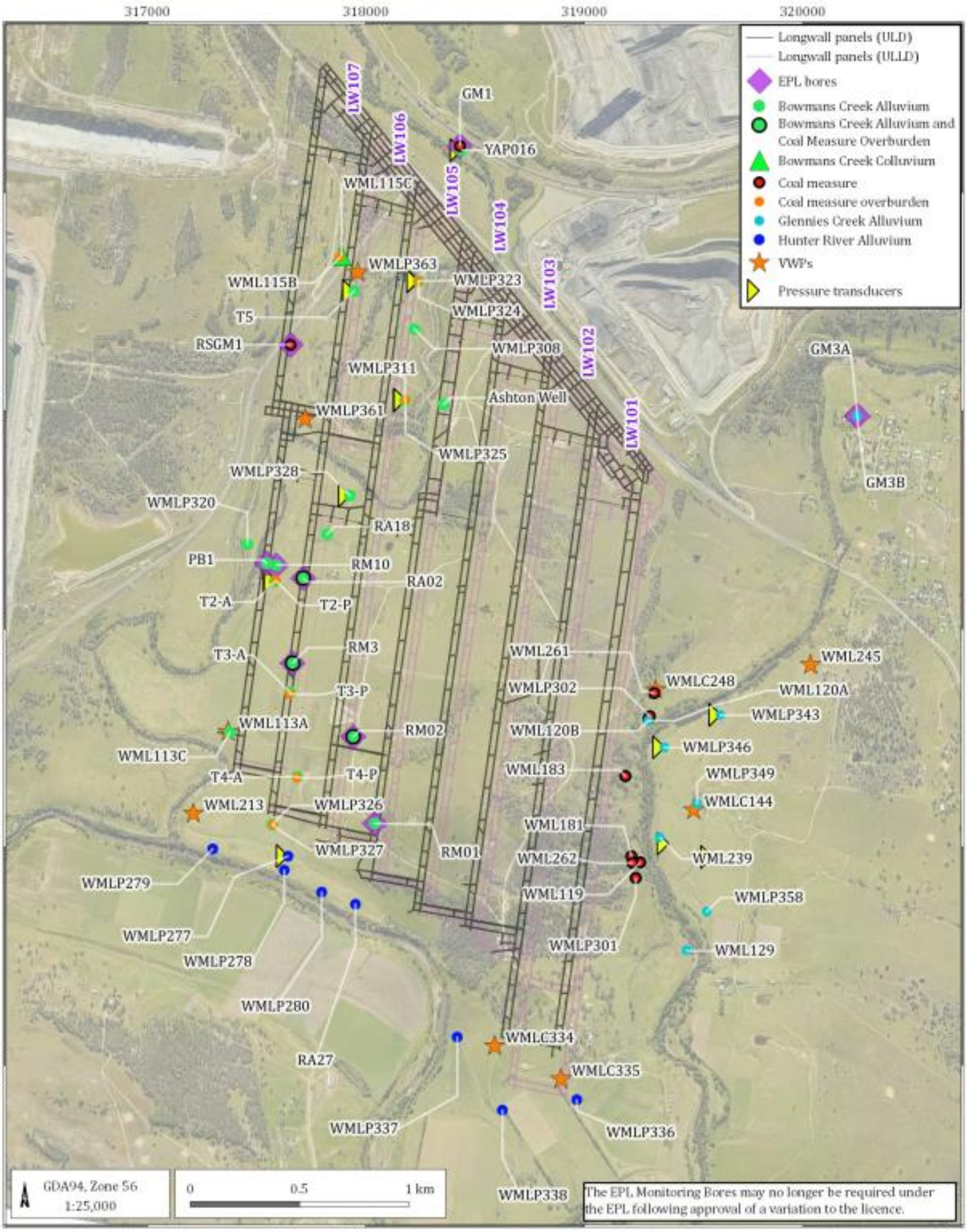

Figure 1 Ashton WMP groundwater monitoring network

3 Adequacy of the existing monitoring program

The groundwater monitoring network at Ashton comprises a total of 64 sites, targeting both the unconsolidated alluvial sediments associated with Bowmans Creek, Glennies Creek and the Hunter River and the Permian coal seams and overburden. The number of bores or VWPs in each formation is summarised below in Table 1.

Table 1 Summary of existing groundwater monitoring network

Formation	Count	Percentage
BCA	21	32.8%
GCA	9	14.1%
HRA	8	12.5%
Permian	26	40.6%
Total	64	100%

The predicted drawdown at Ashton as a result of mining occurs predominantly within the Permian coal measures. The predicted and observed drawdown within the Permian coal measures is in the order of metres to hundreds of metres depending upon where the bores are screened stratigraphically in relation to the mined coal seams, and spatially in terms of where the bores are located in relation to the longwall panels. The bores and VWPs targeting the Permian coal measures are designed to monitor and assess the drawdown and depressurisation that is predicted to occur as a result of underground mining.

There are very minor areas of alluvium that are predicted to be impacted by mining and the magnitude of predicted drawdown in the alluvium is typically less than one metre. The predicted alluvial drawdown occurs in areas that are located on the surface over or laterally adjacent to longwall panel extents, and areas affected by subsidence cracking above the longwall panels. The monitoring bores targeting the unconsolidated alluvial sediments are designed to monitor for potential drawdown in the alluvium and any associated water quality change beyond natural variation. The extent of surface subsidence and surface cracking is also monitored on a regular basis by Ashton.

The main groundwater risks associated with mining activities is related to increased inflow from the alluvium and drawdown within the alluvium. As a result of these acknowledged risks, Ashton has weighted a larger percentage of monitoring bores in the WMP to be monitoring the alluvium (60% of bores within the WMP are installed in the alluvium). In terms of spatial distribution of the alluvium monitoring bores, there is a larger percentage of bores (more than 50%) within the BCA compared with the HRA and GCA. This larger percentage of bores within the BCA is due to the larger footprint of BCA located over the existing longwall panels.

The spatial distribution of the bores within the BCA, GCA and HRA are assessed to be adequate with even and representative spacing over the length of the potentially affected alluvium. The exception to this is the GCA, which has a deficit of monitoring bores immediately to the north and south of the New England Highway. This spatial data gap within the GCA is due to the area not being accessible to Ashton. Attempts by Ashton to gain land access to this area will continue in order to improve the spatial distribution of the groundwater monitoring network in the GCA.

The groundwater monitoring network is monitored and sampled on a regular basis (refer Section 2) and is supported by the installation of dataloggers and pressure transducers to enable groundwater levels and pore pressures to be sampled every six hours. The data is assessed on a monthly basis to ensure the data is consistent with manual measurements, predictions and within the trigger levels outlined in the WMP. The network is well maintained by a qualified AGE hydrogeologist and the methodology used to sample the bores is consistent and carried out in accordance with the relevant guidelines.

In summary, the groundwater monitoring network focusses on the main risks to the groundwater regime (that is the very low likelihood that groundwater levels in the alluvium will affected due to inflow to the underground workings). The monitoring network is adequate to allow a full characterisation of the groundwater regime and to enable the detection of impacts should they occur.

4 Requirement for additional monitoring

The WMP has recently been updated to include additional monitoring bores within the GCA and BCA. As discussed above, the monitoring network focusses on the main risks to the groundwater regime and is assessed as adequate to enable the monitoring of impacts should they occur.

Whilst additional data and monitoring can generally increase hydrogeological understanding at a mine site, in this instance the monitoring network is considered substantial, comprehensive and has been in place and monitored for many years. Regular assessments are carried out with the data to ensure it is captured in a manner that is appropriate and can be considered representative. The processes occurring at the site are well understood and are able to be simulated by the numerical model with a high degree of confidence. In addition to this, given the relatively long history of mining activities Ashton is able to demonstrate through historical activities and monitoring data that the future hydrogeological responses observed at the site are highly likely to be consistent with those observed in the past.

It is recognised that there is a spatial data gap in the northern part of the GCA. This spatial gap is not considered significant as there is currently both up and down stream monitoring within the GCA proximal to this area.

In summary, whilst additional data and monitoring may provide an increased level of understanding, this understanding would only be a very minor or incremental increase over what is currently known. Such additional data is highly unlikely to affect future predictions, and the likelihood and consequences of impact to the wider groundwater system. Also, AGE considers the current Ashton groundwater monitoring network and monitoring program to be sufficient for collecting data that will support the groundwater model and structure.

5 Closure

In our professional opinion, the groundwater monitoring network at Ashton is comprehensive and is adequately distributed spatially and across the various hydrostratigraphic units that are present at the site. The Ashton monitoring network and WMP has been designed to focus on key risk areas to the groundwater regime that have been identified during conceptualisation and modelling. The groundwater monitoring network is well maintained, and the monitoring methodologies and practices are consistent and comply with the appropriate guidelines. The monitoring data allows for an excellent understanding of groundwater system and AGE are of the opinion that additional monitoring bores or data collection, above what is currently included in the WMP, is unnecessary.

Yours sincerely,

Costante Conte
NSW Manager / Principal Hydrogeologist
Australasian Groundwater and Environmental Consultants Pty Ltd

Planning Services
Resource Assessments
Contact: Jack Murphy
Phone: 8217 2016
Email: jack.murphy@planning.nsw.gov.au

Mr Phillip Brown
Environment and Community Manager
Ashton Coal Operations Pty Limited
PO Box 699
Singleton NSW 2330

Dear Mr Brown, Phil

Ashton Coal Project (DA 309-11-2001-i)
Historical Groundwater Review and Assessment

I refer to the revised Historical Groundwater Review and Assessment (dated August 2019), prepared in response to the Department's letter dated 21 March 2018.

The Department has reviewed the above document and considers it fulfils its previous requests. Consequently, the Secretary has approved this document.

Please ensure a finalised copy of this document is made available on the company's website.

Should you have any enquiries in relation to this matter, please contact Jack Murphy.

Yours sincerely,

Howard Reed 30.8.19
Howard Reed
Director
Resource Assessments
As nominee of the Secretary