Appendix 5 Groundwater Impact Assessment

Water and Environment

BOWMANS CREEK DIVERSION: GROUNDWATER IMPACT ASSESSMENT REPORT

Prepared for	Ashton Coal Operations Pty Ltd
Date of Issue	21 October 2009
Our Reference	S55G/600/011G

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EXECUTIVE SUMMARY

RELEVANCE OF 2001 ASHTON COAL PROJECT EIS

Ongoing monitoring of groundwater levels and mine inflow rates, and specific investigations of the Bowmans Creek and Glennies Creek alluvium, has significantly improved the understanding of the groundwater environment around the Ashton Coal Project. This improved hydrogeological understanding has shown that a number of conclusions about the groundwater environment contained the 2001 EIS are now no longer considered to be valid. In particular, these include:

- Previously it was thought that Bowmans Creek was highly connected to its alluvium, and that there was a large volume of groundwater through flow in the alluvial materials. In reality the hydraulic conductivity of the Bowmans Creek alluvium is relatively low (around 0.5 m/d), connection with the creek is limited, and there is little through flow of groundwater.
- Similarly, it was though that the Bowmans Creek alluvium was a 'high quality' resource, with good water quality. Recent investigations have shown that the alluvium groundwater has varying, sometimes poor, water quality, with measured salinity of up to 6,400 µS/cm EC (electrical conductivity). The total alluvium resource is small, at approximately 340ML.
- Although the proposed diversion and undermining of the Bowmans Creek alluvium is predicted to lead to significant de-watering of the alluvium, this is limited to the section downstream of the New England Highway, which is known to have relatively poor permeability and water quality, as discussed above.
- During the 2001 EIS studies, it had been concluded that, prior to mining, water flowed downwards from the Bowmans Creek alluvium to the underlying Permian strata. It is now understood that, in the pre-mining condition, groundwater levels in the underlying Permian were generally above alluvium groundwater levels. This resulted in upward leakage in most areas.
- It was assumed that the alluvial groundwater provides a significant resource that supports Groundwater Dependent Ecosystems (GDEs), in particular River Red Gums. Monitoring indicates that there are no GDEs in the alluvium that is predicted to become fully dewatered due to this proposal. The alluvium around the stands of River Red Gum that are present near the downstream end of Bowmans Creek is predicted to remain saturated, with groundwater drawdown limited to less than 0.5m in that area.
- Most significantly, the improved modelling capability and understanding of the system has shown that there is no risk of upflow from the mine workings to the alluvium in the post mining recovery phase. This means there will be no permanent discharge of highly saline water to the alluvium and Bowmans Creek when groundwater levels re-stabilise post-mining. This eliminates concerns relating to intergenerational equity and associated long term management issues.

A number of other issues raised during agency reviews of the original 2001 EIS have also been addressed as part of this study. These include:

- An improved justification of the boundary between the Hunter River alluvium and Bowmans Creek alluvium.
- A detailed description of the groundwater modelling has been provided, along with an examination of the uncertainty and assumptions associated with the groundwater model.

In terms of impacts to alluvium and river/creek baseflow during mining operations, the improved understanding of the hydrogeological system, and the inclusion of the Bowmans Creek diversions within the numerical model resulted in a number of differences between this assessment and the 2001 EIS. The following table provides a summary comparison of the maximum operational impacts of the full, four seam mining operation on the Bowmans Creek, Glennies Creek and Hunter River alluvium.

Table ES1: Summary Comparison of Maximum Operational Impacts – Bowmans Creek

	Current Assessment	2001 EIS	Comments
Bowmans Creek – baseflow losses	0.13 ML/d	0.4 ML/d	2001 EIS did not include modelling of the diversion.
Bowmans Creek – alluvium groundwater levels	Partly dewatered (0.5m to 2m in saturated areas). Impacts limited to the section south of New England Hwy	Partly dewatered	2001 EIS did not include modelled assessment of the impact of connective fracturing. The text indicates partial dewatering if fracturing does occur.
Glennies Creek – baseflow losses	0.23 ML/d	0.6 ML/d	Current model has much better calibration of levels and calibration against measured mine inflows on Glennies Creek side.
Glennies Creek – alluvium groundwater levels	Maximum 0.4m (generally less than 0.1m)	Maximum 2.5m	Previous model assumed an unrealistic degree of vertical connection between Glennies Creek alluvium and the underlying Permian.
Hunter River – baseflow losses	0.06 ML/d	0.3 ML/d	Previous model included mining in the Pikes Gully closer to the Hunter River
Hunter River – alluvium groundwater levels	Maximum 0.1m	No significant change	Impact limited to area next to interface with Bowmans Creek alluvium

BACKGROUND

The Ashton Coal Project is located 14km west of Singleton in the Hunter Valley region between the villages of Camberwell and Ravensworth on the New England Highway. The Ashton Coal Project consists of both open cut and underground mining operations to access a series of coal seams within the Permian coal measures. The original application for the Ashton Coal Project was lodged in 2002, based on an EIS developed in 2001. The project described in the 2001 EIS comprised 7 longwall panels (LWs 1 to 7).

Mining of the Pikes Gully seam in the first four panels (LWs 1 to 4) was approved under an SMP Application lodged in 2006. Underground mine development commenced in December 2005, and mining of the first longwall panel (LW1) in the Pikes Gully seam began in March 2007. LW1 was completed in October 2007, LW2 in July 2008, and LW3 in March 2009. LW4 is currently nearing completion (October 2009).

In order to maximise access to the reserve, Ashton Coal Operations Ltd (ACOL) is now seeking to carry out further development of the underground mine. Four coal seams are proposed for longwall mining within the project - the Pikes Gully (PG), Upper Liddell (ULD), Upper Lower Liddell (ULLD), and Lower Barrett (LB) seams. The full proposal described within this report involves longwall panel extraction from all four seams. This includes mining beneath parts of the Bowmans Creek floodplain, and diversion of two sections of Bowmans Creek to mitigate against the resulting subsidence effects. This report contains a review of the potential hydrogeological impacts of the proposed progressive development of multi-seam longwall mining, including the proposals for diverting two sections Bowmans Creek.

All impacts shown within this report relate to the cumulative effect of longwall mining of all of the mined seams. This includes the impacts from the mining that has already been carried out within the Pikes Gully. Comparisons against the pre-mining baseline condition therefore refer to a baseline environment prior to any underground mining in the Ashton area.

Because the development at Ashton has been previously subject to a full EIS and Subsidence Management Plans (SMPs), there have been extensive previous groundwater investigations and monitoring borehole installations around the site.

This has been supported by an extensive, ongoing groundwater and surface water monitoring programme that has been in place since the start of mining development at Ashton, and continues to be developed.

The modelling that has been used in this assessment includes the main longwall panels and associated roadways. The small miniwall panels described in the project proposal have not been included in the groundwater modelling, as they lie within the impact footprint of the main longwall panels and the subsidence specialist reports predict that caving above the miniwall panels 'bridges' well below the alluvium. Therefore, miniwalls would not have any significant impact on the groundwater modelling. During the operational mining phase, the longwall panels de-water the strata above the miniwalls, so additional impacts during operations are not feasible. The minimal subsidence predicted to occur above the miniwalls should not make any difference to the final equilibrium levels that would be reached by the post mining groundwater environment. The additional storage capacity contained within the miniwalls may delay post mining recovery slightly, but volumes would be very small in relation to the longwalls.

THE EXISTING ENVIRONMENT

The study area is located within the Hunter Coalfield of the Sydney Basin. The Permian aged coal reserves within the Ashton Coal Project mining lease are mostly within the 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.

The project area includes three major water courses, the Hunter River to the south of the mine and two tributary streams - Glennies Creek and Bowmans Creek. Glennies Creek flows to the east of the mine area and Bowmans Creek flows across the western part of the mine area.

Two distinct aquifer systems occur within the project area:

- A fractured rock aquifer system in the coal measures, with groundwater flow occurring mainly in the coal seams and
- A shallow granular aquifer system in the unconsolidated sediments of the alluvium associated with Bowmans Creek, Glennies Creek and Hunter River.

The coal measures are highly laminar, sedimentary rocks, which means that the majority of the permeability is parallel to bedding, and there is very little hydraulic connectivity between layers. There is also 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.

The overall groundwater flow regime in the pre-mining condition is controlled by recharge and discharge mechanisms. For the shallow alluvium this is dominated by rainfall recharge and discharge to the river/creeks. For the Permian layers the sub-cropping coal seams are recharged by rainfall infiltrating the seams at sub-crop. Low mobility of groundwater within the strata at depth means that groundwater heads in the Permian are, in turn, largely controlled by the physical elevation of these recharge areas. The Permian groundwater generally has higher potentiometric heads than the alluvium, and in low lying areas, the Permian heads may be above the ground surface. This results in upward seepage of saline groundwater from the Permian to the alluvium in some locations.

Elevated salinity is found within much of the Permian coal measures aquifer system. This ranges from around 6,000 µS/cm EC in the coal seams to more than 11,000 µS/cm EC within some of the less permeable overburden layers. Salinity can be lower than this in the coal seams in areas closer to recharge near subcrop. Salinity can be higher than this in low permeability regolith, but generally water quality within the Permian coal measures is within this brackish range.

Salinity within the Glennies Creek and Hunter River alluvium is generally moderate to low, particularly in the more permeable alluvium that contains a higher rate of through flow from surface recharge. In these areas, the salinity is generally below 2,000 µS/cm EC, although areas of higher EC, more 'stagnant' alluvium do exist around Glennies Creek.

The lower hydraulic conductivity of the Bowmans Creek alluvium means that moderately saline conditions (up to 6,400 μS/cm EC) are encountered within much of the groundwater that was tested during the investigation programme.

APPROACH TO IMPACT ASSESSMENT

In order to assess the impacts that the longwall mining and the diversion of Bowmans Creek could have on the hydrogeological environment, a MODFLOW-SURFACT groundwater model was constructed to represent the operational and post mining recovery stages of the project. This was adapted from the original MODFLOW model used in the 2001 EIS, but was significantly updated and improved. In particular it contains an appropriate representation of the groundwater flow regime, and was able to model changes in hydraulic properties of the rock mass as mining progresses. The updated model contains realistic representations of other mines in the area, in particular the Ravensworth underground mine, the Narama open cut, the Ashton North East Open Cut (NEOC) and proposed South East open Cut (SEOC). All of the impacts described below therefore allow for the effects of other mines in the area.

The model was successfully calibrated against 'steady state' pre-mining conditions, and was then subject to a transient calibration to observed inflows and groundwater drawdowns during the early stages of the Ashton underground mine, namely the mining of LW1 to LW3 in the Pikes Gully seam.

POTENTIAL IMPACTS FROM THE PROPOSED MINING

Modelling shows that the target coal seams and overburden within the mine footprint are predicted to be essentially de-watered during mining. Outside of the mine footprint, the main impact from the Ashton mine on potentiometric pressures within Permian strata occurs to the south and south east of the mine, where drawdowns of 10m or more could occur up to 2km from the mine following mining to the Lower Barrett seam. Net impacts to the north, west and north east are minimal due to the influence of other mines to the west and the fact that the areas to the north and north east are up-dip of the Ashton mine.

Model results show that the impacts of the Ashton underground mine on the Bowmans Creek alluvium are limited to the area south of the New England Highway. The alluvium to the north of this is not significantly affected by the Ashton underground mine. The alluvium that is affected, between the highway and the Hunter River, is predicted to be largely de-watered by the end of mining activities, as a direct result of the proposed Ashton underground mine. By the end of mining, saturated alluvium will only remain in the southern end of this reach, between the Hunter River and the Bowmans Creek 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 to 2m in that area.

The maximum impacts on stream baseflows are as follows:

- Bowmans Creek is predicted to change from gaining to losing, from a pre-mining baseflow (discharge from groundwater to the creek) of 30 m^3/d (0.03 ML/d) to a loss of about 100 m^3/d (0.10 ML/d) at the end of mining, ie a reduction of 0.13 ML/d.
- Glennies Creek flow is predicted to reduce by 230 m^3/d (0.23 ML/d) by the end of mining.
- Flow in the Hunter River is predicted to undergo a very small reduction of 60 m^3/d (0.06 ML/d) by the end of mining.

It should be noted that the baseflow impact on Bowmans Creek is likely to occur whether or not the Ashton underground is mined. This is because the Bowmans Creek diversions hydraulically separate much of the creek from the alluvium. If the Ashton underground does not undermine the creek, and the creek diversions are not implemented, then the impacts from the nearby Ravensworth mine have a much larger relative impact on the creek, resulting in a similar level of baseflow losses. With regard to Glennies Creek baseflow impacts, most of the predicted impact occurred during the development heading stage for LW1, before longwall extraction commenced.

The long-term residual impacts on baseflow are discussed below.

Inflows to the proposed underground mine have also been predicted using the updated groundwater model. Mine inflow rates during operations are predicted to reach an initial peak of around 1.4 ML/d during the start of the mining of the ULD seam. This is followed by a slight reduction as overlying layers de-water, before inflow rates increase again once mining of the ULLD commences and connective cracking with the base of the Bowmans Creek alluvium occurs. Maximum inflows of 1.6 ML/d are predicted to occur near the start of the Lower Barrett seam mining. These predicted mine inflow rates are slightly lower than the 2001 EIS prediction, which peaked at 1.9 ML/d during the start of the ULD mining. There is some uncertainty over the timing and amount of surface waters that might enter the mine due to runoff recharge to the disturbed subsidence areas in the floodplain, although these have a relatively minor impact (approximately 0.1 ML/d after mining in the ULD seam reaches the Bowmans Creek floodplain).

The project proposal includes a commitment to ensure that subsidence troughs that will develop on the Bowmans Creek floodplain above the longwall panels will be backfilled as mining progresses to ensure that they are largely 'free draining' following flood events. This means that, whilst some enhanced recharge to groundwater can be expected due to rainfall runoff entering the disturbed areas, there is little risk that surface flooding within the Bowmans Creek floodplain will lead to major minewater inflows during operations. The only risk of this would come from the inundation of the old, subsided creek channel above LW6B. This would be an occasional (1 in 5 years or greater) event, so it has not been included within the base mine inflow assessment, although recommendations for monitoring and response plans are contained within Section 8 of this report.

POTENTIAL IMPACTS FOLLOWING POST MINING RECOVERY

The groundwater model was used to predict potential residual impacts from the Ashton underground mine following 100 years of post mining recovery.

During the post mining period, the groundwater within the mine workings and caved overburden remains highly connected. Because of this, the modelling shows that post recovery groundwater levels within the workings and caved overburden reach a dynamic equilibrium, where inflows from the surface and other strata balance outflows from the mine area.

These changes result in some long term changes to water levels/pressures within the Permian strata. Following recovery and groundwater re-stabilisation, residual drawdowns of up to 15m remain within the Pikes Gully seam in the mine area, extending to the south and south-west in response to the 'flattening' of potentiometric heads in the Ashton and Ravensworth underground mine areas.

These changes in the Permian do not significantly affect the alluvium and there is negligible residual drawdown in the Hunter River or Glennies Creek alluvium from either project. Within the Bowmans Creek alluvium, there will be small sections around the perimeter of each subsidence trough where the alluvium will remain unsaturated due to the enhanced vertical connectivity with the underlying Permian in those zones. However, the alluvium will be substantially re-saturated over most of the floodplain, with generally small (<1 m) residual drawdowns in those parts of the Bowmans Creek alluvium.

The model results show that there is no upward flow of water from the mine workings to the alluvium anywhere within the Bowmans Creek alluvium. This will eliminate the upward migration of saline groundwater from the Permian that occurred in places pre-mining, and led to pockets of saline groundwater within the alluvium in a number of locations. This result represents an improvement in water quality compared with the baseline condition.

The lower post-mining groundwater levels in the Permian do mean that there is a slight reduction in post-mining baseflows when compared with the pre-mining baseline condition, as follows:

- After post-mining recovery, baseflows to the Hunter River return to near baseline conditions, and are predicted to be only 0.015 ML/d less than pre-mining.

- For Bowmans Creek, the changes to the hydrogeological regime and the construction of the diversion channels mean that long-term post-mining baseflows to the creek will be slightly lower (around 0.06ML/d lower) than the pre-mining condition.
- Baseflows in Glennies Creek are predicted to be around 0.055 ML/d lower following post mining recovery than they were in the baseline condition. This is caused by the fact that groundwater heads in the Pikes Gully seam are lower than in the pre-mining condition, so some leakage from Glennies Creek to the mine workings will continue to occur on the eastern side of LW1. These are modelled values, which do not allow for the reduction in permeability that has been occurring, possibly due to progressive clogging of cleats and fissures in the coal seam near outcrop where the seam was initially more permeable. In the long term, it is expected that the permeability would reduce even further. This means that the modelled impact on Glennies Creek is likely to be over-stated, and actual post mining recovery baseflows impacts are likely to be less than 0.03 ML/d.

These post-mining baseflow impacts are marginally worse than the 2001 EIS predictions, which were for minor increases in baseflow for all three rivers following post-mining recovery. This prediction in the EIS is now considered to be erroneous, as it was determined by comparing post-mining conditions with an erroneous conclusion that pre-mining there was a net loss from the streams by downward seepage from the alluvium to the underlying Permian coal measures. However, the 2001 EIS also predicted post-mining salinity increases of 50 μS/cm EC in Bowmans Creek and 14 μS/cm in the Hunter River. These predictions are alos now considered to be erroneous. Current predictions show that this salinity increase should not occur, and that the lack of saline upflow at the end of the post mining recovery period will lead to an improvement in water quality in comparison to pre-mining conditions.

The NSW Office of Water (NOW) has also indicated a potential concern over the impact of mining on the 'buffering capacity' of the Bowmans Creek alluvium. The buffering capacity refers to the ability of the intermediate salinity water contained within the Bowmans Creek alluvium to act as a buffer between the creek and the upwelling, saline, Permian groundwater during drought periods. It is thought that the presence of the less saline water within the alluvium delays the encroachment of the saline Permian groundwater and hence reduces the rate of increase of salinity within the creek during drought periods. However, the modelled recovery hydrographs conclusively show that groundwater recovery occurs first within the Bowmans Creek alluvium, before potentiometric heads within the mine workings come close to surface level. This, combined with the lack of upwards flow from the Permian to the alluvium post-mining, means that impacts on 'buffering capacity' are not an issue for the recovery phase.

POTENTIAL IMPACTS ON GROUNDWATER DEPENDENT ECOSYSTEMS AND OTHER GROUNDWATER USERS

Because impacts on river flows and groundwater levels within the Hunter River, Glennies Creek and their associated alluvium are so small, both during mining and in the post mining condition, it is very unlikely that there would be any impact on GDEs associated with those water courses. For Bowmans Creek, monitoring carried out by ERM indicates that there are no GDEs in the alluvium that is forecast to become fully de-watered between the New England Highway and the Hunter River. Some stands of red gum have been reported along the river to the south of the western creek diversion, in the area where the alluvium is predicted to remain saturated. Model results show that groundwater drawdowns in this area are less than 0.5m, even at the end of mining to the Lower Barrett seam.

As the Ashton underground mine does not significantly affect alluvium groundwater levels to the north of the New England Highway, or on the south side of the Hunter River, there will be no impacts from the scheme on registered groundwater licence holders. Predicted maximum drawdowns of less than 0.1m in the Glennies Creek alluvium around Camberwell village mean that there will be no impact on the registered borehole there, even if it is still operational.

EFFECT OF EARLY CESSATION OF MINING

The groundwater impact assessment is based on multi-seam longwall mining of four seams down to the Lower Barrett seam, together with the associated diversion of sections of Bowmans Creek, and recovery for a 100 year post-mining period.

It was considered prudent to also consider the effect that an unanticipated early cessation of mining might have on the potential impacts of the project, if mining were to stop early due to either economic or technical constraints. Accordingly, a separate assessment was undertaken of the potential impacts of mining only to the end of the Upper Liddell seam, ie only the upper two seams. This scenario also included a 100 year post-mining recovery period.

Early cessation of mining after the Upper Liddell seam would reduce the lateral extent of pressure head reductions in the Permian to around 1.5km from the mine, slightly less than for the proposed full four-seam mining project.

Impacts on alluvium and stream baseflows for an early cessation of mining at the end of the ULD seam are marginally lower than for the proposed project.

Baseflow reductions on the Hunter River and Glennies Creek would be 0.05 ML/d and 0.22 ML/d respectively. Slightly less drawdown impacts on alluvium would occur, but these are marginal for the proposed project in any case.

For Bowmans Creek, baseflow reduction would be 0.1 ML/d (rather than 0.13 ML/d). The area of de-watered alluvium would be similar, as this is largely related to the separation of the alluvium from the creek around the diverted sections. Impacts on the saturated alluvium in the southern end of the reach would be slightly less, with most of that area experiencing drawdowns of less than 0.5m.

Similar long-term responses are seen following recovery after mining only to the ULD seam.

Potentiometric heads around the mine workings would be slightly higher, and residual drawdowns therefore slightly lower, at between 10 an 15 m. As with the full mining proposal, the model results show that if mining were to stop after the ULD seam, post-mining there would be no upward flow of water from the mine workings to the alluvium anywhere within the Bowmans Creek alluvium. This will lead to an improvement in water quality compared with pre-mining conditions.

Long-term baseflow impacts would be slightly less than for the proposed project, as follows:

- Post-mining baseflows to Hunter River would be 0.012 ML/d less than pre-mining baseflows.
- Bowmans Creek long-term post-mining baseflows will be slightly lower (0.056 ML/d lower) than the pre-mining condition.
- Long-term post-mining baseflows in Glennies Creek are predicted to be around 0.055 ML/d lower following post mining recovery than they were in the baseline condition.

In conclusion, an early cessation to mining would not result in any worse outcome than the full four-seam mining proposed. In most aspects, the short-term and long-term impacts would be slightly less.

MONITORING AND MANAGEMENT OF IMPACTS

A comprehensive monitoring program is already in place, and some recommendations for additional monitoring are outlined in the report. It is recommended that the project's existing Groundwater Management Plan, with appropriate adjustments, be used for determining appropriate management strategies and response measures for any unforeseen impacts.

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APPENDIX C WATER QUALITY MONITORING RESULTS

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1 INTRODUCTION

1.1 BACKGROUND

The Ashton Coal Project is located 14km west of Singleton in the Hunter Valley region (Figure 1.1) between the villages of Camberwell and Ravensworth on the New England Highway (Figure 1.2). The Ashton Coal Project consists of both open cut and underground mining operations to access a series of coal seams within the Permian Foybrook Formation of the Whitingham Coal Measures.

The open cut mine, which is located north of the New England Highway, commenced operations in 2003. Coal is recovered from several seams of varying thickness, in two open cuts – the smaller Arties Pit and the larger Barrett Pit. These are collectively known as the North East Open Cut (NEOC). The underground mine is located south of the New England Highway, and is accessed from the northern side of the highway via a portal in the Arties Pit.

The initial mine plan comprised seven longwall panels (LWs 1 to 7), the first four of which were approved for mining of the Pikes Gully seam (LWs 1 to 4) under an SMP Application lodged in 2006. Underground mine development commenced in December 2005, and mining of the first longwall panel (LW1) in the Pikes Gully seam began in March 2007. LW1 was completed in October 2007, LW2 in July 2008, LW3 in March 2009, and LW4 is nearing completion at September 2009.

In order to maximise access to the reserve, Ashton Coal Operations Ltd (ACOL) is now seeking to carry out further development generally in accordance with the existing consent issued by the Minister of Planning in 2003. This proposal involves full longwall panel extraction beneath parts of the Bowmans Creek floodplain, and a diversion of two sections of Bowmans Creek (about 1,735m total) to mitigate against the subsidence effects that will result from that longwall mining.

This assessment includes the results of extensive monitoring of mining to date, and uses improved modelling capability that has been gained since the 2001 EIS. This has provided a significantly greater understanding of the hydrogeological system and the potential impacts of the mining proposal. Where relevant, comparisons are made against the 2001 EIS within this report.

1.2 MINING PROPOSAL

It is proposed that longwall mining will be carried out within all four seams proposed in the 2001 EIS, namely the Pikes Gully, Upper Liddell, Upper Lower Liddell and the Lower Barrett Seams. The layout of the proposed mine in each of the four seams is shown in Figures 1.3 and 1.4. For the purposes of this assessment it has been assumed that all of these longwall panels will be 'stacked' (i.e. they lie directly beneath each other in each of the four seams). This represents a worst case in terms of subsidence and mining impacts, which results in a deliberately conservative assessment in this groundwater impact assessment report.

The impact assessment described in this report is based on sequential mining of all four seams, and a 100 year post-mining recovery period. In order to assess the potential short-term and long-term impacts should the project not proceed to its intended completion because of unforeseen economic or technical issues, an assessment has also been made for the case where mining is terminated after extraction of the two upper seams, the Pikes Gully and Upper Liddell. The results of this assessment are also included in this report.

The modelling that has been used in this assessment includes the main longwall panels and associated roadways. The small miniwall panels described in the project proposal have not been included in the groundwater modelling, as they lie within the impact footprint of the main longwall panels and should not therefore affect the groundwater impact assessment. Because the miniwalls have a width to depth ratio of less than 0.6, previous modelling (SCT 2008) has shown that the caving will 'bridge' above the miniwall panels, and there will be a substantial zone (50m+) of unaffected Permian rock between the panels and the base of the Bowmans Creek alluvium.

The subsidence specialist report for this EA confirms that 'bridging' below the alluvium will be maintained for multi-seam mining. Effects on groundwater could therefore only occur at depth within the Permian.

This does not significantly affect the groundwater impact assessment for the following reasons:

- During the operational mining phase, the impacts described in Section 6 show that the Permian overburden within the footprint of the longwall panels becomes dewatered (see Section 6, Figures 6.11 and 6.12). Although the miniwalls could have some minor impacts on timing of minewater inflows, additional groundwater impacts beyond those caused by the longwall panels are not realistically feasible.
- In the post mining phase, the Permian within the mine footprint is highly connected due to the presence of the mine roadways and the caved overburden above the longwall panels (see Section 7). The Permian groundwater levels reach an equilibrium that is more than 45mAHD, well above any caved zone that will exist above the miniwall panels. Therefore, the presence of the miniwall panels will not make any difference to the final equilibrium levels that would be reached by the post mining groundwater environment. The additional storage capacity contained within the miniwalls could delay recovery slightly, but volumes are very small in relation to the longwalls.

Based on the above, it was not considered necessary to include the miniwalls within the modelling assessment.

1.3 REPORT OBJECTIVE

The progressive longwall mining of the Pikes Gully, Upper Liddell, Upper Lower Liddell and Lower Barrett Seams, combined with the diversion of Bowmans Creek, is a Major Project pursuant to the provisions of the Environmental Planning and Assessment Act (EP & A Act), 1979. A Major Project Application and Environmental Assessment Report have been prepared for the project for assessment and determination by the Minister for Planning.

The objective of this report is to provide sufficient information on the pre-mining groundwater environment of the mining area and its immediate surrounds to assess the potential impacts on groundwater levels, stream baseflows and water quality from development of the project, such that any concerns regarding groundwater and surface water resources, Groundwater Dependant Ecosystems (GDE's) and existing groundwater users are addressed to the satisfaction of the Minister for Planning. This includes the impacts to groundwater and surface water that will result from the diversion of Bowmans Creek.

This report is structured as follows:

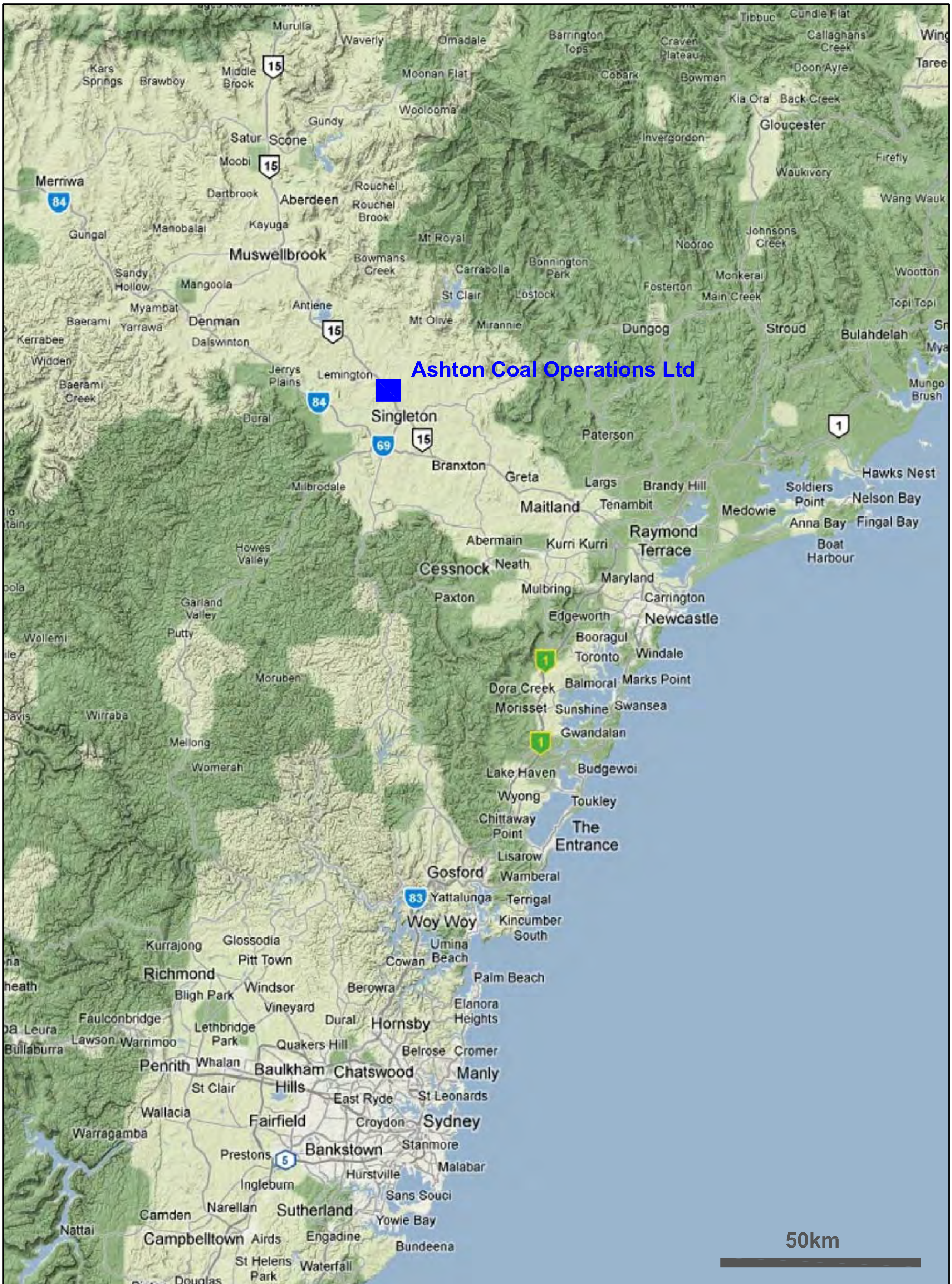
- Section 2 contains a summary of previous groundwater investigations undertaken.
- Section 3 details the groundwater investigations undertaken as part of this project.
- Section 4 reports on the existing groundwater environment within the proposed project area.
- Section 5 outlines the mining proposal, giving a brief summary of the proposed operations and the nature of the creek diversions.
- Section 6 provides a summary of the groundwater modelling work undertaken to assess the potential impacts of the proposal.
- Section 7 describes the potential groundwater impacts of the proposed project on groundwater resources, groundwater quality, GDEs and other groundwater users.
- Section 8 details proposed monitoring, mitigation and management strategies in relation to any identified potential impacts.
- Section 9 provides conclusions on the outcomes of the study.
- Section 10 provides a list of references.

1.4 DIRECTOR GENERAL'S REQUIREMENTS

DG requirements for the assessment that relate to the groundwater environment are listed in Table 1.1. along with the section of this report where they are addressed.

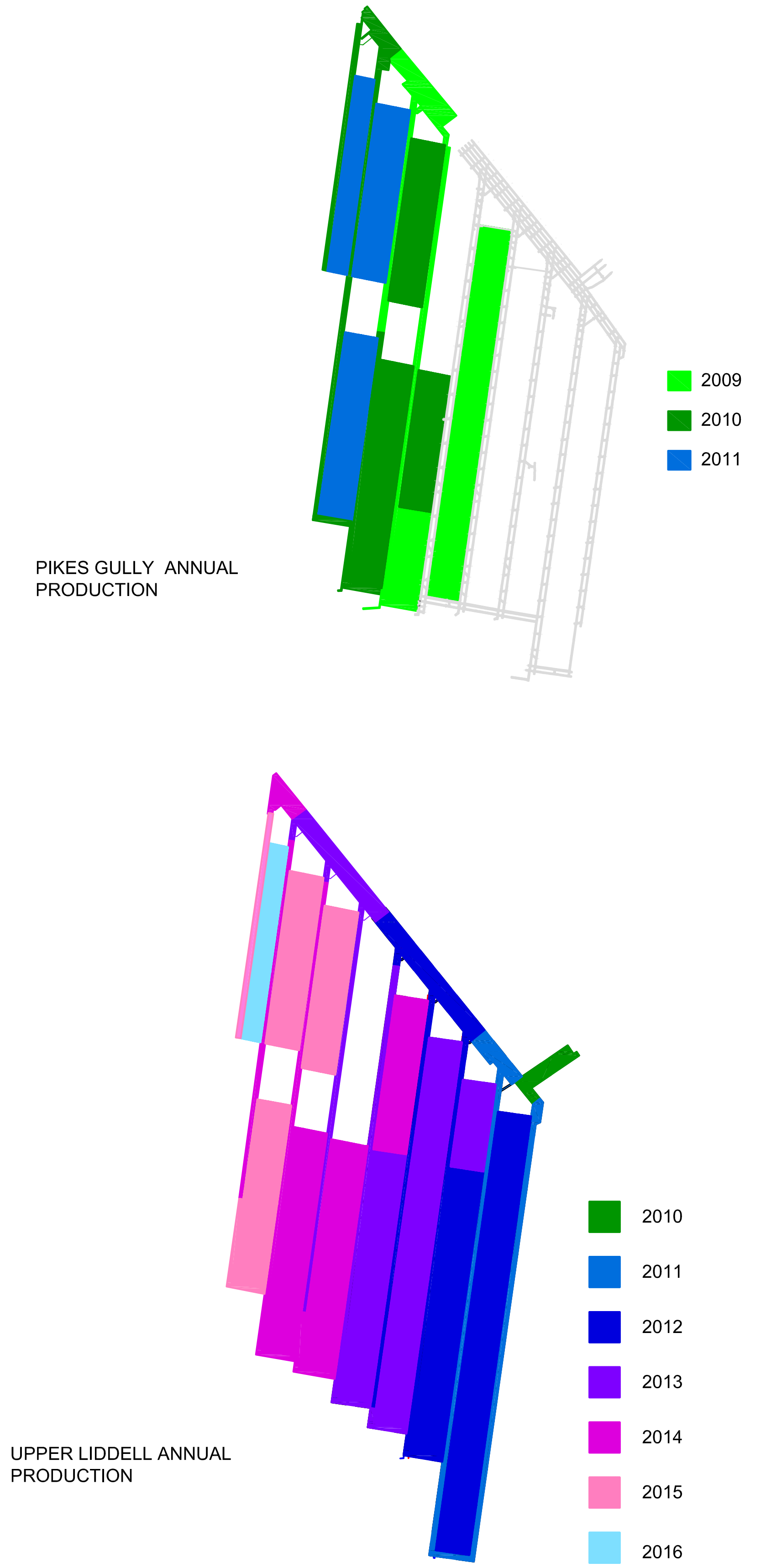
Table 1.1: Director – General's Requirements

Director General's Requirement	Relevant Section of Report
A description of the existing environment, using sufficient baseline data;	Section 4
An assessment of the potential impacts of the proposal, including any potential cumulative impacts, taking into consideration any relevant policies, guidelines, plans and statutory provisions;	Sections 6 & 7
An assessment of the potential impacts of these subsidence effects on the natural and built environment, with particular reference to Bowmans Creek and the associated riparian environment;	Sections 6 & 7
A detailed assessment of the potential impacts of the proposal using appropriate quantitative modelling, on: the quantity and quality of both surface and ground water resources, with particular reference to alluvial groundwater; water users, both in the vicinity of and downstream of the project. the riparian and ecological values of the watercourses both on site and downstream of the proposal environmental flows	Sections 6 & 7
A comparison of these impact predictions against those associated with the existing mine plan, including detailed explanations for any differences	Sections 6 & 7
A description of the measures that would be implemented to avoid, minimise, mitigate, rehabilitate/remediate, monitor and/or offset the potential impacts of the proposed modification	Sections 5, & 8

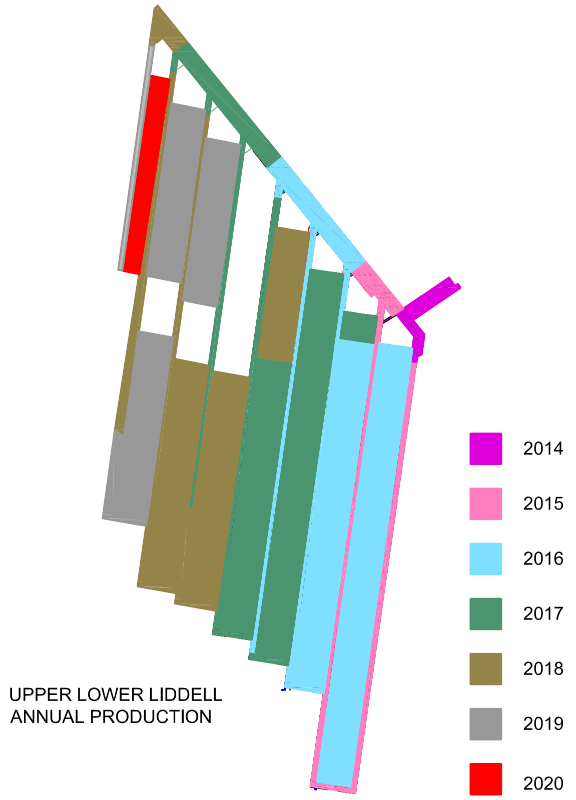


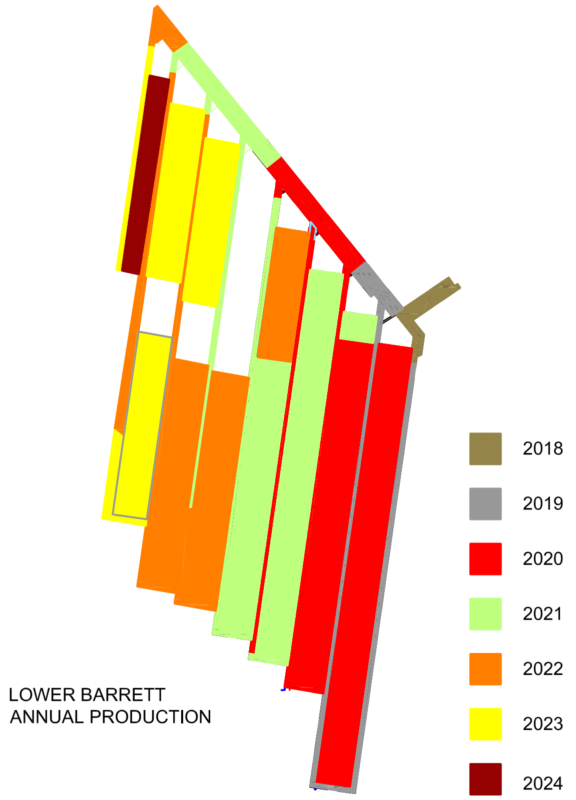
Date: 30 September 2009	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PZ	Job No: S55G	**PROJECT LOCATION PLAN ASHTON COAL OPERATIONS**
Drawing No: S55G-001	Rev: 0	
aquaterra		**Figure 1.1**

Date: 1 October 2009	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PZ	Job No: S55G	**ASHTON PROJECT AREA**
Drawing No: S55G-002a	Rev: A	
aquaterra		**Figure 1.2**



Date:	4 August 2009	Scale:	as indicated	**Ashton Coal Operations Ltd**
Initials:	JVDA	Job No:	S55G	**PIKES GULLY AND UPPER LIDDELL ANNUAL PRODUCTION SCHEDULE**
Drawing No:	S55G - 003	Rev:	0	
aquaterra				**Figure 1.3**





Date: 4 August 2009	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: JVDA	Job No: S55G	**UPPER LOWER LIDDELL AND LOWER BARRETT ANNUAL PRODUCTION SCHEDULE**
Drawing No: S55G - 004	Rev: 0	
aquaterra		**Figure 1.4**

1.5 RELEVANT STATE POLICIES AND GUIDELINES

This report has also been prepared with due consideration of relevant state policies and guidelines including:

- NSW Groundwater Policy Framework Document – General.
- NSW Groundwater Quantity Management Policy.
- NSW Groundwater Quality Protection Policy.
- NSW Groundwater Dependant Ecosystem Policy.
- Guidelines for Fresh and Marine Water Quality' (ANZECC).
- The Hunter Unregulated and Alluvial Water Sources Water Sharing Plan (WSP).

1.6 WATER LICENSING

The Hunter Unregulated and Alluvial Water Sources Water Sharing Plan (HUAWS WSP), was gazetted on the 1st August 2009. This means that Bowmans Creek now falls under section 50 the Water Management Act 2000. Under section 60 of the Water Management Act 2000, a water access licence is required to take water from a water source. The Proposed Modification does not take any water from a 'water source'. The review set out below has been undertaken to consider whether the Proposed Modification is consistent with the WSP.

Bowmans Creek lies within the Jerrys Management Zone of the Jerrys Water Source of the Hunter Extraction Management Unit. The Jerrys Water Source includes 'all water contained within all alluvial sediments below the surface of the land shown on the registered plan for [these] water sources' (section 3 (c)). As well as regulating total annual extraction allowances, the WSP contains flow class restrictions and 'cease to abstract' controls during periods of low flow. Under clauses 17, 19 and 68 of the WSP, only those works that extract directly from the creek, or take water from the alluvium within 40m of the high bank of the creek are subject to flow class restrictions and environmental 'cease to flow' rules. In the case of Bowmans Creek, (from year 6 of the WSP) water will only permitted to be taken by means of a pump from within 40m of the high bank of the creek whilst there is 'visible flow in the river in the downstream vicinity of the water supply work'.

This groundwater impact assessment has concentrated on identifying the total amount of water lost from the Jerrys Water Source. This has been done by evaluating the baseflow impact on Bowmans Creek associated with the proposed diversion and mining modification. This impact represents the total water which flows out from the 'Jerrys Water Source'. It includes direct loss of recharge, and the impact that the reduction in groundwater heads in the alluvium has on hydraulic gradients between the creek and the alluvium, which cause the creek to lose water to other water sources.

The impact of this proposal on the Jerrys Water Source, and other users that rely on that and other downstream water sources, can therefore be offset through the surrender of water allocations that allow for the baseflow losses described in Section 7.4.3 and Section 7.4.4. Water from the alluvium effectively enters the Permian strata above the mineworkings in the areas above the proposed longwall panels. As shown in Figure 7.1., these are all located more than 40m away from the high bank of the diverted creek. There are no specific sensitive environmental areas named within the WSP under Clause 41 in relation to the Jerrys Water Source, and no other licensed users within 200m of the proposed longwall panels (as proscribed within Clause 39). Accordingly, it is considered that the modification is consistent with the provisions of the HUAWS WSP.

2 PREVIOUS GROUNDWATER INVESTIGATIONS

2.1 SUMMARY OF GROUNDWATER INVESTIGATIONS

Because the development at Ashton has been subject to a full EIS (HLA, 2001) and Subsidence Management Plans (SMPs) for the development of longwall panels 1-4 (LW1-4), and longwall/miniwall panels 5-9 (LW/MW5-9) in the Pikes Gully Seam, there have been extensive previous groundwater investigations and monitoring borehole installations around the site. The majority of the information contained within this report is based on the data gathered from those previous studies, and from the ongoing monitoring programme that is in place around the site.

Groundwater studies were undertaken during the period 2000 to 2001 to support the Environmental Impact Statement for approval to develop the Ashton coal mining operations (HLA, 2001). The investigations were undertaken in support of both the North East Open Cut (NEOC) operations north of the New England Highway and the underground operations south of the highway.

Investigations were then undertaken during 2005 and 2006 to provide additional information in support of the underground mining, and specifically in support of the SMP for LW1 to LW4 in the Pikes Gully Seam (PDA, 2006). This was followed during September and October 2007 by a focussed drilling program that was undertaken in and around the Bowmans Creek floodplain (Aquaterra, 2008). The objective of that investigation was to delineate the extent of the saturated alluvium and determine the nature and properties of the alluvial aquifer system associated with Bowmans Creek.

Further investigations were then undertaken in 2008 and early 2009 around the eastern side of the site and the Glennies Creek area to support the EA for the Ashton South East Open Cut (SEOC) mining proposal (Aquaterra, 2009). These investigations concentrated on the alluvium and colluvium of the eastern side of Glennies Creek, but also included vibrating wire and piezometer installation into the underlying Permian strata.

2.2 PIEZOMETER / MONITORING BORE AND TEST BORE INSTALLATION

Previous site investigations have resulted in the completion of an extensive network of investigation boreholes that have supported the detailed understanding of the local geology, as discussed in Sections 4 and 6. Where appropriate, groundwater monitoring bores have been installed as part of this drilling programme. A total of 100 piezometers have now been installed across the project area as part of previous investigations. This includes 81 standpipe piezometers, 16 vibrating wire piezometers and three test bores drilled as part of the SEOC investigations. The locations of all the monitoring bores installed during previous investigations are shown in Figure 2.1.

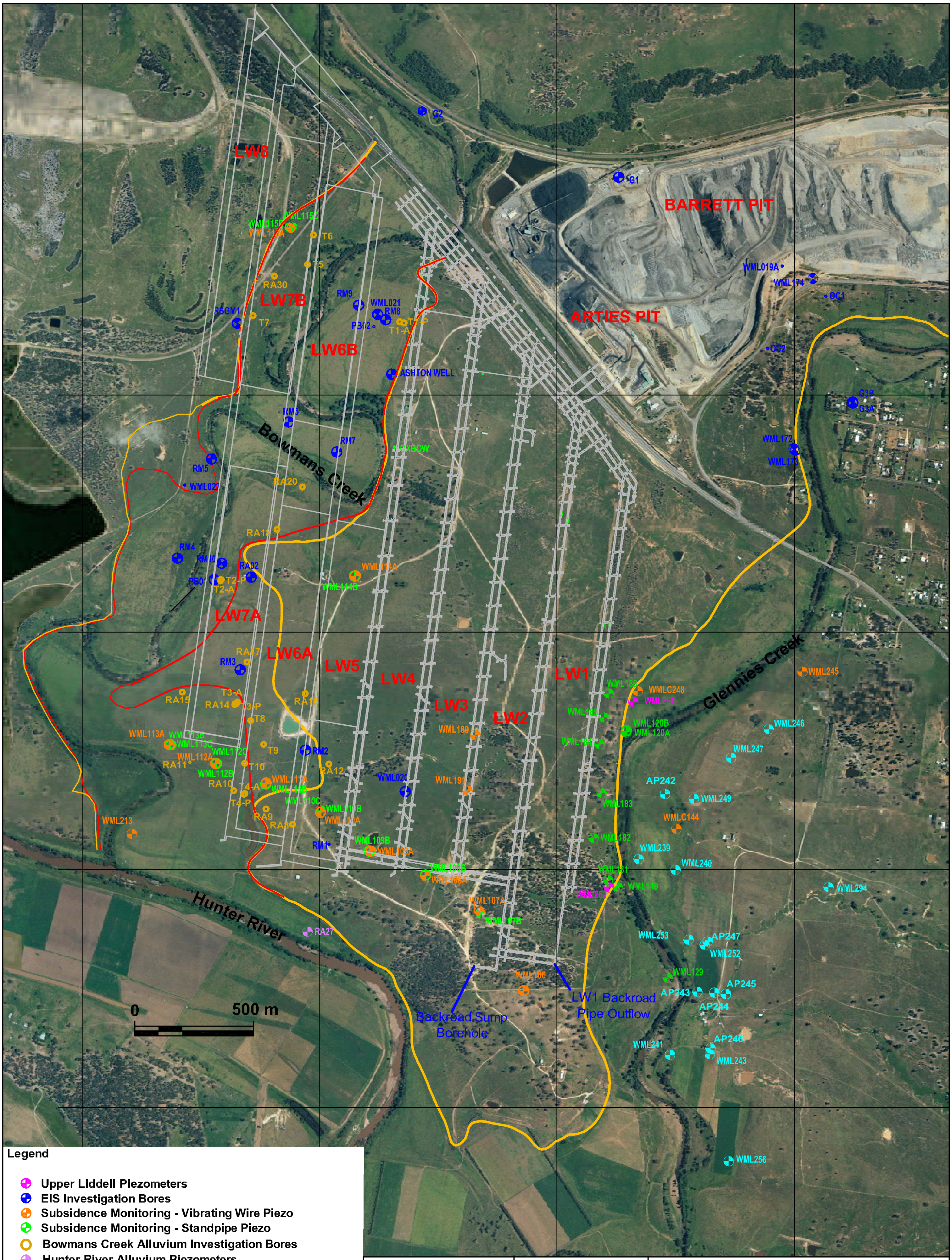
A summary of the locations, depths, construction and monitored horizons for all of the monitoring bores is contained within Appendix A of this report.

2.2.1 PIEZOMETER COMPLETION

Vibrating wire piezometers were installed immediately after the relevant exploration hole had been cored and involved the grouting of the borehole with the vibrating wire piezometer at the appropriate depths. Existing coal exploration drillholes converted to standpipe piezometers were drilled at diameters of 100mm or 125mm. Each bore was cased with 50mm diameter PVC casing and screened adjacent to the desired monitoring interval. The bore annulus was gravel packed over the target monitoring interval, and a bentonite seal set above and below the screened zone to ensure that the screened section was isolated. The remainder of the annulus above the bentonite seal was then backfilled with cement grout. All piezometers were completed at surface with a concrete block, to prevent ingress of surface runoff or contamination, and secured within a padlocked steel monument.

2.2.2 TEST BORE COMPLETION

The three test bores drilled in the Glennies Creek alluvium were completed to 100mm diameter to allow higher rate pumping tests. These were screened, grouted and finished as described for the piezometers above.



Legend

- Upper Liddell Piezometers
- EIS Investigation Bores
- Subsidence Monitoring - Vibrating Wire Piezo
- Subsidence Monitoring - Standpipe Piezo
- Bowmans Creek Alluvium Investigation Bores
- Hunter River Alluvium Piezometers
- Glennies Creek Alluvium Piezometers
- LW1 - Glennies Ck Barrier Piezometers
- Dry / Abandoned / Lost Bore
- Extent Of Alluvium
- Extent Of Saturated Bowmans Creek Alluvium

Date:	1 October 2009	Scale:	as shown	**Ashton Coal Operations Ltd**
Initials:	PZ	Job No:	S55G	MONITORING BORE LOCATION PLAN
Drawing No:	S55G-005a	Revision:	A	
aquaterra				**Figure 2.1**

2.2.3 HYDRAULIC TESTING

Hydraulic testing involving slug tests and constant rate pumping tests have been carried out for the EIS, SMP investigations, Bowmans Creek investigations and in support of the SEOC EA. Test results for all monitoring bores are included in Appendix B, and are summarised, with appropriate references, below.

Within the Ashton Coal Project area, test pumping indicated hydraulic conductivity values for the Pikes Gully coal seam in the range 0.01 m/d to 10 m/d (PDA, 2006 and Aquaterra, 2008a), with the high end of the range considered to be representative of conditions near outcrop. Testing of the Pikes Gully seam at depth in bores WML20 and WML21 revealed hydraulic conductivity values of 0.015 m/d to 0.02 m/d (PDA, 2006), which are considered to be representative of conductivity well removed from outcrop. More recent testing of the Upper Liddell seam carried out as part of the investigations for this project revealed hydraulic conductivity values of 0.002 and 0.03 m/d (Section 3.2.2).

Hydraulic testing of standpipe piezometers completed in the upper parts of the Permian coal measures (generally free of coal seams) revealed hydraulic conductivities in the range 0.01 to 3.3 m/d with a median value of 0.1 m/d (Aquaterra, 2008b). In most cases, the tested section was within the weathered zone, which has properties more akin to alluvium or colluvium than fractured rock.

The results of packer testing and analysis for permeability over a number of intervals within the Permian coal measures in boreholes WMLC213 (located southwest of the mine area), WMLC210 and WMLC233 (located above LWs 3 and 4 respectively) showed the following (SCT, 2008a and 2008c):

- Most permeability results were in the order of 10^{-9}m/s (10^{-4}m/d).
- Some test results in the depth range 50m to 100m, where there was very little fracturing, indicated permeability less than 10^{-11}m/s ($<10^{-6}$m/d).
- Some permeabilities in the shallow, upper sections of the Permian were in the order of 10^{-8} to 10^{-7}m/s (10^{-3} to 10^{-2}m/d).

Bores WMLC210 and WMLC233 were tested prior to longwall extraction, and were then grouted up. A new hole WMLC264 was drilled after completion of LW3 at a site adjacent to WMLC210, and tested to determine post-extraction permeabilities. The post-longwall permeability values determined at WMLC264 were found to be identical with pre-longwall values in the interval from surface down to about 40m, but were much higher than pre-longwall values between 40m and 50m depth below surface.

Hydraulic testing of the Bowmans Creek alluvium (Aquaterra, 2008) revealed a high variability in hydraulic conductivity, with values in the range 0.0002 to 15 m/d, and a median value of 0.7 m/d.

Floodplain alluvium of the Hunter River was tested at one site near the southern end of the Ashton underground mine area (RA27 – see Figure 2.1), revealing a hydraulic conductivity of 50 m/d (Aquaterra, 2008). This is consistent with the results of extensive testing at the Hunter Valley No.1 mine, where an average permeability of about 45 m/day was established (HLA, 2001).

Testing for the SEOC (Aquaterra, 2009) showed large variation in the hydraulic properties in the alluvium and colluvium around Glennies Creek. Values ranged from less than 0.1 m/d to over 100 m/d. However, very high values were found to be very localised and unrepresentative of the alluvium as a whole, and the geometric mean was found to be much lower, at only 0.6 m/d. The values at the higher end of the range reflect the presence of localized lenses of cleaner coarse gravels, while the very low values are typical of the clay-silt matrix which encloses the gravels over most of the floodplain area.

2.2.4 GROUNDWATER QUALITY

The majority of the piezometers installed during the various investigations were purged in accordance with AS/NZS 5667 (Standards Australia, 1998) and water samples were collected for field analysis of pH, electrical conductivity (EC) and temperature, and for laboratory testing of the following parameters:

- pH, electrical conductivity (EC) and total dissolved solids (TDS).
- major cations and anions and
- dissolved metals (As, B, Cd, Cr, Cu, Fe, Ni, Pb, Mn, Se, Zn, Hg).

A summary of the results obtained for each piezometer is provided within Appendix C.

2.3 GROUNDWATER MONITORING PROGRAMME

As well as the water level monitoring and quality samples gathered as part of the EA and SMP investigations, a Groundwater Management Plan (GWMP) has been in place since 2005. The GWMP includes the monitoring of a large number of piezometers. The piezometers that form part of the current monitoring network are shown in Figure 2.1.

Groundwater levels within these piezometers are measured monthly to assess seasonal variations and variations associated with mining activity. Water quality samples for EC, TSS, TDS and pH are collected every quarter, whilst other parameters are monitored annually. These water quality monitoring results are included within Appendix C.

2.4 SURFACE WATER QUALITY

Surface water quality for Bowmans Creek and Glennies Creek has been monitored monthly for pH, EC and TSS since 2000. Samples are taken at 5 sites on Bowmans Creek, 4 sites on the Hunter River, and 3 sites on Glennies Creek. The locations of these surface water monitoring sites are shown in Figure 2.2.

In addition to this, there is a NOW monitoring station on Bowmans Creek between the New England Highway and the Hunter River (Foy Brook 210130), which has provided continuous monitoring information up to at least August 2008. Whilst there have been some reliability issues with this monitor, it does provide useful data on the EC values within the creek during periods of high and low flow.

2.5 PREVIOUS GROUNDWATER MODELLING

A MODFLOW based groundwater model was used for the EIS for the original 2001 application (HLA, 2001).

A MODFLOW-SURFACT model was used for the LW/MW 5-9 SMP investigations (Aquaterra, 2008b). This was initially derived from the HLA model, but included a number of significant improvements. The MODFLOW-SURFACT model included an approach that allowed for a much more realistic representation of the cracking and permeability increases that occur above longwall panels. The updated model included more layers, unsaturated flow conditions and changing hydraulic parameters over time. It has been used, with further improvements, for the groundwater modelling contained in this report.

2.6 SURVEY OF EXISTING GROUNDWATER OCCURRENCE AND USE

Information on registered groundwater users near the proposed mining area was sought as part of the 2001 EIS and 2009 SEOC investigations. Searches of the NOW database indicated that no registered groundwater bores are present within the Ashton Project area.

There are no registered bores within 1km of the proposed mining area, and only four bores within 3km of the site (Figure 2.3). The closest is a shallow well in Glennies Creek alluvium, located in Camberwell Village, to the east of the underground mine and south of the NEOC (registered bore GW064515). This well was installed in 1919 and consists of a concrete riser. The original use was domestic, however it is not known if the well is still operational.

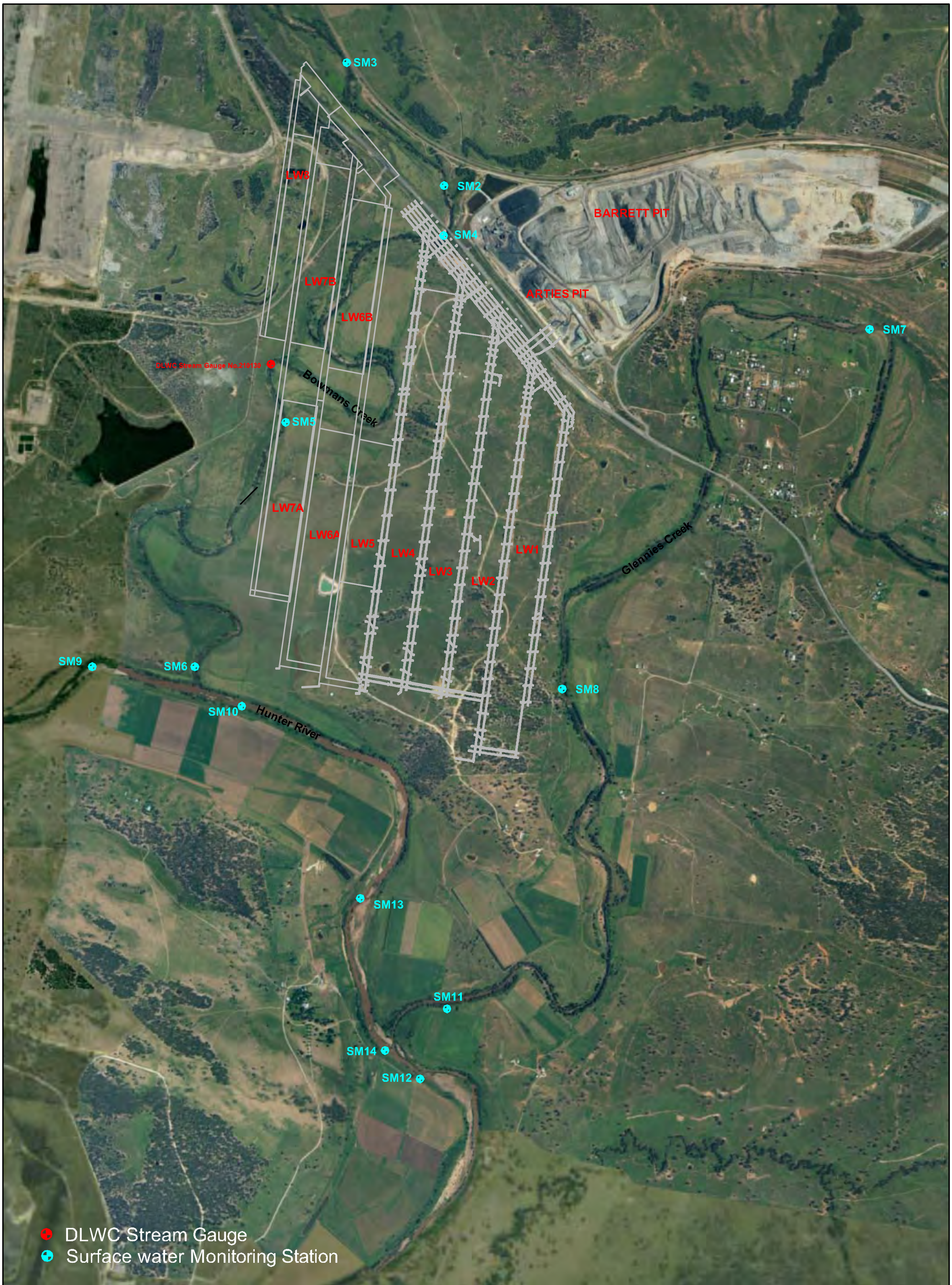
Two others are associated with the Bowmans Creek alluvium to the north of the RTA road bridge, and the fourth is in the Hunter River alluvium on the southern side of the Hunter River. Several bores also exist far to the northeast and northwest within the Bowmans Creek and Glennies Creek alluvium.

There is an unregistered well on the Ashton lease, called the Ashton Well, which was installed some time ago within the Bowmans Creek alluvium to supply water for the dairy and two houses, all of which are now abandoned.

2.7 MINEWATER INFLOWS AND DISCHARGES

Groundwater inflows to the underground workings were first observed in the Pikes Gully LW1 development headings, about 450m from the northern end on the eastern gateroad. Similar inflows were encountered on the LW2 headings and the Northwest Mains as they advanced below the regional groundwater level (around 50-55 mAHD). Total groundwater inflow rate to the underground mine is determined by a water balance approach, using flow rates on the discharge pipelines and the imported water pipeline. Water exported from the mine is monitored by flow meters on the discharge pipelines, as is the water pumped into the mine to meet operational needs of the longwall operation.

Details of recorded flow rates are included within Section 4.7.2 of this report. The recorded total inflow rate includes all the groundwater seepages into TG1-A, all goaf inflows from LW1, LW2, LW3 and LW4, seepages into maingate roads of LW5, all inflows to the NW Mains, and other miscellaneous seepages.



Date:	1 October2009	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials:	PZ	Job No: S55G	**SURFACE WATER MONITORING LOCATION PLAN**
Drawing No:	S55G-025	Rev: 0	
aquaterra			**Figure 2.2**

Date:	10 August 2009	Scale:	As Shown	**Ashton Coal Operations Pty Ltd**
Initials:	JVDA	Job No:	S55G	**Locations of DWE Registered Bores**
Drawing No:	S55G-027a	Rev:	A	

aquaterra

Legend:

- 2 km radius
- 4 km radius
- Licenced Bore
- Cadastre

Figure 2.3

3 RECENT GROUNDWATER INVESTIGATIONS

3.1 OVERVIEW AND PURPOSE

As most of the previous investigations had been focussed on the Pikes Gully Seam, its overburden and the alluvium/colluvium/regolith layer, further specific investigations have been carried out to provide additional information on the hydraulic characteristics of the Upper Liddell Seam, and to provide additional monitoring points below the Pikes Gully Seam. Standpipe piezometers were installed to provide information on the hydraulic conductivity of the Upper Liddell Seam in the zone between the eastern side of the underground mine and the subcrop of the seam beneath the Glennies Creek floodplain.

3.2 PIEZOMETER DRILLING AND CONSTRUCTION

3.2.1 MONITORING BORE DRILLING AND CONSTRUCTION

Two new standpipe piezometers were installed, and an existing exploration drillhole WML248 was completed as a multi-level vibrating wire piezometer bore. The locations of the three new piezometer bores are shown in Figure 3.1. All three are located east of the underground mining area, between the mine and Glennies Creek.

Piezometer WML261 was drilled at a site on the western edge of the Glennies Creek floodplain, as close as practicable to LW1 near its northern end, north of the section of Glennies Creek that comes closest to the underground mine. The site is approximately 370m from the subcrop of the Upper Liddell Seam. The Upper Liddell Seam is relatively shallow in this locality at around 30m below surface. Piezometer WML261 was completed with 150mm diameter casing and screen in order to allow extended constant rate test pumping if necessary.

Piezometer WML262 was drilled to the south of the section of Glennies Creek closest to the mine, adjacent to existing Pikes Gully piezometers WML119 and WML186. At this site, the Upper Liddell Seam was encountered at a depth of about 57m below surface, and the site is approximately 640m from the Upper Liddell Seam subcrop line. Piezometer WML262 was completed to 60m with 50mm casing and screen.

Both standpipe piezometers were screened across the Upper Liddell Seam, with the annulus gravel-packed through the screen interval, and sealed above with a bentonite seal.

Borehole WML248 comprises vibrating wire piezometers set at the Upper Lower Liddell, Upper Lower Lower Liddell, Lower Barrett and Hebden1 Seams, encased in a fully grouted hole.

3.2.2 HYDRAULIC TESTING

Constant Rate Tests (CRTs) were performed on WML261 and WML262 using a low capacity pump. WML261 was subjected to a 45 minute constant rate test at a rate of 16 m^3/day, and recovery. WML262 was pumped for 7 minutes at a rate of 14 m^3/day and recovery. The short duration of the pumping tests for both piezometers was due to rapid dewatering of the piezometers to the pump inlet, attributed to the low hydraulic conductivity of the coal seam.

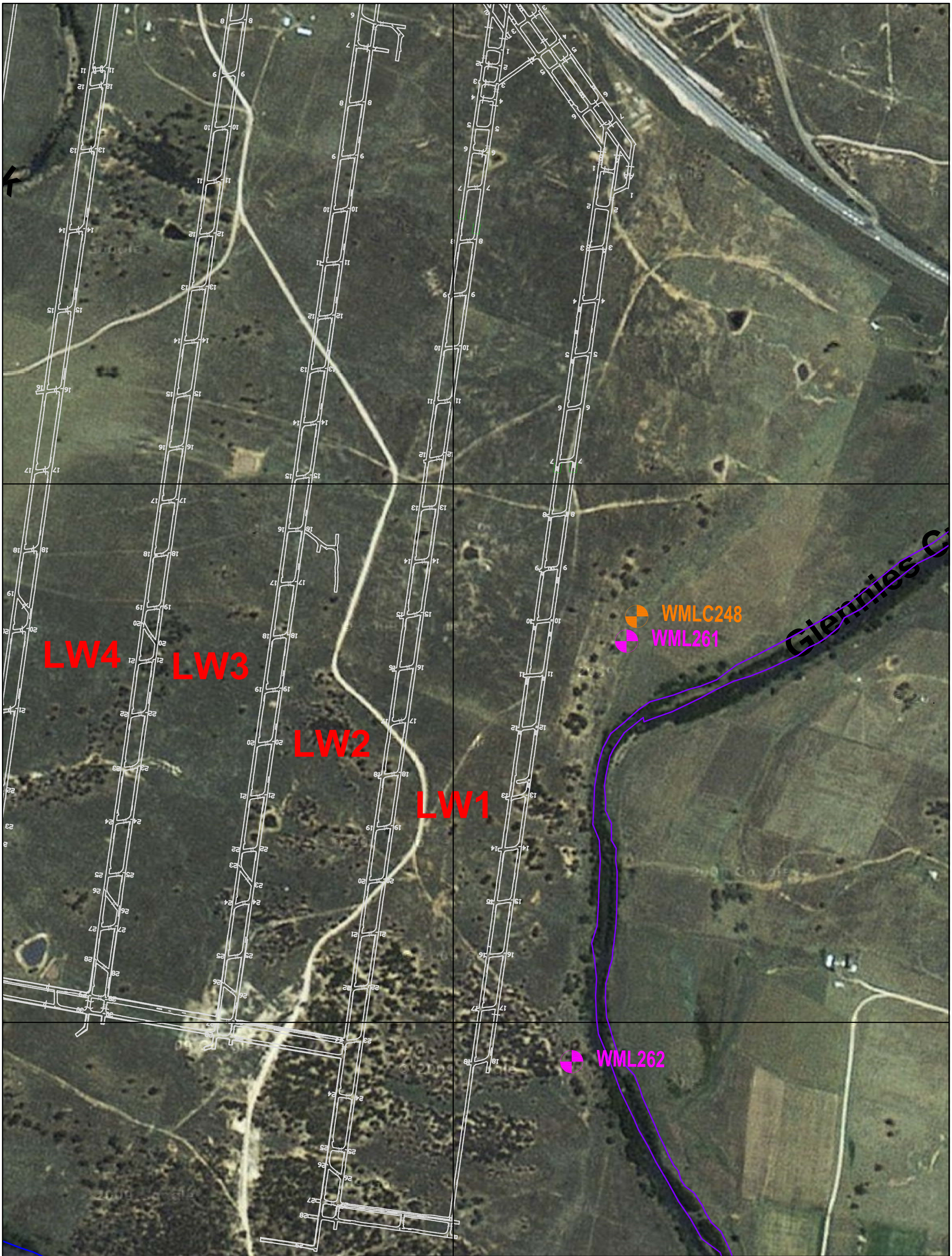
A suite of published analytical methods have been used to analyse the pumping test data from the piezometers. The following methods have been used in this analysis:

- Jacob's straight-line method for unsteady flow in a confined aquifer (Cooper and Jacob, 1946).
- Theis Recovery method (Cooper and Jacob, 1946), which is derived for confined aquifers.
- The recovery data ('rising heads') measured in WML262 after the constant rate test were analysed using the Hvorslev method (Hvorslev, 1951) for slug test analysis. This analysis was deemed suitable due to the rapid dewatering of this piezometer during pumping and the very slow subsequent recovery of groundwater levels.

Hydraulic testing of the Upper Liddell coal seam indicated that the horizontal hydraulic conductivities (Kh) are in the order of 0.002 to 0.03m/d. The higher hydraulic conductivity of 0.03m/d was measured in WML261 which is slightly closer to the subcrop line and has a shallower depth of cover than WML262.

3.3 GROUNDWATER QUALITY

Groundwater salinities of the ULD seam measured during the CRT were 2,510µS/cm (1,390mg/L TDS) in WML261, and 6,270 µS /cm (3,500mg/L TDS) in WML262. The lower EC encountered in WML261 may reflect some connection with the fresher groundwaters in the overlying alluvium.



Legend

- ULD Test Bores
- Multi VW Piezometer

Date: 29 June 2009	Scale: as shown	Ashton Coal Operations Ltd
Initials: ASF	Job No: S55G	ASHTON COAL MINE LOCATION OF PIEZOMETERS INSTALLED IN THE UPPER LIDDELL SEAM
Drawing No: S55-021	Revision: 0	Figure 3.1

4 DESCRIPTION OF THE EXISTING HYDROGEOLOGICAL ENVIRONMENT

4.1 REGIONAL SETTING

The proposal (Figure 1.2) comprises a multi-seam longwall mining operation, extracting from four target seams, in an area between the New England Highway and the Hunter River.

The surface topography generally dips to the west and is gently undulating over most of the area. Surface elevation varies between about 100 mAHD along the eastern ridge to around 50 mAHD at the south-western corner near the confluence of Bowmans Creek with Hunter River. East of the mine area there is a steeper slope that forms an escarpment above Glennies Creek, and in the south there are some steeper slopes leading down to the Hunter River. The topography flattens around Bowmans Creek, and rises again on the north western side around Longwall 8.

The project area includes three major water courses, the Hunter River to the south of the mine and two tributary streams - Glennies Creek to the east of the mine area and Bowmans Creek across the western part of the mine area.

4.2 CLIMATE

4.2.1 RAINFALL AND EVAPORATION

The climate of the region is temperate with hot summers and cool winters. The average daily maximum temperature ranges from 31.7 ºC in January to 17.4 ºC in July.

Table 4.1 summarises rainfall data from the Jerry's Plains weather station, situated approximately 14 km to the southwest of the Ashton Project. The table lists the mean monthly rainfall and mean annual rainfall, based on more than 100 years of rainfall data since 1884. Evaporation data (pan evaporation records) are available from Scone, approximately 100km west of Ashton. Table 4.1 shows that there is an excess of evaporation over rainfall in all months, although rainfall and potential evaporation are close to being in balance in the winter months (June and July). It should be noted that this table refers to actual measured evaporation values, and has not been adjusted by a 'pan factor' (usually around 0.85). The actual balance is therefore less negative, but there is still a rainfall deficit compared to evaporation in most months, and a large annual deficit for the area.

Table 4.1: Long-term Average Monthly Rainfall at Jerry's Plains and Evaporation at Scone (mm)

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall*	80.3	69.7	58.4	43.9	41.2	47.7	43.7	36.7	42.1	51.7	57.1	66.8	639
Evaporation#	220	169	154	118	89	56	69	81	112	164	195	204	1630
Balance	-140	-99	-96	-74	-48	-8	-25	-44	-70	-112	-138	-137	-991

Source: Bureau of Meteorology (2008)

*BOM Jerry's Plains Meteorological Station

BOM Scone SCS Meteorological Station

4.3 GEOLOGY

The study area is located within the Hunter Coalfield of the Sydney Basin. The Permian aged coal reserves within the Ashton Coal Project mining lease are mostly within the 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 overlying Jerry's Plains Sub-Group. Both sub-groups are part of the Whittingham Coal Measures, the basal coal-bearing sequence of the Singleton Supergroup. Regional surface geology is shown on Figure 4.1.

The major mineable coal seams considered suitable for longwall mining are (in descending stratigraphic order) the Pikes Gully, Upper Liddell, Upper Lower Liddell, and Lower Barrett Seams. The Bayswater Seam, which is stratigraphically higher than the Pikes Gully seam, was previously mined in the former Bayswater open cut, and is currently being mined at the Narama Pit, both to the west of the project area. The Bayswater Seam has only limited presence in the southwestern corner of the Ashton underground mine area. Lemington Seams 1-19 of varying thickness between the Pikes Gully Seam and the base of the Bayswater seam, are present in the overburden across the mining area. The Lemington seams and others in the sequence are mined in the Ashton NEOC to the north of the New England Highway.

The target coal seams are separated by interburden sediments, which comprise sandstone, siltstone, conglomerate, mudstone, and shale, as well as occasional minor coal seams. A representative geological cross section through the area is presented in Figure 4.2.

The main regional geological structures in the area are the Bayswater Syncline, the axis of which is located to the west of Ashton in the Ravensworth South and Narama mines; the Camberwell Anticline, which passes to the east, through Camberwell village and the Camberwell open cut; and, further to the east, the Glennies Creek Syncline (Figure 4.1). The axes of these structures run from N to S and NNW to SSE respectively.

The coal seams to be mined at Ashton outcrop in on the western and north-eastern limbs of the Camberwell anticline. The subcrop patterns for the seams derived from the Ashton geological model are shown in Figure 4.3. The regional geology was extrapolated out to the boundary of the groundwater modelling area by making use of published mapping and geological references in various public company reports.

No major faults or other significant structures or igneous intrusions (dykes or sills) are known to occur in the mining area, although dykes and small scale structures such as rolls or folds in the seams may be encountered in the mine.

The Pikes Gully coal seam thickness in the mine area varies between 2m and 3m, though it is generally in the range of 2.3 to 2.8m. The Pikes Gully seam outcrops/subcrops in the eastern part of the Ashton Coal Project area and is up to about 200m deep (around -140m AHD) in the south west. The Lower Barrett seam, which is the deepest seam planned for underground mining at Ashton, occurs at depths ranging from 40m to more than 300m below ground (0 to -240m AHD). The interburdens between the seams vary in thickness from 7m to 63m. A summary of the mean depths and thicknesses is given in Table 4.2.

Table 4.2: Thicknesses of Coal Seams and Interburden Layers in the Ashton Project Area (m)

Geological Units	Average	Minimum	Maximum
Pikes Gully overburden (Pikes Gully to base of alluvium)	Variable from 0m to 200m, due to dip on strata		
Pikes Gully	2.2	1.8	3.0
Interburden – Upper Liddell to Pikes Gully	36	13	63
Upper Liddell Seam	2.2		3.2
Interburden – Upper Lower Liddell to Upper Liddell	28	7	47
Upper Lower Liddell Seam	2.1		6.1
Interburden – Lower Barrett to Upper Lower Liddell	40	24	62
Lower Barrett Seam	2.2		5.9

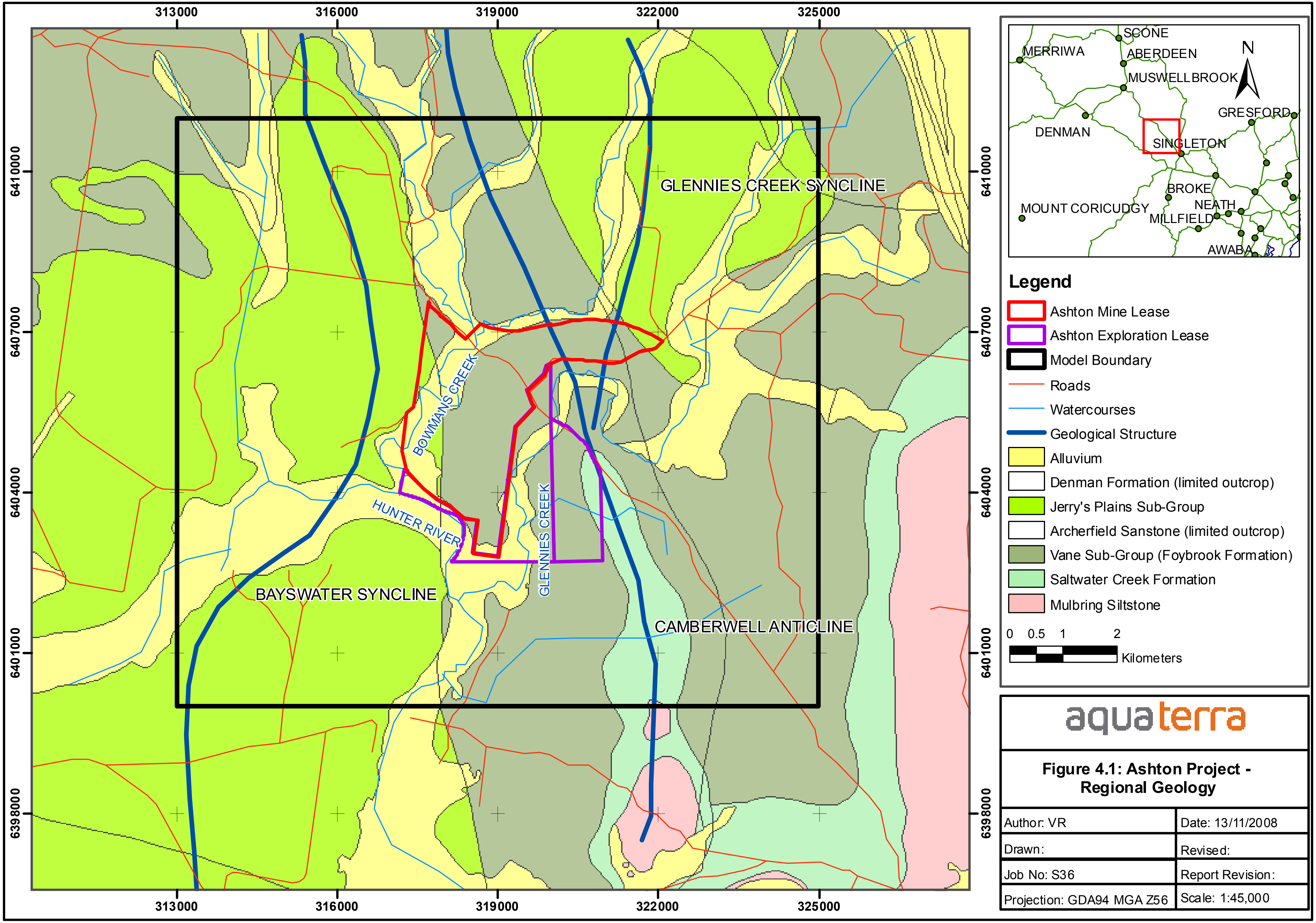
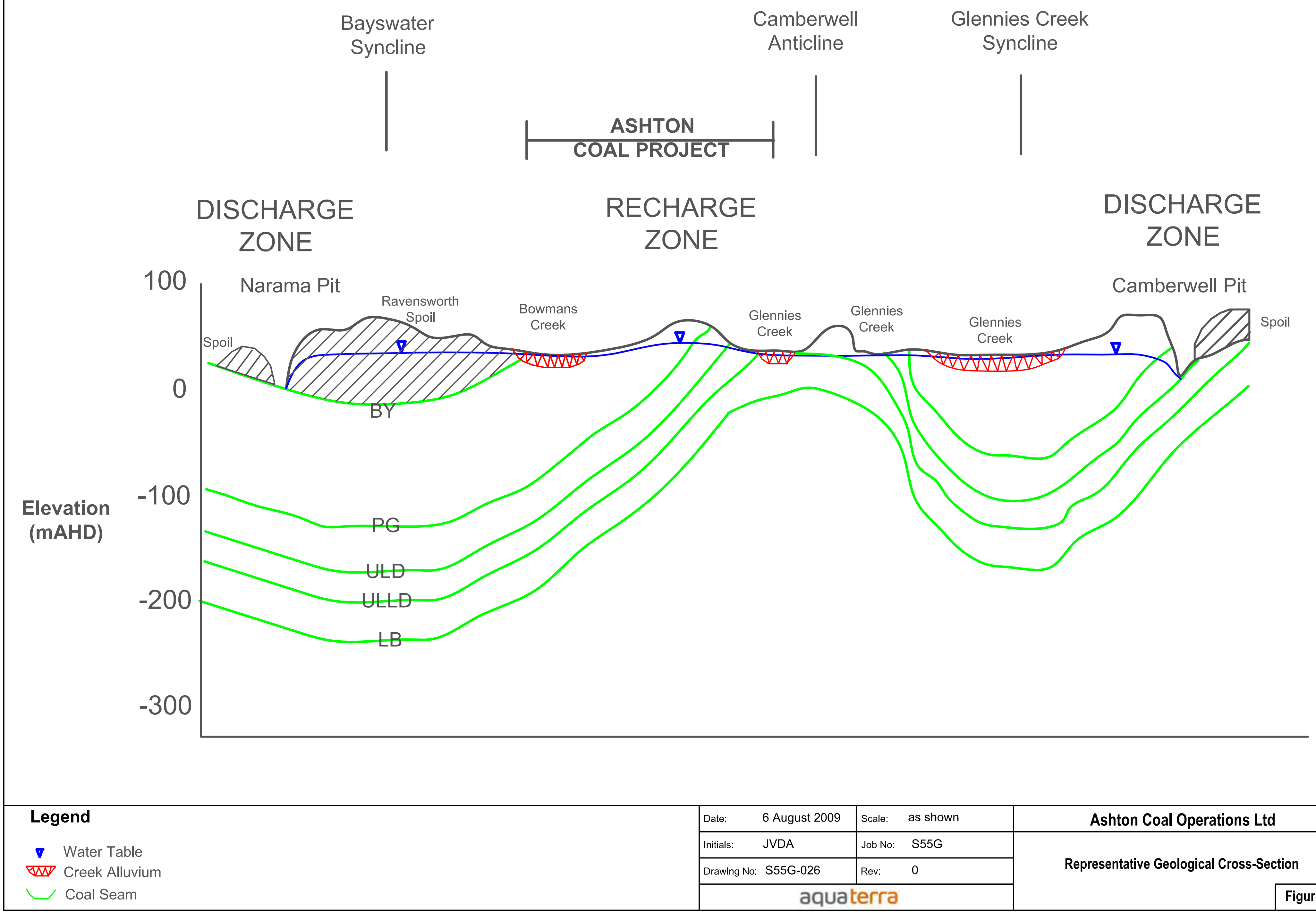
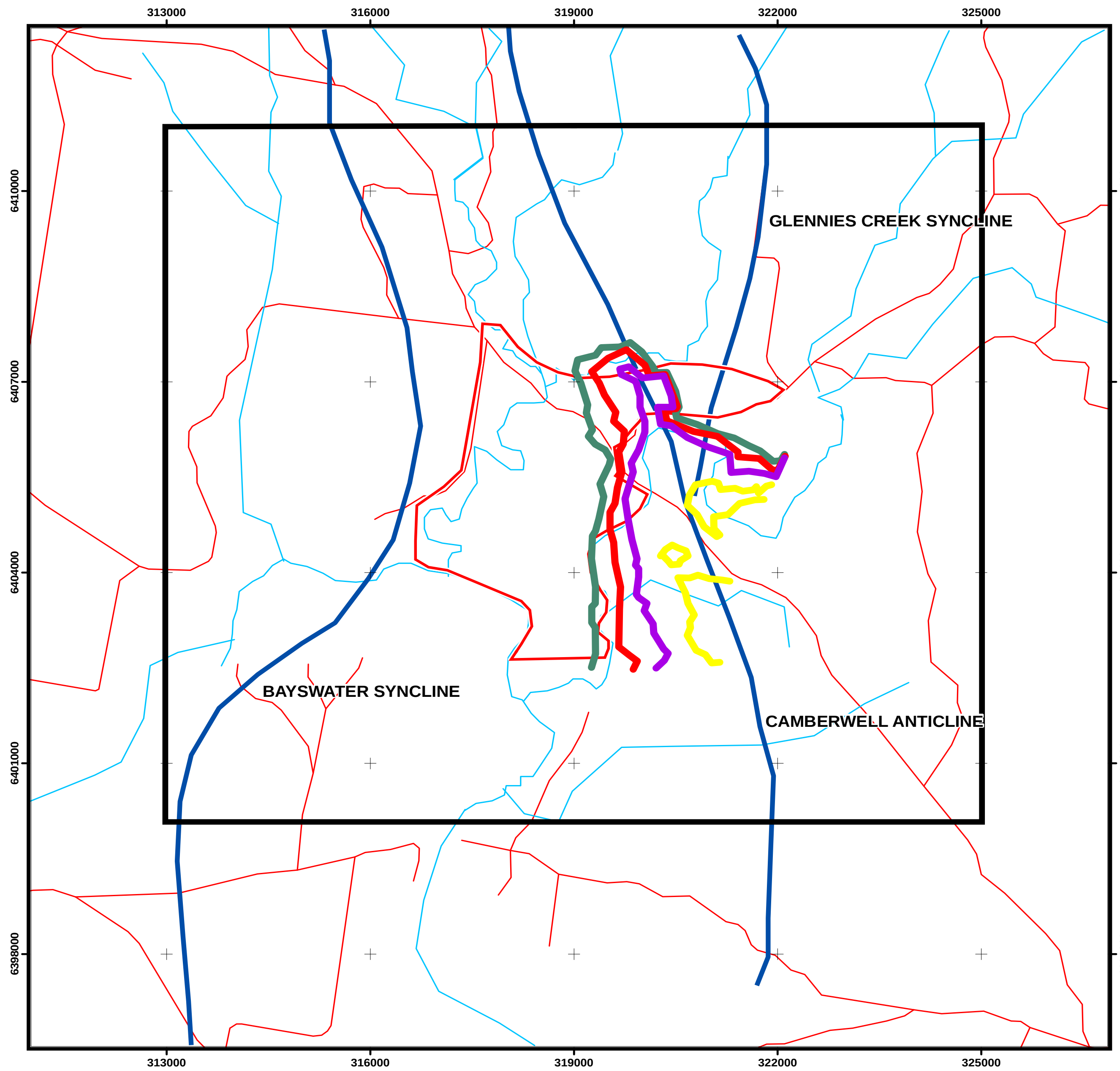


Figure 4.1: Ashton Project - Regional Geology

Author: VR	Date: 13/11/2008
Drawn:	Revised:
Job No: S36	Report Revision:
Projection: GDA94 MGA Z56	Scale: 1:45,000



Date:	6 August 2009	Scale:	as shown	**Ashton Coal Operations Ltd**
Initials:	JVDA	Job No:	S55G	**Representative Geological Cross-Section**
Drawing No:	S55G-026	Rev:	0	
aquaterra				**Figure 4.2**



Legend

- Model outline
- Ashton Coal Project
- Geological Structure
- Roads
- Watercourses
- Lower Barrett Coal Seam Outcrop/Subcrop
- Upper Lower Liddell Coal Seam Outcrop/Subcrop
- Upper Liddell Coal Seam Outcrop/Subcrop
- Pikes Gully Coal Seam Outcrop/Subcrop

Date: 04 August 2009	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: JVDA	Job No: S55G	**Approximate Sub-crop of Target Coal Seams**
Drawing No: S55G-022	Rev: 0	
aquaterra		**Figure 4.3**

Within the project area, alluvium occurs in association with the Hunter River and its tributaries Bowmans Creek and Glennies Creek. Investigation drilling of the Bowmans Creek alluvium (Aquaterra, 2008) indicates up to about 15 metres of sandy silts, silts and silty clays, with occasional horizons of silty sands and gravels. Maximum recorded saturated thickness is 4.5m.

Investigation drilling of the Glennies Creek floodplain and regolith indicated up to about 8 -10 m of sandy silts, silts and silty clays, generally overlying coarse sandy gravels. Maximum recorded saturated thickness is 6m.

The Hunter River alluvium was found to comprise mainly clay and silty clay, with gravel horizons. A basal gravel horizon 8.5m thick was drilled in RA27. The saturated thickness in this bore was 6m, but greater saturated thicknesses may occur. The Hunter River alluvium is generally more permeable than the Bowmans Creek alluvium.

4.4 OVERVIEW OF THE MAIN HYDROGEOLOGICAL UNITS

Two distinct aquifer systems occur within or near the project area:

- A fractured rock aquifer system in the coal measures, with groundwater flow mainly in the coal seams and
- A shallow granular aquifer system in the unconsolidated sediments of the alluvium associated with Bowmans Creek, Glennies Creek and Hunter River.

Some 'perched' groundwater may also occur within the upper weathered mantle of the Permian coal measures, although it is limited and was not encountered in every borehole.

4.4.1 PERMIAN COAL MEASURES

The permeability of the coal measures is generally low, with rock mass permeabilities more than two orders of magnitude lower than the unconsolidated alluvial aquifers. Within the coal measures, the most permeable horizons are the coal seams, which commonly have a hydraulic conductivity one to two orders of magnitude higher than the siltstones, shales and sandstone units. The coal seams are generally more brittle and therefore more densely fractured than the overburden and interburden strata, which causes the higher permeability.

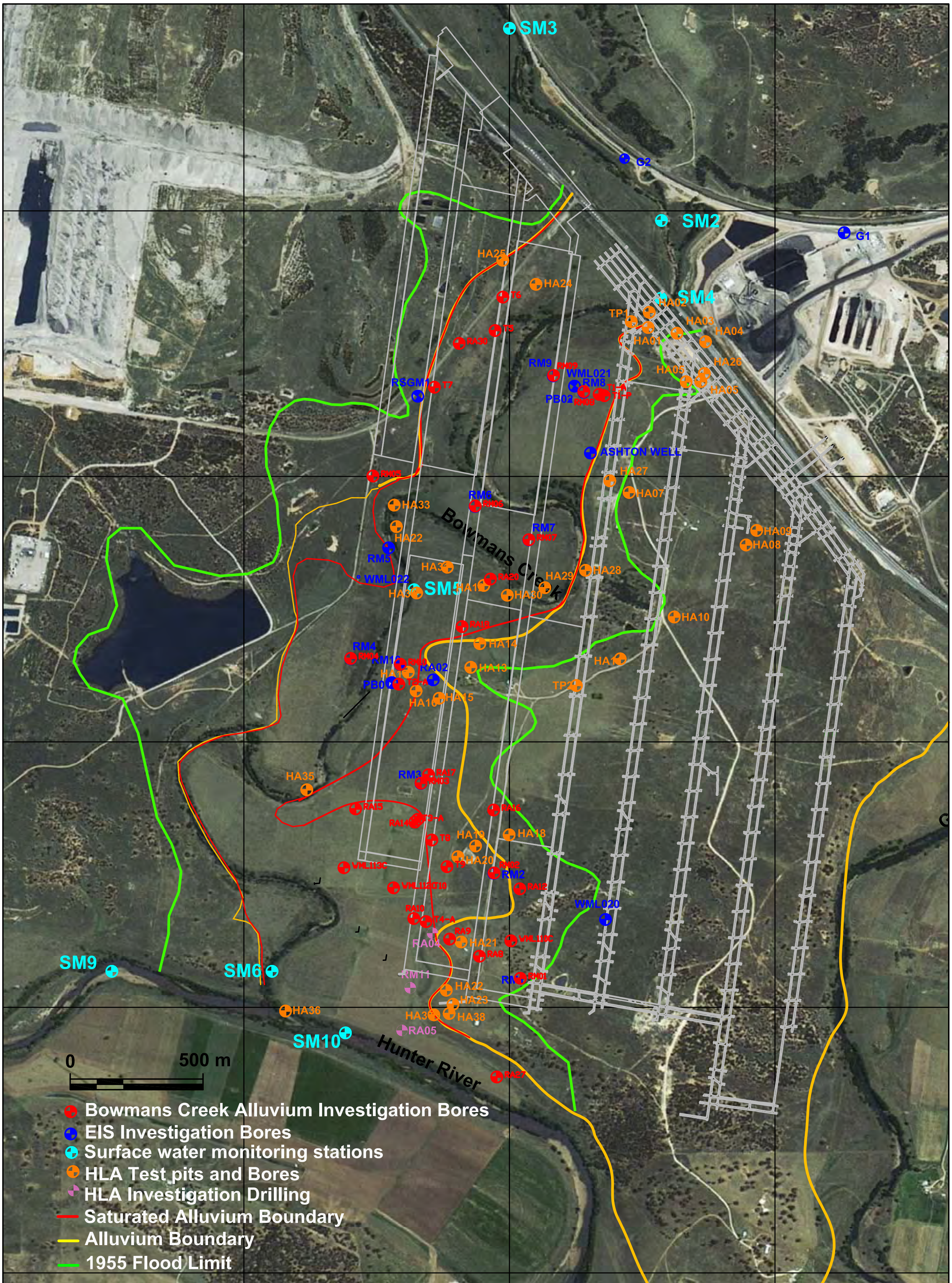
Within the coal seams, the groundwater flows predominantly through cleat fractures, with very little evidence of structure-related fracturing. Due to the laminar nature of the coal measures, groundwater flow generally occurs within, or along the boundaries between, stratigraphic layers. This means that effective rock mass vertical permeability is significantly lower than horizontal (typically three or more orders of magnitude).

4.4.2 ALLUVIUM

Bowmans Creek

The Bowmans Creek alluvium is characterised by fine silts and clays, sometimes containing large cobbles, and silty sands. The presence of fine silts and clays as a matrix around the cobbles and sands has a strong moderating influence on the alluvium hydraulic conductivity, as discussed in Section 4.5.

The lateral extent of saturated Bowmans Creek alluvium has been determined from a combination of aerial photography, aeromagnetic survey, ground mapping, the results of exploration drilling, and monitoring of groundwater levels over a range of above and below average climatic conditions (Aquaterra, 2008). The limits of saturated alluvium for Bowmans Creek are shown on Figure 4.4, and are based on groundwater levels in July 2007, which represents the high point in groundwater levels over the period during which monitoring records have been maintained on the Ashton Project (2001 to 2009).



Date: 6 October 2009	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PZ	Job No: S55G	**Limits of Bowmans Creek Alluvium**
Drawing No: S55G-010	Rev: 0	
aquaterra		**Figure 4.4**

The alluvium merges with colluvium along the flanks of the floodplain. The demarcation between alluvium and colluvium has been determined generally on the basis of lithology, groundwater level and salinity.

Drilling and aeromagnetic investigations (HLA, 2001; Aquaterra, 2008) have shown that there is a sharp demarcation between the Bowmans Creek alluvium and the Hunter River alluvium. This sharp line of demarcation extends across the confluence, with no evidence for an embayment of Hunter River alluvium into the Bowmans Creek valley.

Contours of the base of alluvium beneath the Bowmans Creek floodplain are plotted on Figure 4.5. These are based on the results of drilling. The contours show a clear incised valley profile, with the course of the incised valley not coincident with the present drainage line in all locations. The saturated thickness of the alluvium reaches a maximum of around 4.5m.

Glennies Creek

The Glennies Creek alluvium generally occurs in association with the deposition of paleo-sediments by the creek. These deposits occur within two main terraces, a lower terrace adjacent to the creek, and an upper terrace that merges with colluvium and finally regolith associated with the slopes of the rising Permian subcrop. The terraces are tiered, with an elevation change between terraces in the order of 1-3 m.

The meander of Glennies Creek that runs closest to the underground mine (LW1) incises to the edge of the alluvium and some Permian bedrock is visible in the stream banks. This is close to the subcrop of the Pikes Gully seam, as shown in Figure 4.3. Some enhanced connectivity between the river and the Permian subcrop has therefore been allowed for in the modelling assessment described in Section 6 of this report.

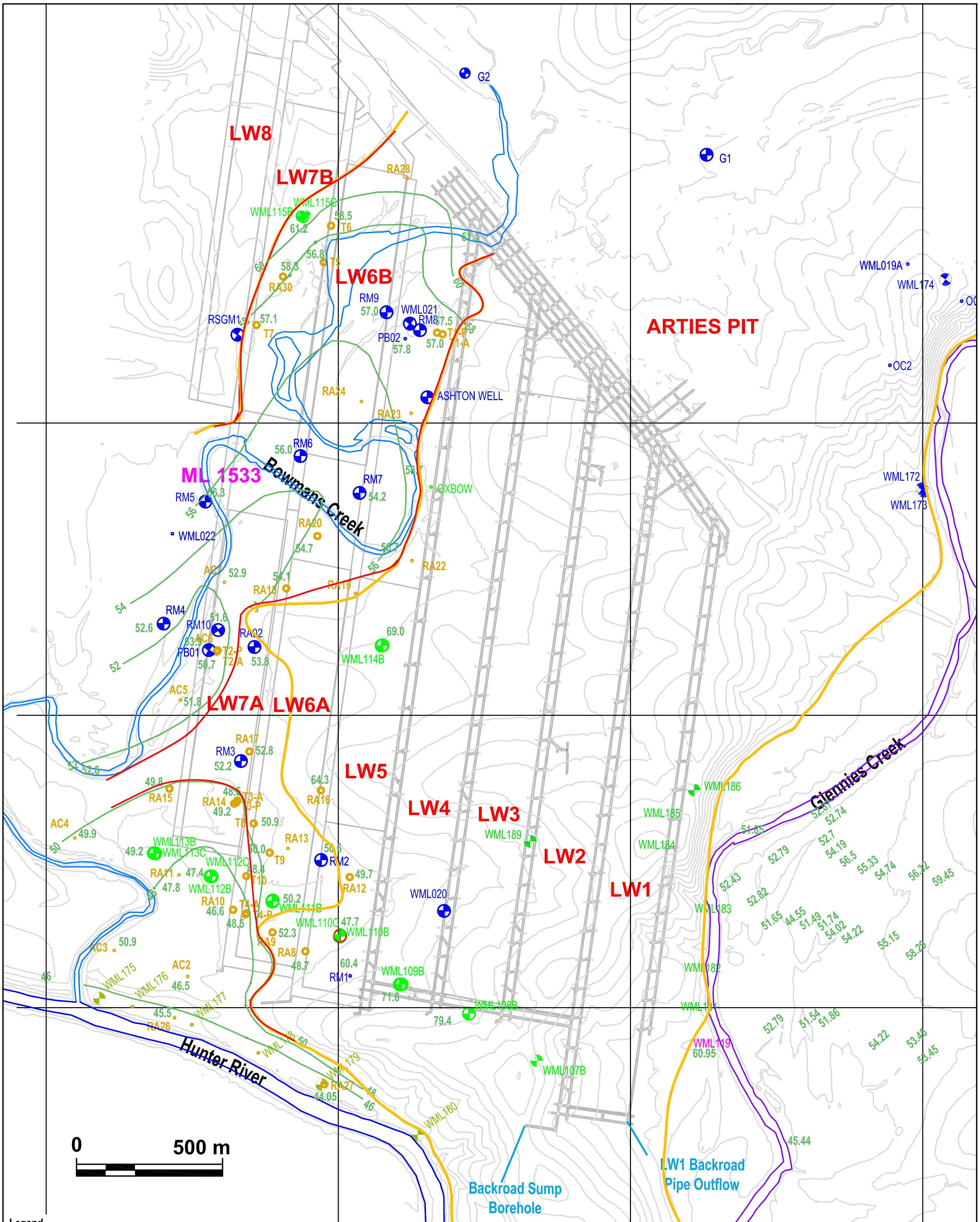
As noted in Section 3, investigations for the SEOC project (Aquaterra, 2009) showed that the alluvium associated with Glennies Creek has a highly variable hydraulic conductivity, which appears to have been caused by paleo-geomorphology and drainage conditions during the deposition of the alluvium. This variability in hydraulic conductivity has also been included within the modelling assessment for this project.

Hunter River

The investigations into the Hunter River alluvium across the southern end of the site indicate that it is deeper and generally more transmissive than either the Bowmans Creek or Glennies Creek alluvium. Floodplain alluvium of the Hunter River was extensively tested at the neighbouring Hunter Valley No.1 mine in 1992. Those results indicated that 'typical' basal sands and gravels are present within the alluvium, resulting in alluvium permeability 2 to 4 times that of the current day river bed sediments.

4.5 AQUIFER PARAMETERS – ESTIMATES OF HYDRAULIC CONDUCTIVITY

The hydraulic testing program was discussed in Sections 2.2 and 3.3. A summary of representative aquifer properties of the hydrogeological units in the project area is given in Table 4.3. This summarises the range and mean values of hydraulic conductivity obtained from analysis of the hydraulic test data collected from previous investigations for the principal hydrogeological units. The values of storativity and specific yield contained in the table have been estimated based on experience of the nature of the rock in this area.



Legend

- EIS Investigation Bores
- Subsidence Monitoring - Standpipe Piezo
- Bowmans Creek Alluvium Investigation Bores
- Hunter River Alluvium Piezometer
- Abandoned / Lost Bore
- Alluvium Boundary
- Boundary of Saturated Alluvium
- 49.2 Base of Alluvium (mAHD)
- Contours of Base of Bowmans Ck Alluvium

Date: 03 October 2009	Scale: as shown		
Initials: PZ	Job No: S55G		
Drawing No: S55G-011	Revision: 0		

Ashton Coal Operations Ltd

BOWMANS CREEK ALLUVIUM
CONTOURS OF BASE OF ALLUVIUM
(m AHD)

aquaterra

Figure 4.5

Table 4.3: Representative Aquifer Parameters for Main Hydrogeological Units

Units	Horizontal Hydraulic Conductivity (m/d)		Confined Storativity	Unconfined Specific Yield
	Tested Range	**Median**		
Bowmans Creek alluvium	0.0002 to 15	0.7	0.0001	0.05
Glennies Creek alluvium	0.07 to 180	0.6*	0.0001	0.05
Floodplain alluvium of the Hunter River	50	50	0.0001	0.1
Pikes Gully Coal Seam	0.01 to 10**	0.04	0.0001	0.005
Other coal seams	0.002 to 0.03	n/a	0.0001	0.005
Interburden/overburden above Pikes Gully	<0.000001 to 0.008	0.0003	0.00001	0.005

Notes:

* This value is the calculated geometric mean. High permeability values for Glennies Creek alluvium relate to localised areas under specific depositional environments. This variability has been appropriately allowed for in the groundwater modelling and assessment.

**The value of 10 m/d (1 x 10^{-4} m/s) determined at WML120a is much higher than all other test results for the Pikes Gully seam, and is atypical for coal seams in the Hunter Valley. Bore WML120a is located close to outcrop, updip from the underground mine, and the result is believed to be more indicative of weathered Pikes Gully 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 100m from outcrop.

These ranges have been used in the groundwater modelling described in Section 6. They show that permeabilities within the Bowmans Creek alluvium are generally much lower than were assumed for the 2001 EIS, and that there is a high degree of variability within the Glennies Creek alluvium. This demonstrates the importance of the clay-silt matrix, which occurs within most of the ‘gravel’ layers that had been previously assumed to be highly transmissive.

The following inferences have been made about the hydraulic nature of the hydrogeological units based on the hydraulic testing, field observations and experience of the coal measures in this area:

- The Pikes Gully seam appears to have a higher hydraulic conductivity than the deeper coal seams, probably due to greater cleating of the coal and more open fractures due to the lower overburden pressures.
- The overburden above the Pikes Gully contains multiple coal seams (the Bayswater and Lemington seams) and lower overburden compression, and hence has a higher bulk rock mass permeability than the interburden beneath the Pikes Gully, particularly in terms of horizontal hydraulic conductivity.
- The coal measures are highly laminar sedimentary rocks. The majority of the permeability is therefore parallel to bedding (caused by fracturing and shear preferentially along the bedding planes). It is therefore considered that vertical permeability in the undisturbed rock mass is at least two or three orders of magnitude less than the measured, mainly horizontal, permeability.
- 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.

4.6 CURRENT GROUNDWATER USE

4.6.1 CENSUS AND NOW REGISTERED SITES

Searches of the NOW groundwater bore database and groundwater censuses have been carried out for previous investigations, as described in Section 2.6. A further record search has been carried out as part of this study, which did not reveal any new registered users. Ongoing operations and groundwater monitoring for the site have not revealed any new registered or unregistered groundwater users in the area.

4.6.2 OTHER COAL MINES

The closest active coal mines to the Ashton underground mine are the Ravensworth underground mine (RUM) and the Narama open cut mine, both to the west of Ashton. The Narama open cut is still active, recovering coal from the upper seams (Bayswater etc). The RUM workings are currently within the Pikes Gully seam and mining is planned to progress into the Upper Liddell, Middle Liddell and Lower Barrett seams over a longer timescale than the Ashton proposals.

Groundwater use at these mines is not known, but will be much more significantly affected by their own activities than by anything to do with the Ashton mine.

4.7 GROUNDWATER LEVELS AND FLOW PATTERNS

Groundwater levels were initially collected during the EIS studies in 2000 and 2001, and routine monitoring across the area commenced in 2003. Extensive data on groundwater levels have been gathered and the monitoring network expanded significantly during subsequent EA and SMP investigations. Hydrographs from all groundwater monitoring bores are shown as part of the transient calibration results, as contained in Appendix E.

4.7.1 PRE-MINING CONDITIONS

Data from the 2001 EIS

The earliest records for the site come from the EIS groundwater investigations. These consisted mainly of open boreholes, and the water levels would represent a composite of the heads throughout the Permian, but probably dominated by the most permeable coal seam intersected in each hole. However, three screened piezometer water levels were taken, in bores WML19a (Lower Barrett seam), WML20 and WML21 (Pikes Gully seam). These indicated potentiometric heads between 61 mAHD and 65 mAHD. The open borehole monitoring data collected within the Permian showed groundwater levels in the range 54 to 68 mAHD, with one reading (WML011, located to the north east of Arties Pit) at 78 mAHD. Based on these levels, groundwater gradients were to the south and south west.

Data from the Bowmans Creek alluvium piezometers showed groundwater levels in the range 55 mAHD to 60 mAHD. Data from the Pikes Gully borehole WML21 and the Bowmans Creek alluvium boreholes RM08 and RM09 near the same location showed a significant upwards gradient from the Permian to the Bowmans Creek alluvium (around 4 or 5m head difference).

Data from the Ashton Monitoring Network Prior to the Start of Underground Mining (2006-2007)

The installation of the main monitoring network prior to the start of underground mining, provided significantly more potentiometric data for specific horizons within the Permian strata. Most of these monitoring bores were installed after some years of open cut mining and therefore do not directly indicate pre-mining groundwater levels. However, by back-projection of trends, and by reference to the piezometric head profiles, it has been possible to infer indicative pre-mining levels at several locations.

The interpreted potentiometric surface within the coal measures above the underground mining area prior to the start of mining is shown on Figure 4.6). Groundwater levels in the Pikes Gully seam had already been slightly affected by the NEOC and underground development headings by the time underground mining started, but most of the monitoring points were sufficiently far from this area to provide a reasonable indication of groundwater levels prior to mining impacts.

This data shows that the pre-mining Permian potentiometric surface was between 55 and 65 mAHD. There was a slight mound on the water table surface above Longwall 2, where the water table was around 65 mAHD, compared with around 55-60 mAHD in the south western end of the mine area. The groundwater levels in the Pikes Gully seam beneath the Glennies Creek alluvium would have been approximately 52 mAHD or higher.

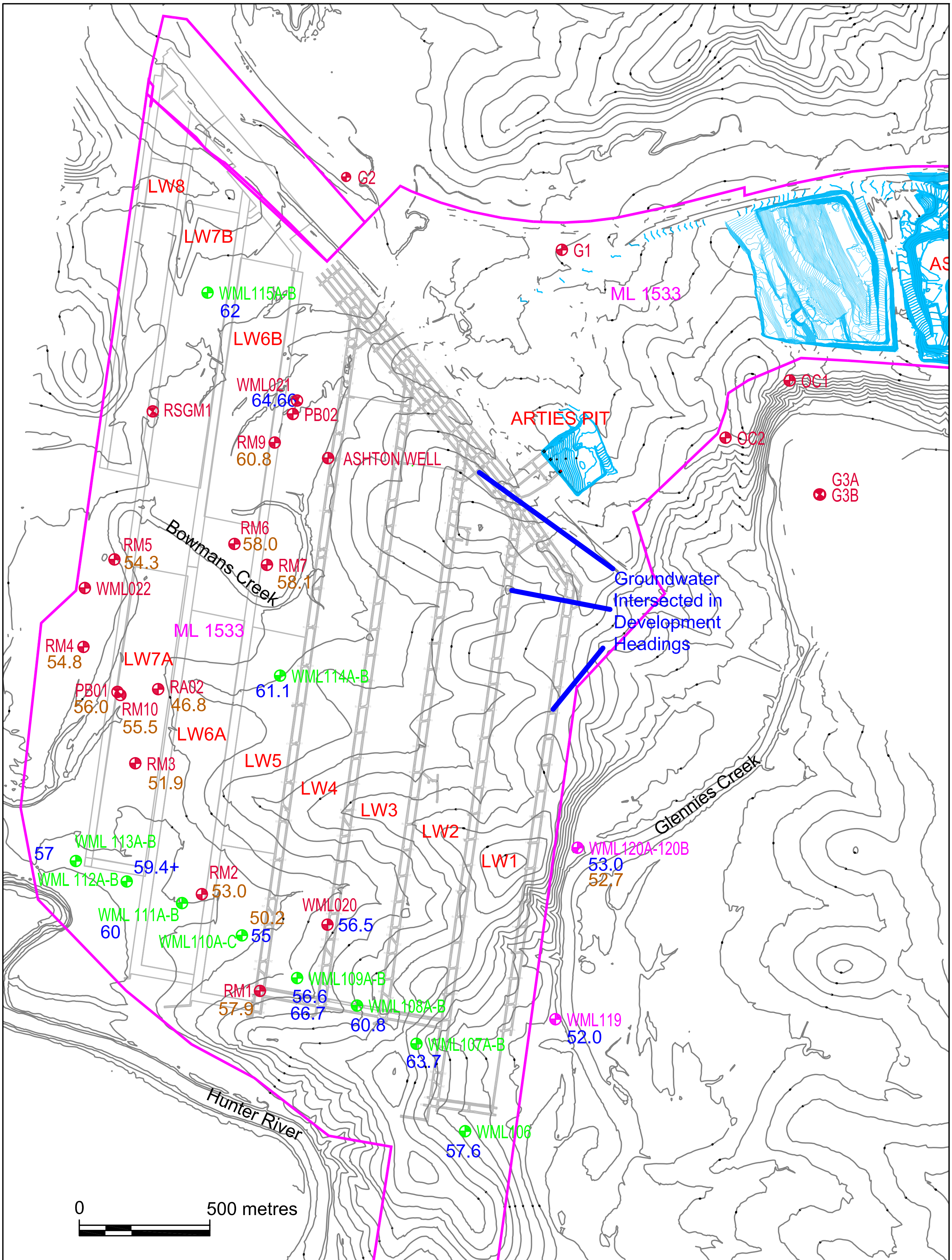
Alluvium groundwater levels around Bowmans Creek were generally well below the deeper Permian groundwater levels, but in some areas may have been slightly higher than those in the shallow, weathered Permian, as illustrated on Figures 4.7 and 4.8. These are composite plots of the paired alluvium/coal measures piezometers T1-A and -P, T2-A and -P, T3-A and -P, and T4-A and –P, together with other piezometers close to these sites. At the T1 site, the near-surface weathered Permian groundwater level was higher than the alluvium groundwater, but at the other three sites the alluvium water level is 0.4 to 0.5m higher than the water level in the shallow, weathered Permian. In these areas, the near-surface weathered Permian has the character more of a granular aquifer, and is recharged from above by downward percolation of rainfall, rather than by flow along the bedding from updip areas, as is the case with the deeper Permian below the base of weathering.

Records of groundwater levels in the deeper Permian beneath the Bowmans Creek valley indicate that groundwater heads were generally higher than those in the alluvium, and there was a trend of increasing potentiometric head with depth. Figure 4.9 shows composite hydrograph plots for the WML111 and WML112 sites, where vibrating wire piezometers are installed in various Lemington seams, and standpipe piezometers monitor water levels in the alluvium and near-surface weathered coal measures. These bores are located well away from both the open cut and underground operations, and had not experienced significant impacts from Ashton’s mining activity prior to 2008, although the shallow seams (Bayswater and upper Lemington seams) may have been affected by adjacent mining operations (Narama or HVO).

The alluvium groundwater level is seen to be higher than the Bayswater Seam and upper Lemington seams, but the deeper Lemington seams had increasingly higher heads. However, even in the case of the Bayswater and upper Lemington seams, back-projection of the hydrograph trends indicates that these seams would also have had heads higher than the alluvium prior to the commencement of mining at Ashton.

At WML111, the Lemington 15 Seam head in 2007 was above ground level, while prior to piezometer installation, the open hole at WML112 was flowing (i.e. the composite head for the Permian sequence was above ground level). At both sites, the Lemington 15 Seam head was about 6-8m higher than the alluvium groundwater level when monitoring started.

Overall this indicates a pre-mining condition where sub-cropping Permian coal seams are recharged by rainfall infiltrating the seams. Low mobility of groundwater within the strata at depth means that groundwater heads in the Permian are, in turn, largely controlled by the physical elevation of these recharge areas. Hence, in low topographic areas such as the Bowmans Creek valley, the Permian had higher potentiometric heads than the alluvium. The Permian discharges at a slow rate to the rivers and creeks, and groundwater levels are therefore above the river/creek water levels.



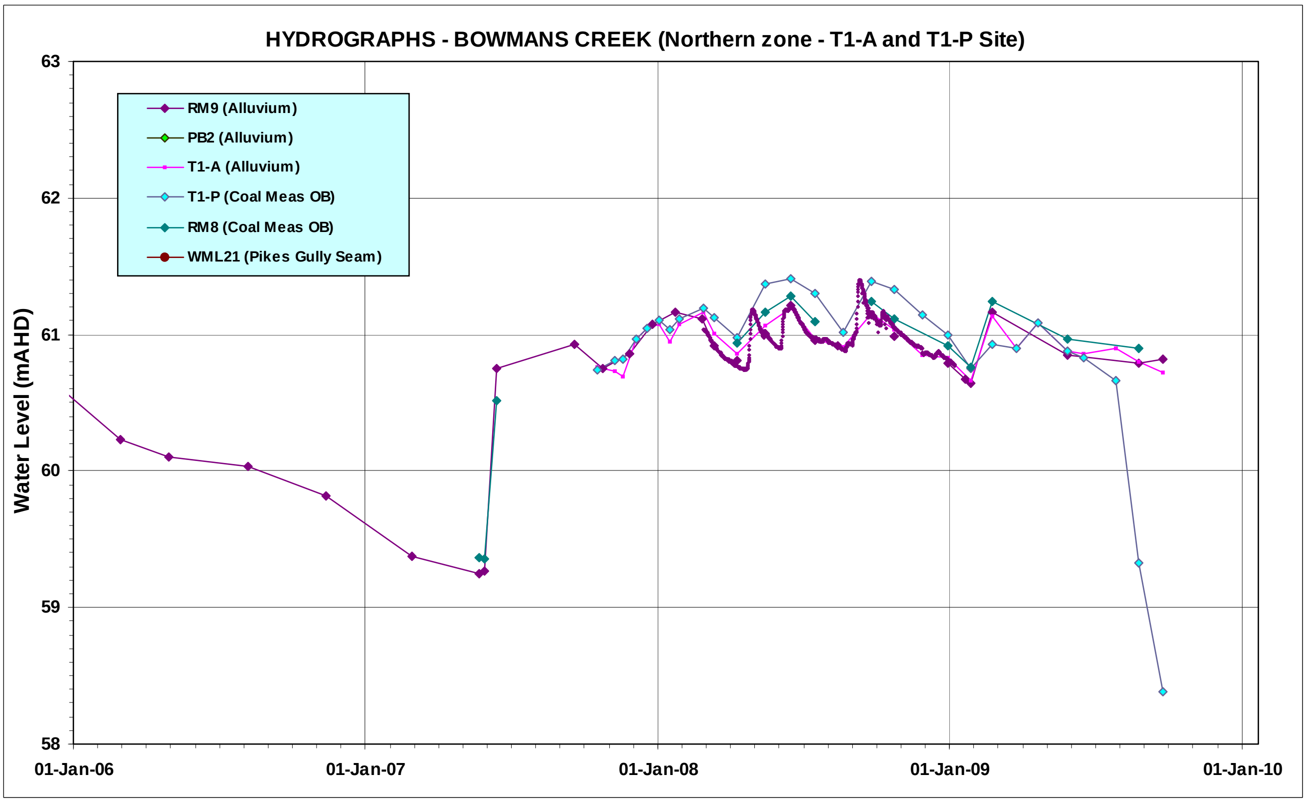
Legend

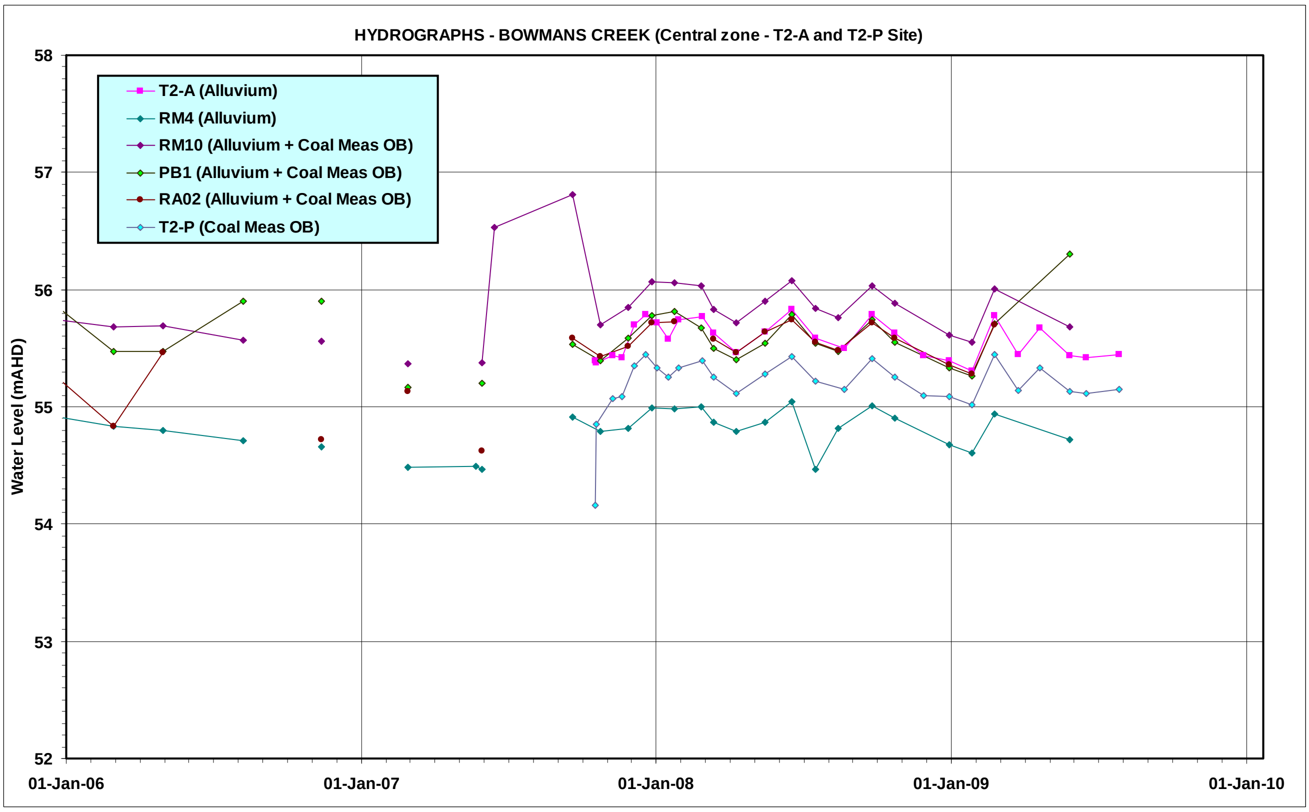
- EIS Investigation Bores
- SMP Ivestigation Piezometers
- Subsidence Monitoring Bores
- 60.6 Coal Measures Groundwater Level (mAHD)
- 60.6 Alluvium Groundwater Level (mAHD)

Date:	30 September 2009	Scale:	as shown	**Ashton Coal Operations Ltd**
Initials:	PZ	Job No:	S55G	**GROUNDWATER LEVELS PRIOR TO MINING**
Drawing No:	S55G-012a	Revision:	0	

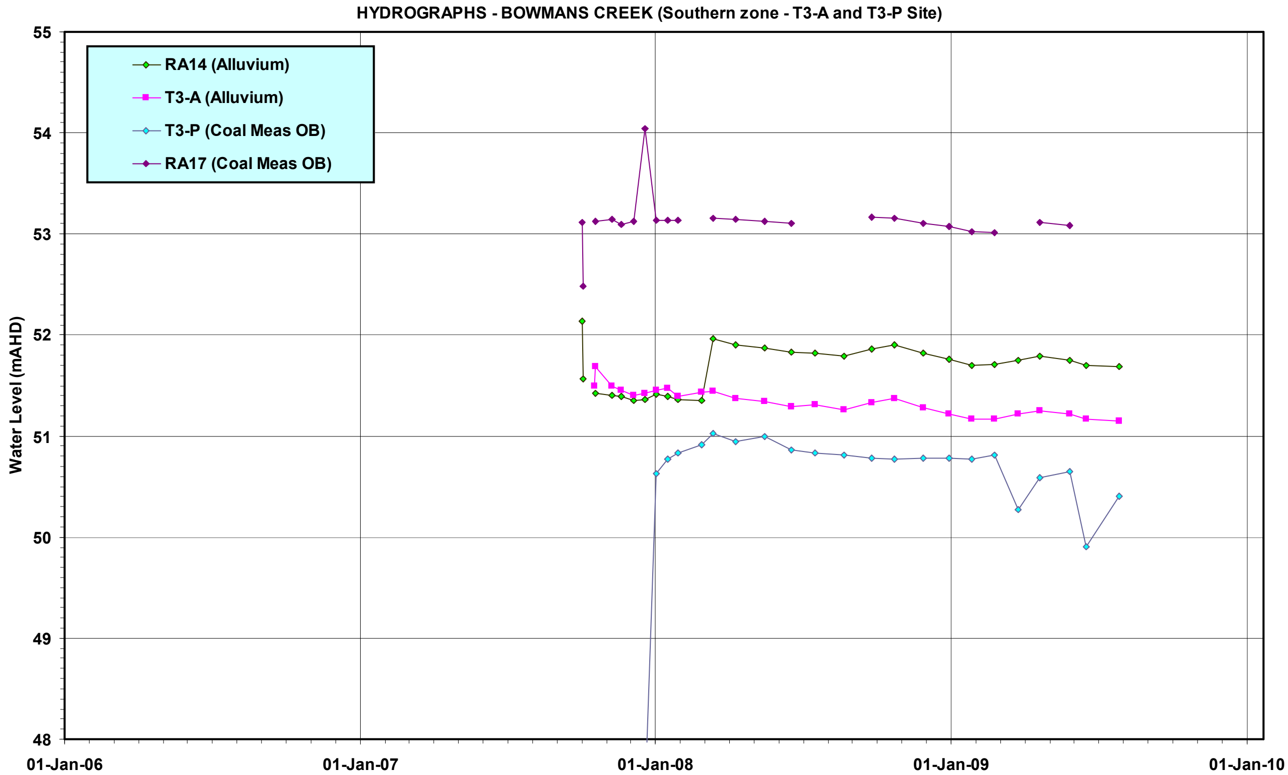
aquaterra

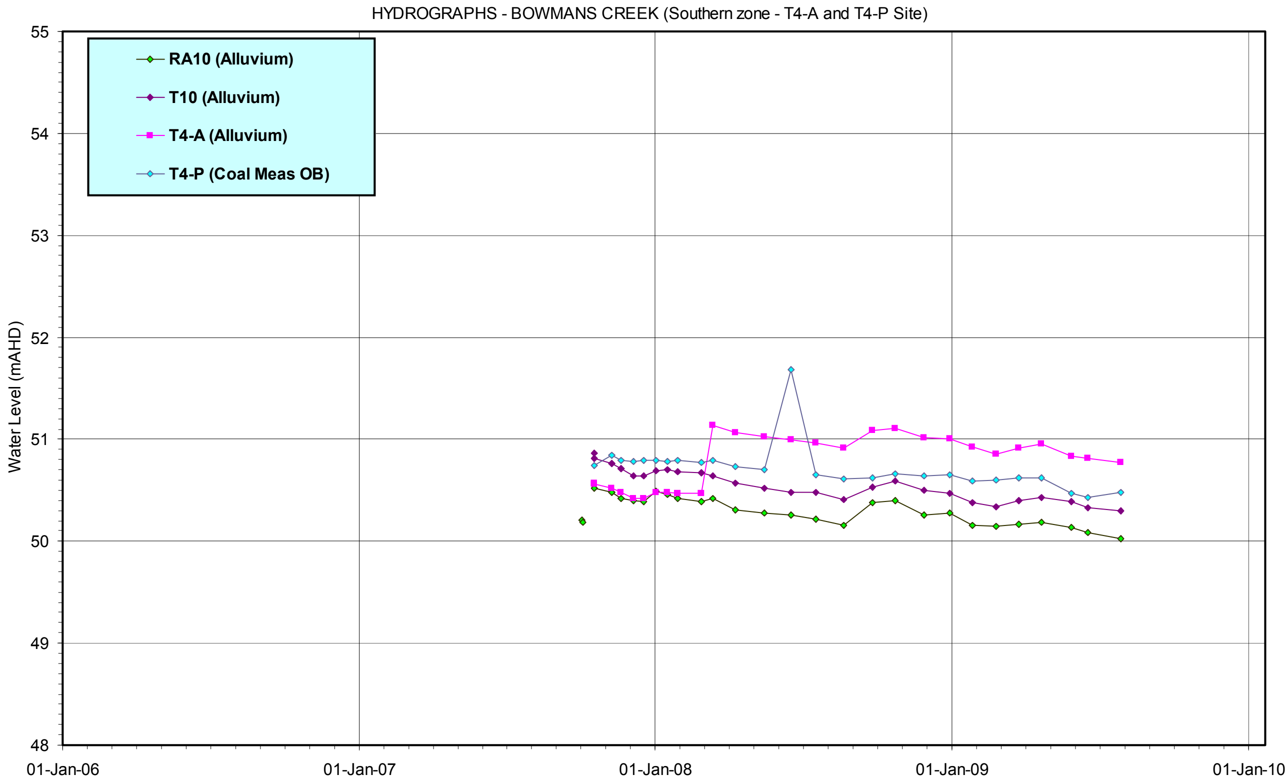
Figure 4.6



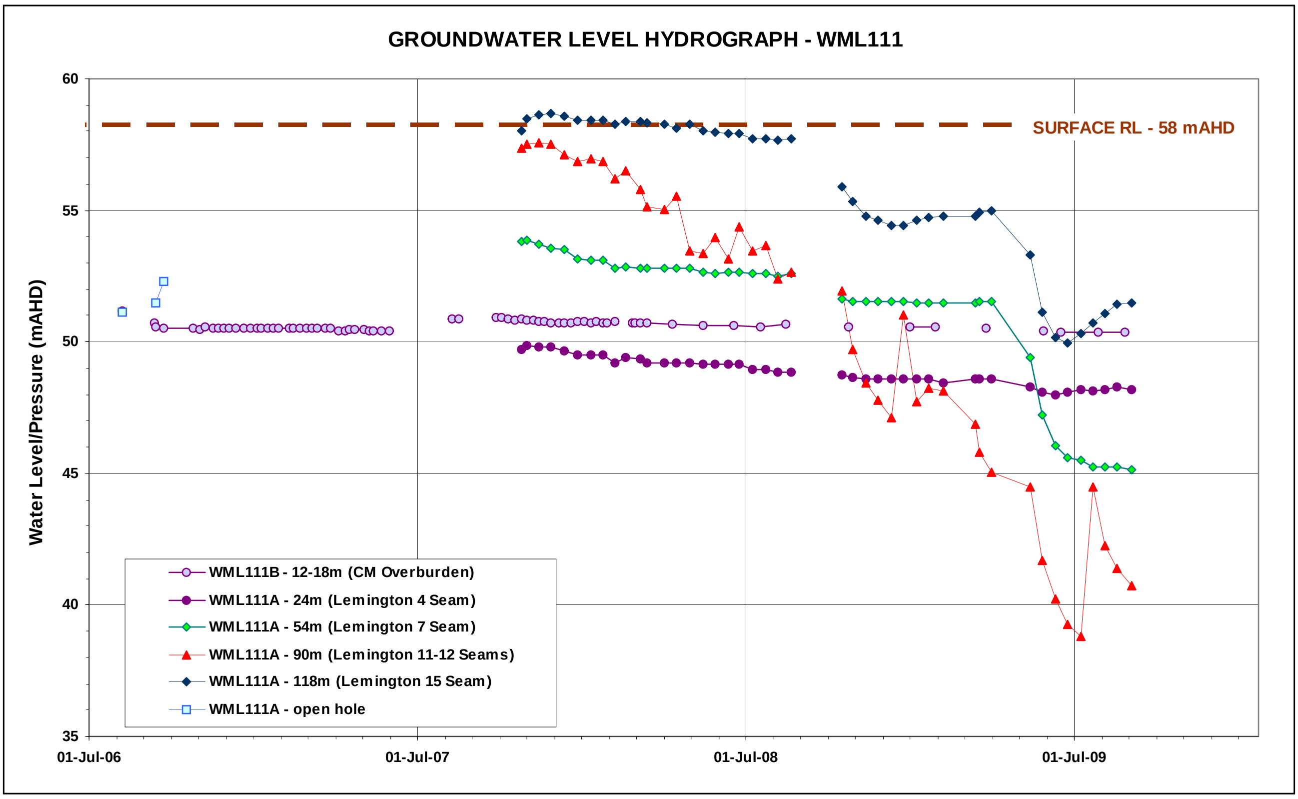


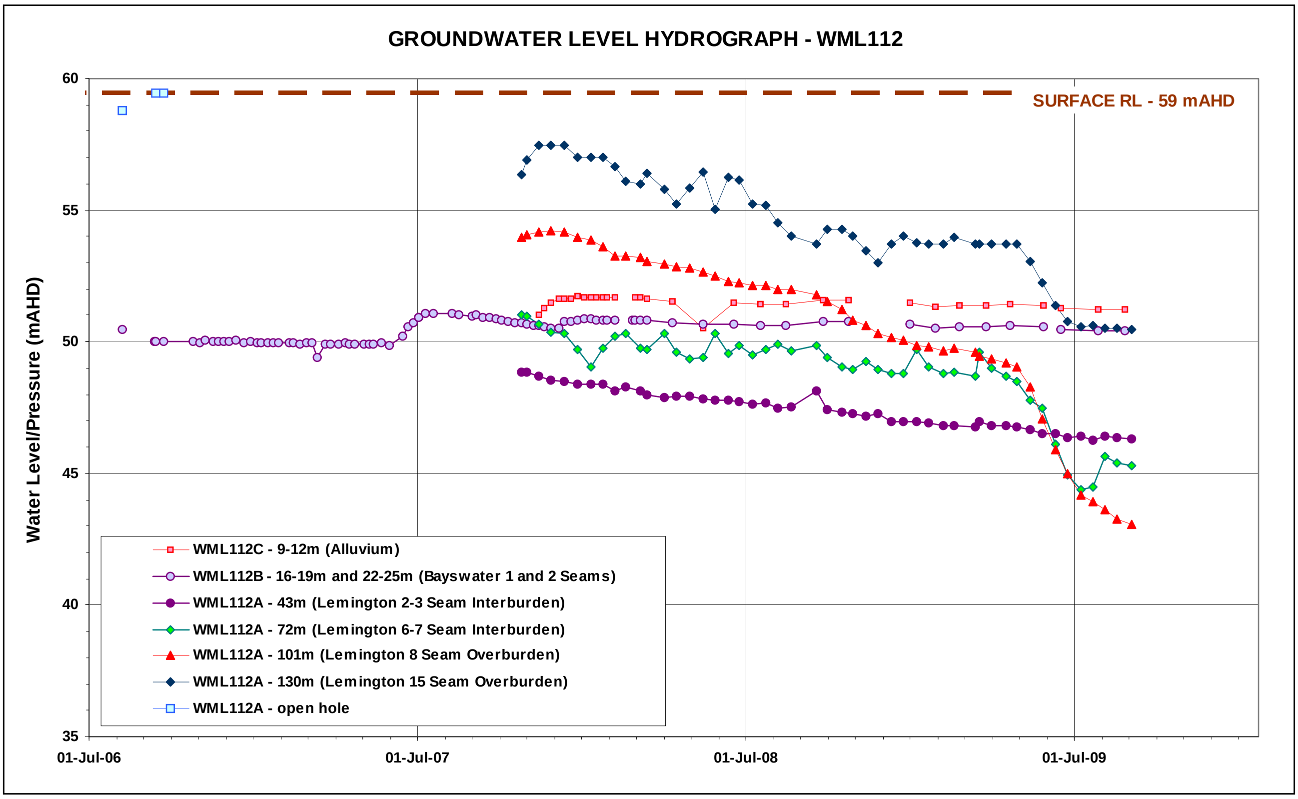
Date: 6 October 2009	Scale: as shown	**Ashton Coal Operations Ltd**
Initials: PZ	Job No: S55G	**BOWMANS CREEK ALLUVIUM HYDROGRAPHS T1-A and P; T2-A and P**
Drawing No: S55G-023	Rev: 0	
aquaterra		**Figure 4.7**





Date: 6 August 2009	Scale: as shown	**Ashton Coal Operations Ltd**
Initials: PZ	Job No: S55G	**BOWMANS CREEK ALLUVIUM HYDROGRAPHS T3-A and P; T4-A and P**
Drawing No: S55G-024	Rev: 0	
aquaterra		**Figure 4.8**





Date: 1 October 2009	Scale: as shown	**Ashton Coal Operations Ltd**
Initials: PZ	Job No: S55G	**BOWMANS CREEK ALLUVIUM MULTI-LEVEL VIBRATING WIRE HYDROGRAPHS WML111 and WML112**
Drawing No: S55G-013a	Rev: 0	
aquaterra		**Figure 4.9**

Groundwater level contours for the Bowmans Creek alluvium in January 2008 are shown in Figure 4.10. The contours show a gradient from north to south (i.e. upstream to downstream), and also with a component of gradient towards Bowmans Creek. Groundwater elevations ranged from around 62 mAHD at the upstream end near New England Highway to around 50 mAHD at the downstream end near the confluence with Hunter River.

In the Glennies Creek area to the east of the project site, groundwater levels in the upper part of the Permian coal measures and the weathered regolith also tended to reflect the local topography, with higher groundwater levels in elevated areas and lower levels in the valleys. Groundwater flow within the Glennies Creek alluvium is generally towards Glennies Creek and downstream along the valley, although the gradients are relatively flat.

Groundwater levels in the coal measures at depth in the Glennies Creek area are again more regionally-controlled, and are independent of the local topography. The multi-level vibrating wire piezometer bore WMLC144 located between the SEOC and Glennies Creek (Figure 4.11) had a water level about 6m higher than Glennies Creek (i.e. water level 58.5 mAHD compared with the creek water level of 52.5 mAHD) before it was grouted prior to installation. After installation of piezometers and grouting of the hole, the recorded pressures in the lower seams (Upper and Lower Barrett Seams) were initially higher than the Glennies Creek alluvium, but have since drawn down, possibly due to the influence of the NEOC or other mining activity.

4.7.2 IMPACT OF MINING OPERATIONS TO DATE

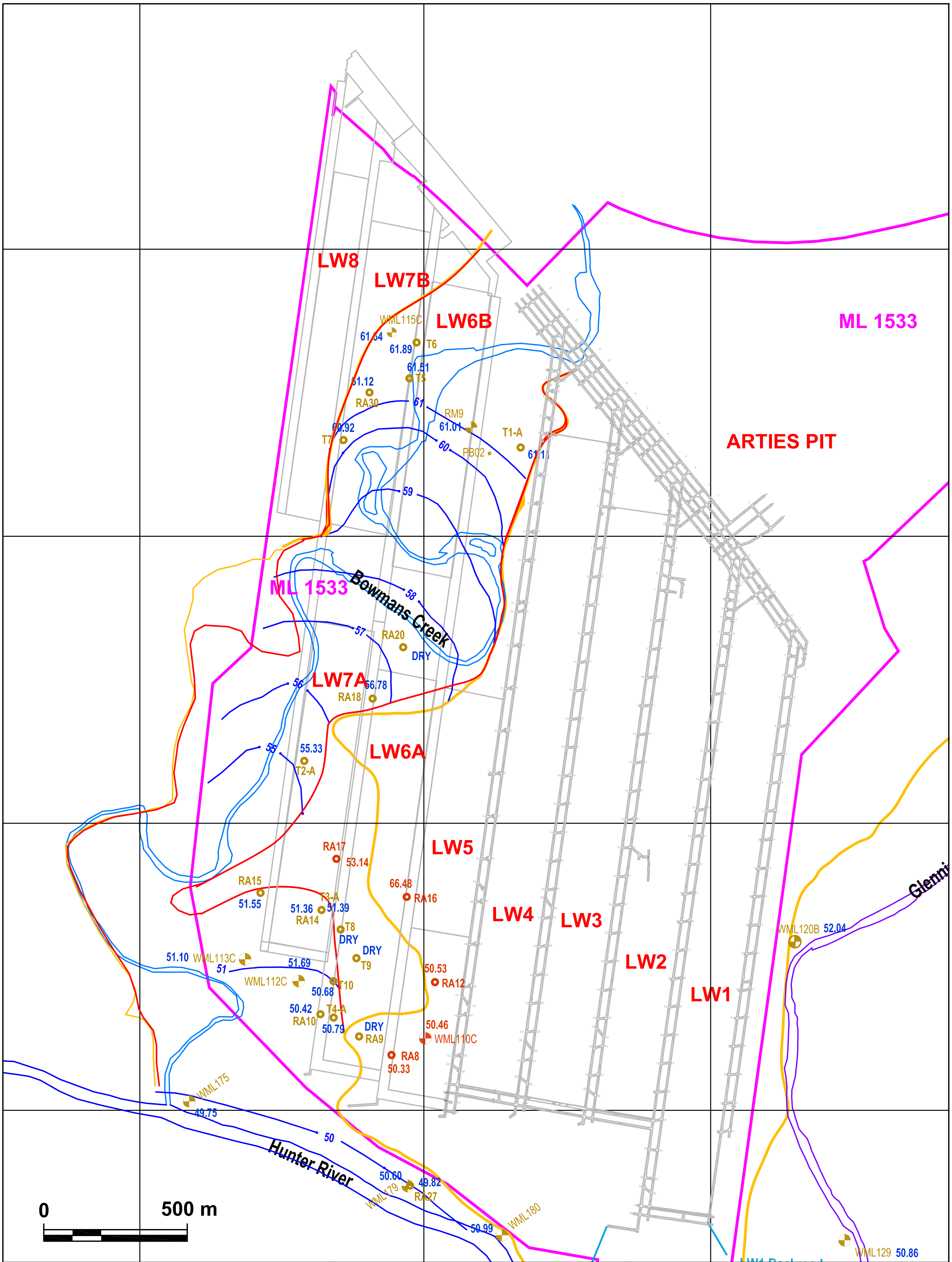
Groundwater Levels and Permeability

Mining of the Ashton NEOC and underground longwall panels LW1-3 has reduced groundwater levels within the deeper Permian to the stage where the Pikes Gully is largely dewatered over the longwall panel area (Aquaterra, 2009b and 2009c). Groundwater contours of the measured potentiometric heads at the end of the mining of LW3 are shown in Figure 4.12. Although impacts on the Pikes Gully seam are large, the groundwater contours show that effects are localised, with steep gradients around the mining perimeter indicating low hydraulic connectivity with the strata outside the mined area.

Figure 4.13 shows the hydrostatic head profiles for multi-level vibrating wire piezometers WML189 and WML191 (which are located above chain pillars between LW2 and LW3) and WML115A and WML213, which are located outside the area affected by the mining of LW1-3. The plots represent a snapshot of groundwater pressures in relation to the elevation for each piezometer, at the following times: prior to LW1 development (baseline levels), post LW1 extraction, post LW2 extraction and post LW3 extraction.

Generally, under pre-mining conditions, in the Ashton area, pressures plot close to the 45° “hydrostatic line”, although there is a slight shift from the line due to the upward head gradient. During mining, WML189 and WML191 show that there is significant, rapid depressurisation of Permian layers for up to 50m above the coal seam. However, outside of the mined area, large impacts are limited to the Pikes Gully seam, and overlying seams show a muted, slow response. This demonstrates the lack of vertical hydraulic connectivity between Permian layers, except where direct fracturing due to mining has occurred.

Several piezometers have shown partial recovery of groundwater levels after initial drawdown impacts from mining. The best example of this is WML107-98m set at the Lemington 19 Seam (Figure 4.14), which showed drawdowns during LW1 development headings, and again at the start of LW2 and LW3 extraction.



Legend

- Alluvium Piezometer
- Alluvium Piezometer
- Colluvium Piezometer
- Alluvium Groundwater Level (mAHD)
- Boundary of Alluvium
- Boundary of Saturated Alluvium

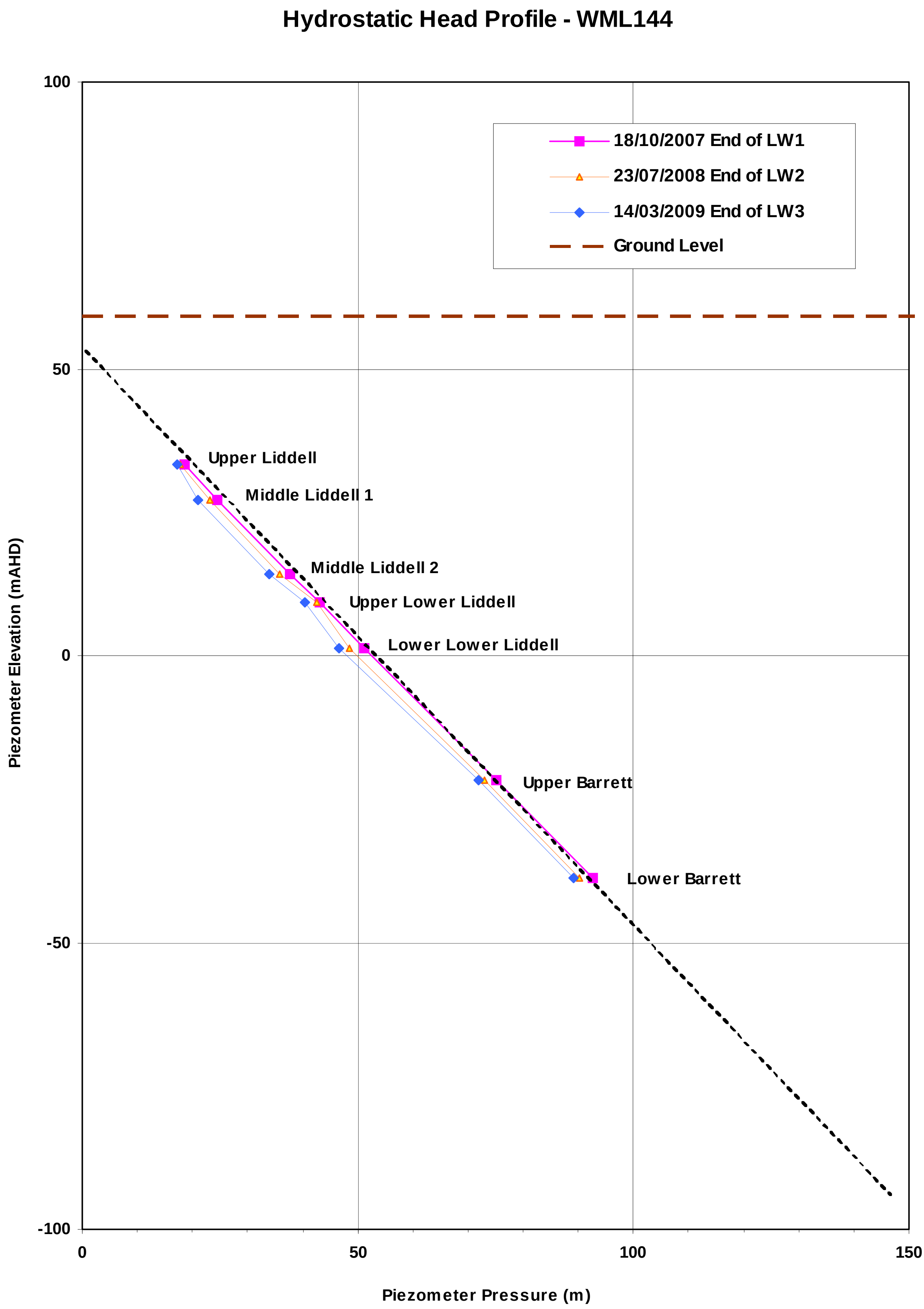
Date:	04 August 2009	Scale:	as shown
Initials:	JVDA	Job No:	S55G
Drawing No:	S55G-014	Revision:	0

aquaterra

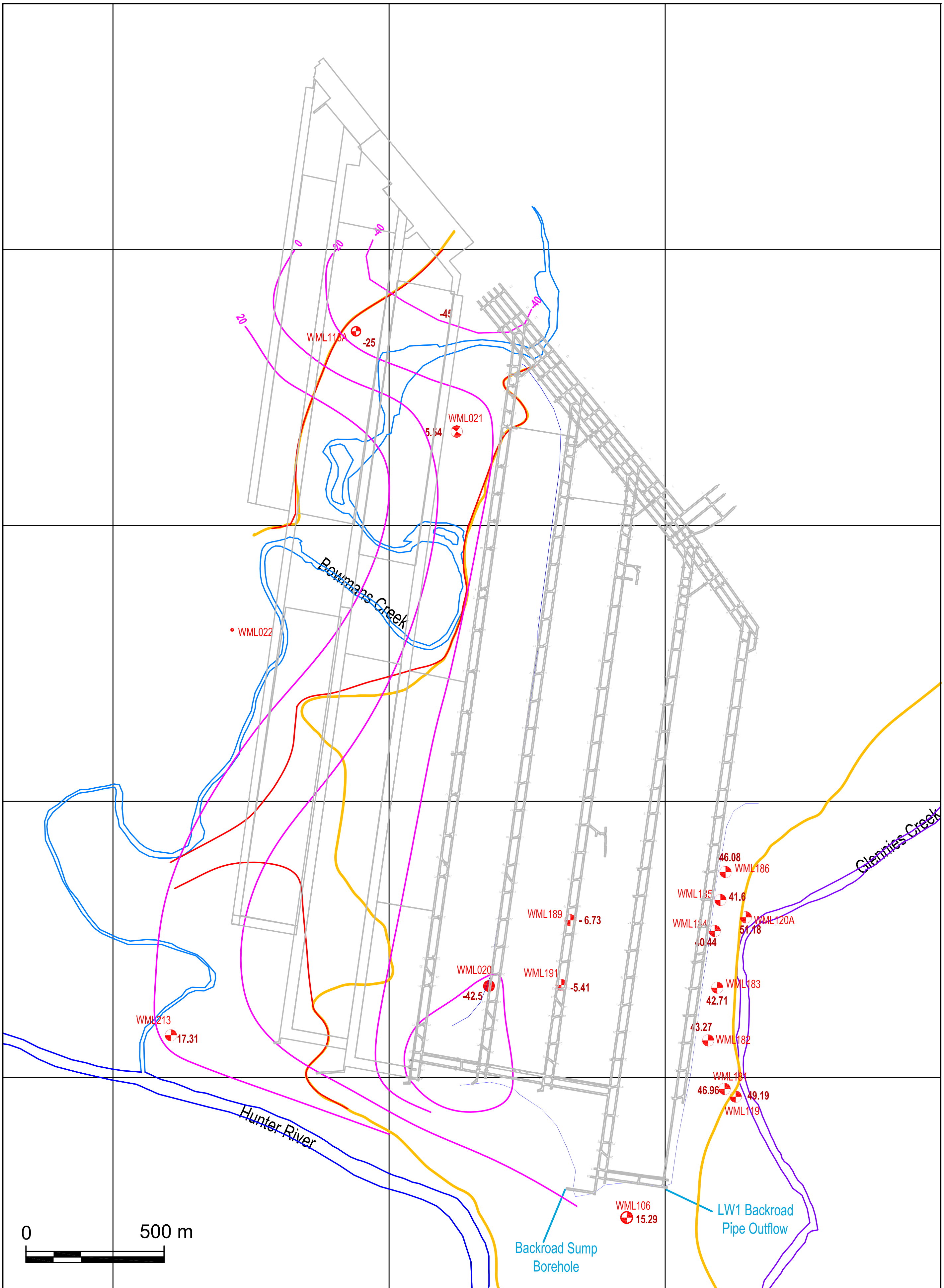
Ashton Coal Operations Ltd

ALLUVIUM GROUNDWATER CONTOURS (mAHD)

Figure 4.10



Date:	04 August 2009	Scale:	as indicated	**Ashton Coal Operations Ltd**
Initials:	JVDA	Job No:	S55G	**HYDROSTATIC HEAD PROFILES FOR BORE WML144**
Drawing No:	S55G-015	Rev:	A	
aquaterra				**Figure 4.11**



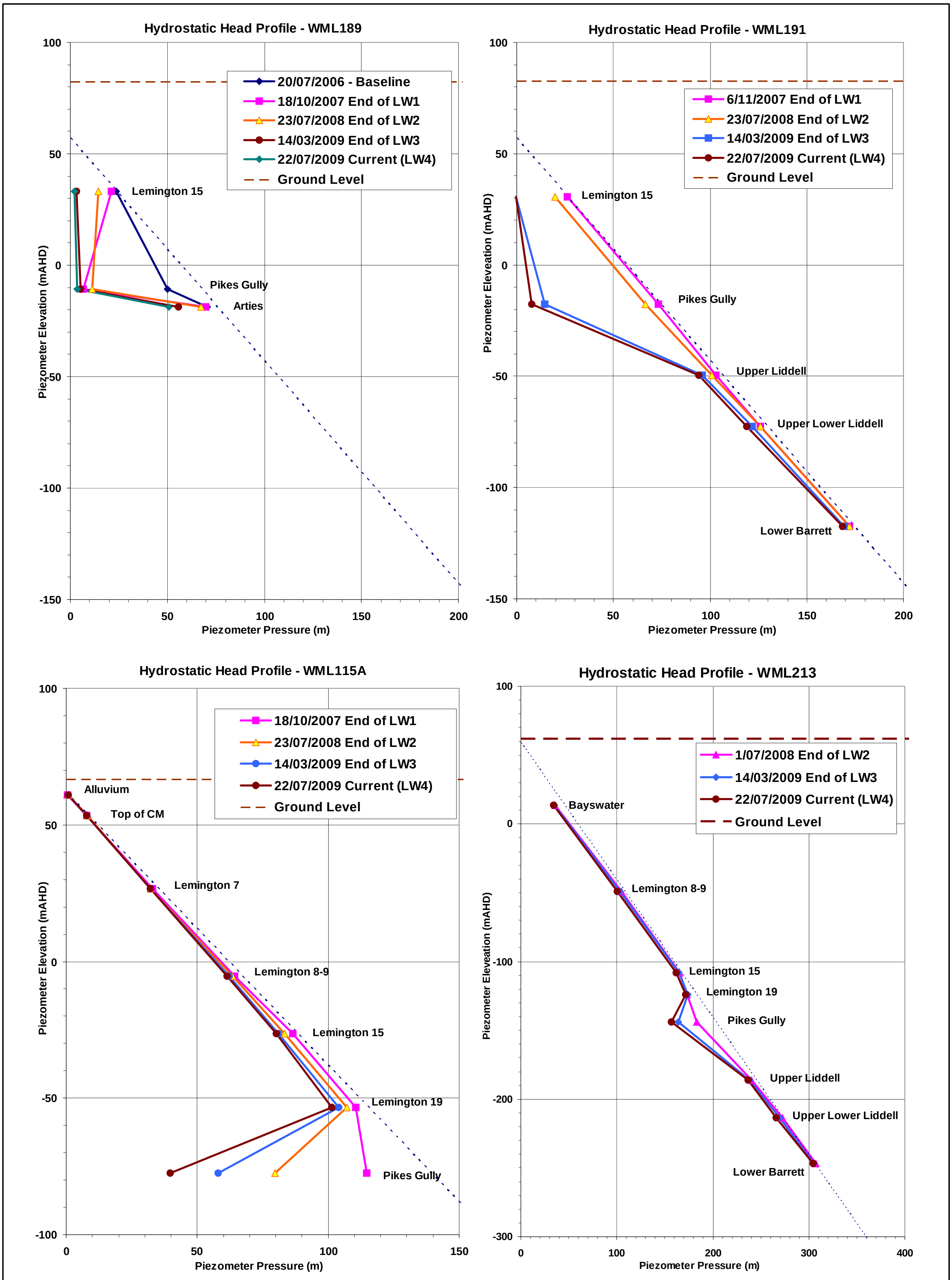
Pikes Gully Potentiometric Surface (mAHD) Apr 2009
Pikes Gully Piezometer
-26.3 GW Level (mAHD) Apr 2009
Extent of dewatered Pikes Gully Seam

Date:	6 October 2009	Scale:	as shown
Initials:	JVDA	Job No:	S55G
Drawing No:	S55G-017	Revision:	0

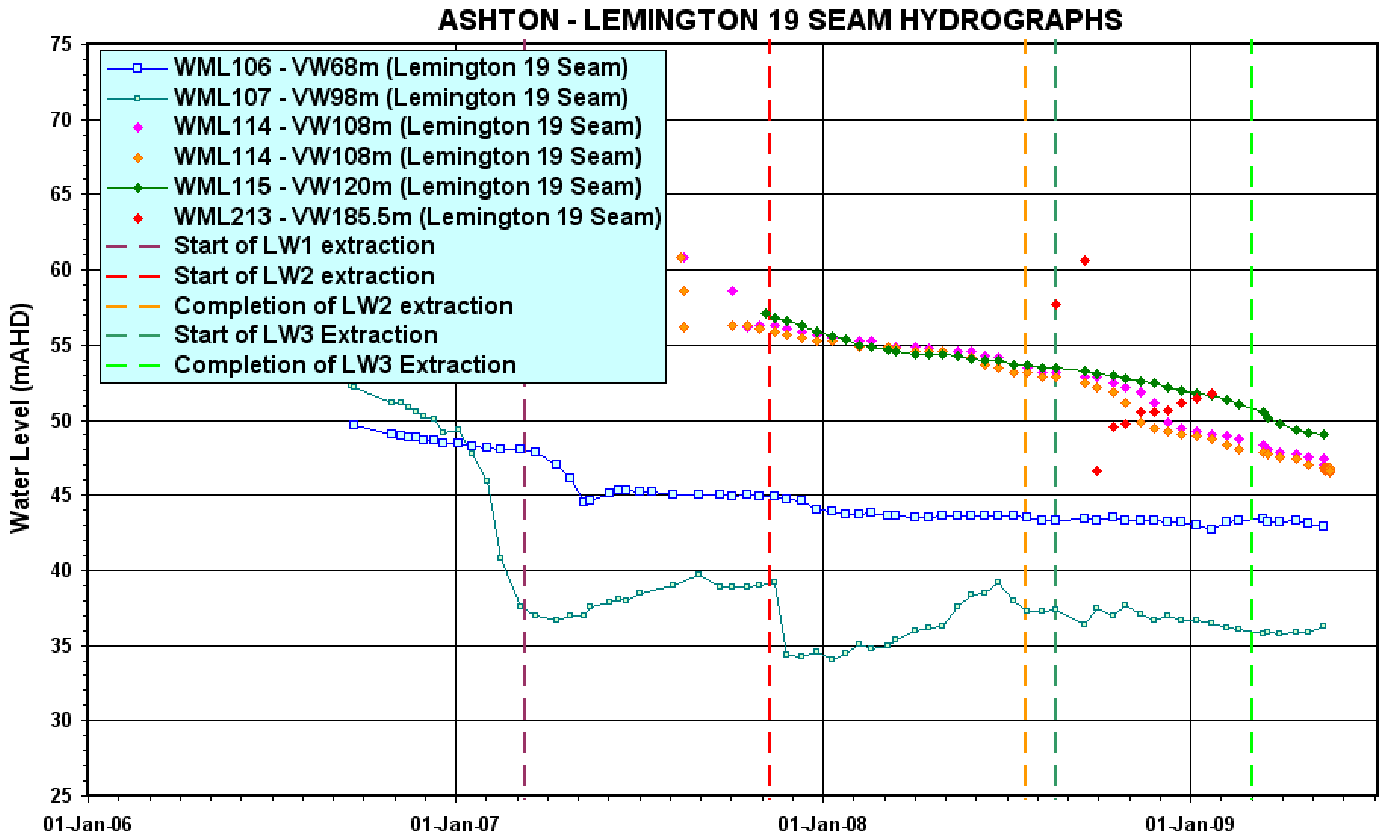
Ashton Coal Operations Ltd

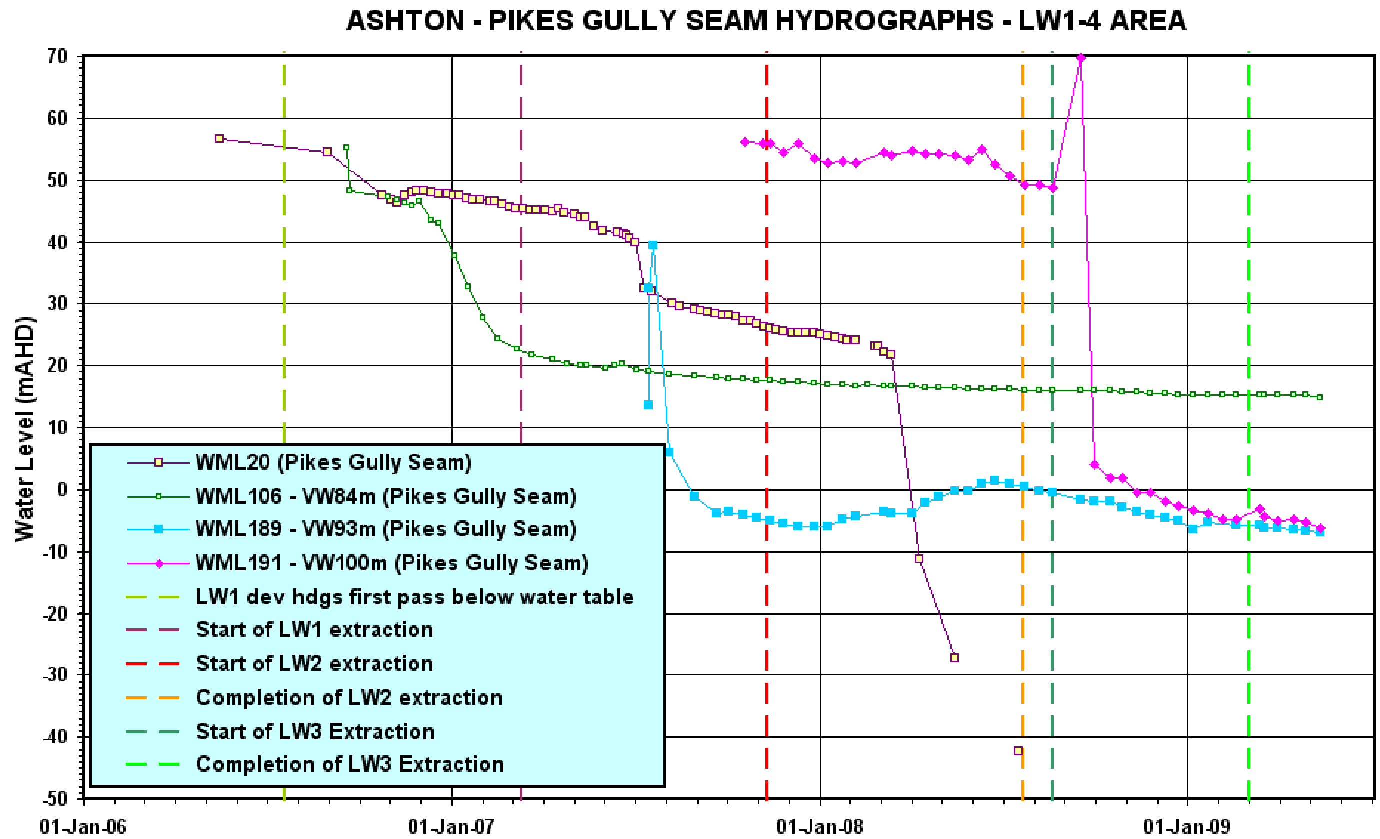
GROUNDWATER LEVELS - PIKES GULLY (mAHD)

Figure 4.12



Date: 10 June 2009	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: JVDA	Job No: S55G	**HYDROSTATIC HEAD PROFILES FOR WML189, WML191, WML115 and WML213**
Drawing No: S55G-016	Rev: 0	
aquaterra		**Figure 4.13**





Date: 04 August 2009	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PZ	Job No: S55G	**HYDROSTATIC HEAD PROFILES For the Lemington 19 Seam and Pikes Gully Seam**
Drawing No: S55G-018	Rev: 0	
aquaterra		**Figure 4.14**

Following each initial drawdown, the groundwater level has risen by several metres, although each rise represents only partial recovery. Similar effects were seen during the mining of LW2 at WML106-68m (Lemington 19 Seam) and WML189-93m (Pikes Gully Seam). It is thought that this 'recovery' process may be caused by either or both of the following two factors (Booth 2009):

1. **Changes in storage.** As overburden strata experience stress relief or tension from longwall mining, there is a tendency for bedding planes and other existing fractures/fissures to dilate. This leads to an increase in effective storage capacity within the rock mass. For unconfined or partially confined rock layers this effect is usually small. However, for highly confined rock layers with very low specific storage, such as those that can occur within the coal measures, this can lead to large apparent drawdowns in observation bores, even when there is relatively little bed separation or fissure dilation.

   This effect does not require any bulk movement of groundwater (or dewatering), and it can occur in areas where there is very little effective change in permeability (fissures do not have to be inter-connected for the change in storage to occur). It simply requires that there is a small change in effective void storage within the rock mass itself. Over time the bedding plane separation will tend to decrease as the rock mass 'settles' and re-compresses after the initial change in stress regime, which leads to the apparent 'recovery' seen in the observation bores. This can happen very quickly, or it can take much longer, particularly where changes in stress have been transferred along strata layers for some distance away from the main subsidence area.

   This effect does not have any significant impact on the wider groundwater environment, or on the modelling of impacts from the mine. It simply needs to be accounted for when interpreting the hydrographs obtained from monitoring bores.

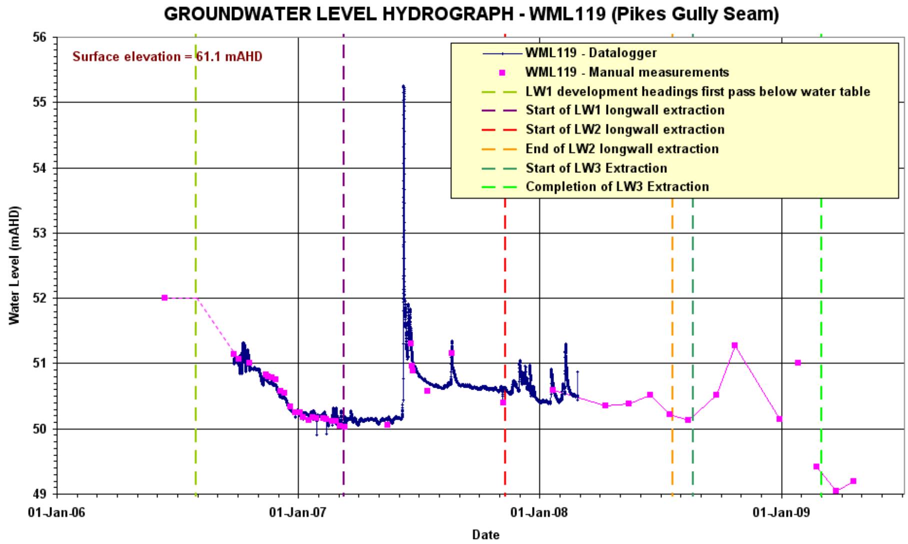
2. **Decreases in bulk permeability**. Where layer bulk permeability is increased and the strata is being de-watered by mining, the initial increase in permeability can start to reduce as the strata layers re-compact and/or become filled by fines that have been mobilised by the caving and groundwater movements. This starts to steepen the hydraulic gradient, leading to rises in groundwater level in observation bores.

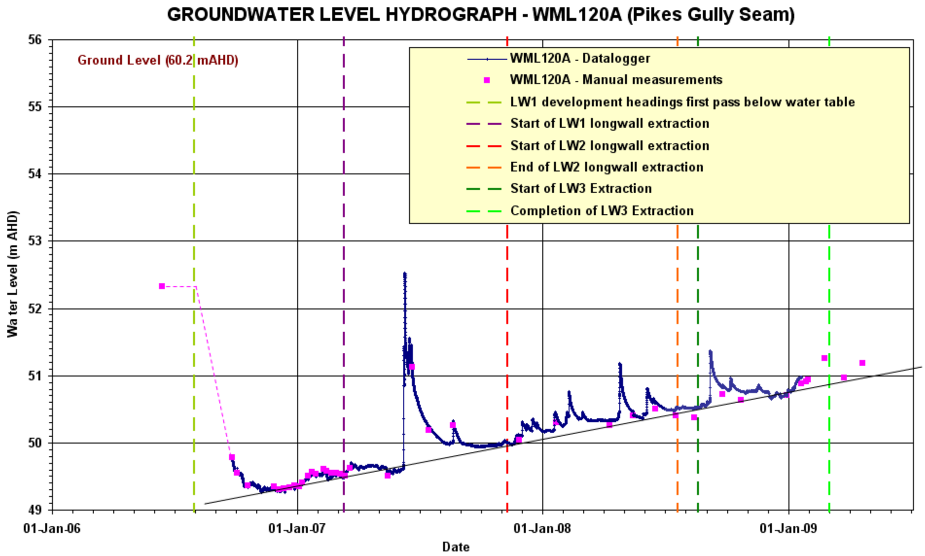
As described in Section 2.2.3, permeability testing before and after the mining of LW3 showed very little change in permeability within the upper parts of the panel overburden in mid panel areas.

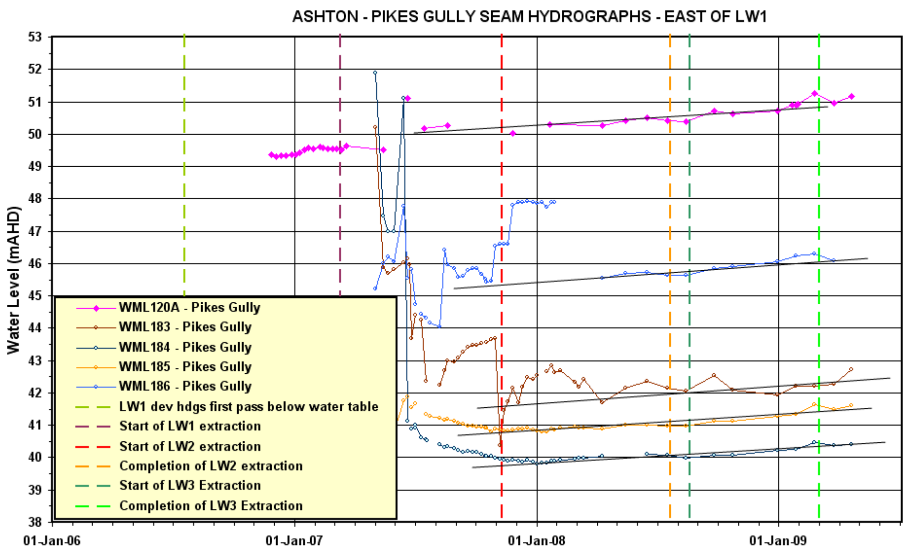
Standpipe piezometers WML120A and WML183 to WML186, located within the Pikes Gully Seam between LW1 and Glennies Creek, have also shown steady recovery post LW1 extraction (Figure 4.15). As well as the steady recovery in groundwater levels in the barrier, the rate of seepage inflows to TG1A has steadily declined through the same period. This response is particularly significant, as the water level in these bores is controlled by the head difference between Glennies Creek alluvium to the east and TG1A (the eastern heading alongside LW1) to the west, and the hydraulic conductivity of the Pikes Gully Seam between the two.

The groundwater level in the Glennies Creek alluvium has remained essentially unchanged during this period (see bore WML120B in Figure 4.16), and the TG1A elevation is fixed, so the head difference between Glennies Creek alluvium and TG1A has remained unchanged during the period of ongoing mining. Hence, by reference to Darcy's Law, the steady decline in seepage rate and progressive rise in water levels in the observation bores within the barrier between LW1 and Glennies Creek can only be explained by a reduction in hydraulic conductivity in the Pikes Gully Seam within this barrier. This may be due to a progressive silting up of the cleat fractures, or possibly a delayed benefit from the TG1A rib-grouting measures that were implemented to reduce inflows during LW1 extraction.

A small drawdown of 0.4m was observed in alluvium monitoring bore WML120B (near Glennies Creek and adjacent to WML120A), between June 2006 and December 2006, coinciding with the advance of TG1A past the bore location (Figure 4.16). No further drawdown occurred in the alluvium bores during subsequent extractions of LW1, LW2 or LW3. All drawdown impacts occurred during the development heading stage of LW1.

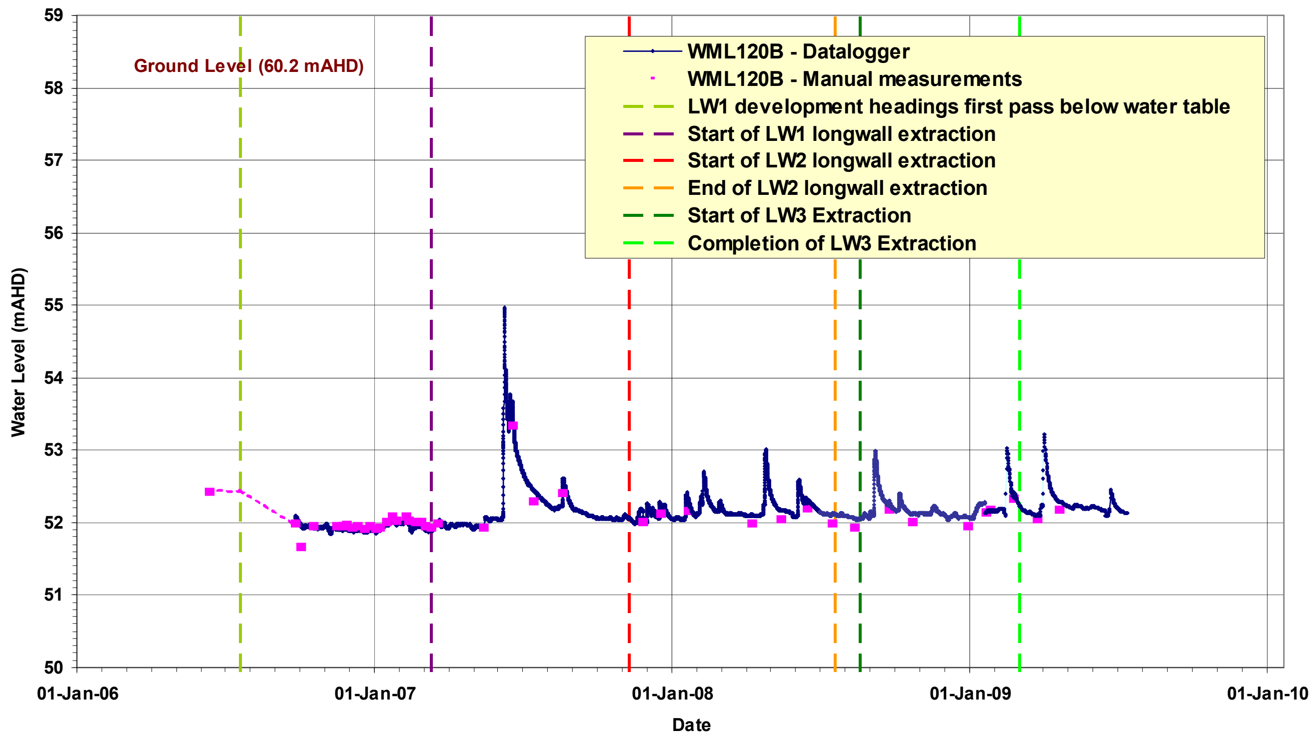






Date:	10 June 2009	Scale:	as indicated	**Ashton Coal Operations Ltd**
Initials:	JVDA	Job No:	S55G	**GROUNDWATER LEVEL HYDROGRAPHS Pikes Gully Seam WML119, WML120A and WML181-186**
Drawing No:	S55G-039	Rev:	A	
aquaterra				**Figure 4.15**

GROUNDWATER LEVEL HYDROGRAPH - WML120B (Glennies Creek Alluvium)



Date: 4 August 2009	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: PZ	Job No: S55G	**GROUNDWATER LEVEL HYDROGRAPH GLENNIES CREEK ALLUVIUM WML120B**
Drawing No: S55G-019	Rev: 0	
aquaterra		**Figure 4.16**

Mine Inflows and Baseflow Impacts

The recorded total groundwater inflow rate to the underground mine at the completion of LW1 was 0.48 ML/d (5.5 L/s), and during extraction of LW3 varied between about 0.2 and 0.6 ML/d, (i.e. between 2 and 7 L/s) with an average of around 0.4 ML/d (Aquaterra, 2009b and 2009c). These are compared against the predictions from the original 2001 EIS in Figure 4.17. This shows that the original EIS tended to over-estimate impacts. A significantly improved calibration has been achieved with the current groundwater model, as discussed in Section 6.

Water quality from the seepages varies, and most has improved over time as water from Glennies Creek and other near surface sources has been drawn into the Pikes Gully seam. Initial EC concentrations ranged between 1,000 and 8,500 µS/cm.

The flow rate of total seepage into TG1A (easternmost heading of LW1) is monitored separately from other inflows, to allow assessment of inflows from the Glennies Creek area. The TG1A seepage inflow rate, as measured from the LW1 Backroad Pipe, reached a peak rate of 3.4 L/s in July 2007, but has since declined to an average rate of 2.4 L/s over the period of LW3 extraction (August 2008 to March 2009). Based on EC comparisons with the in-situ salinities of both the Pikes Gully seam and Glennies Creek alluvium it has been estimated that approximately 70% of the total seepage for the later period is derived from the Glennies Creek alluvium, i.e. an average of 1.6 L/s (equivalent to 0.14 ML/d). Estimated flow rates from the Glennies Creek alluvium through to the mine, based on recorded inflows and this 70% adjustment, are shown in Figure 4.17. This factor may over-estimate the input from the Glennies Creek alluvium at the start of the inflow record, as more of the initial inflow may have been associated with storage release from the Permian strata. EC values, as shown in Figure 4.18, were certainly much higher near the start of the inflow record. However, the higher initial values generally just reflect the fact that fresher, near surface groundwaters will have had to ‘push’ the in-situ deeper groundwaters into the mine before the fresher waters could migrate into the tailgate. It is therefore impossible to quantify how much of the initial higher inflow related to the release of storage around the development heading.

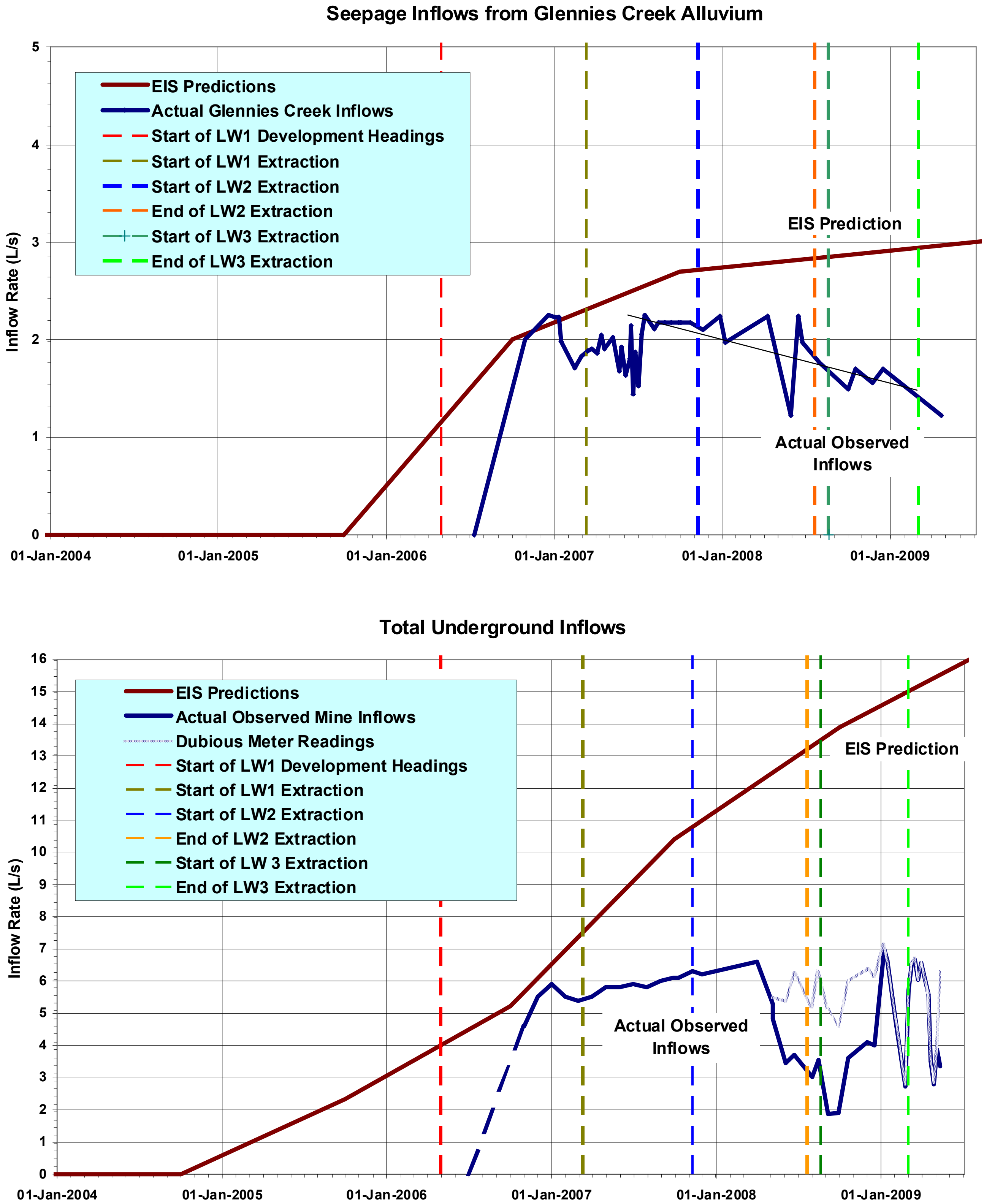
The seepage rate from the Glennies Creek alluvium continues to decline gradually. This reconciles with the apparent reduction in permeability and increase in groundwater heads in the Pikes Gully seam within the barrier, as discussed in the previous section.

4.8 SURFACE WATER FEATURES

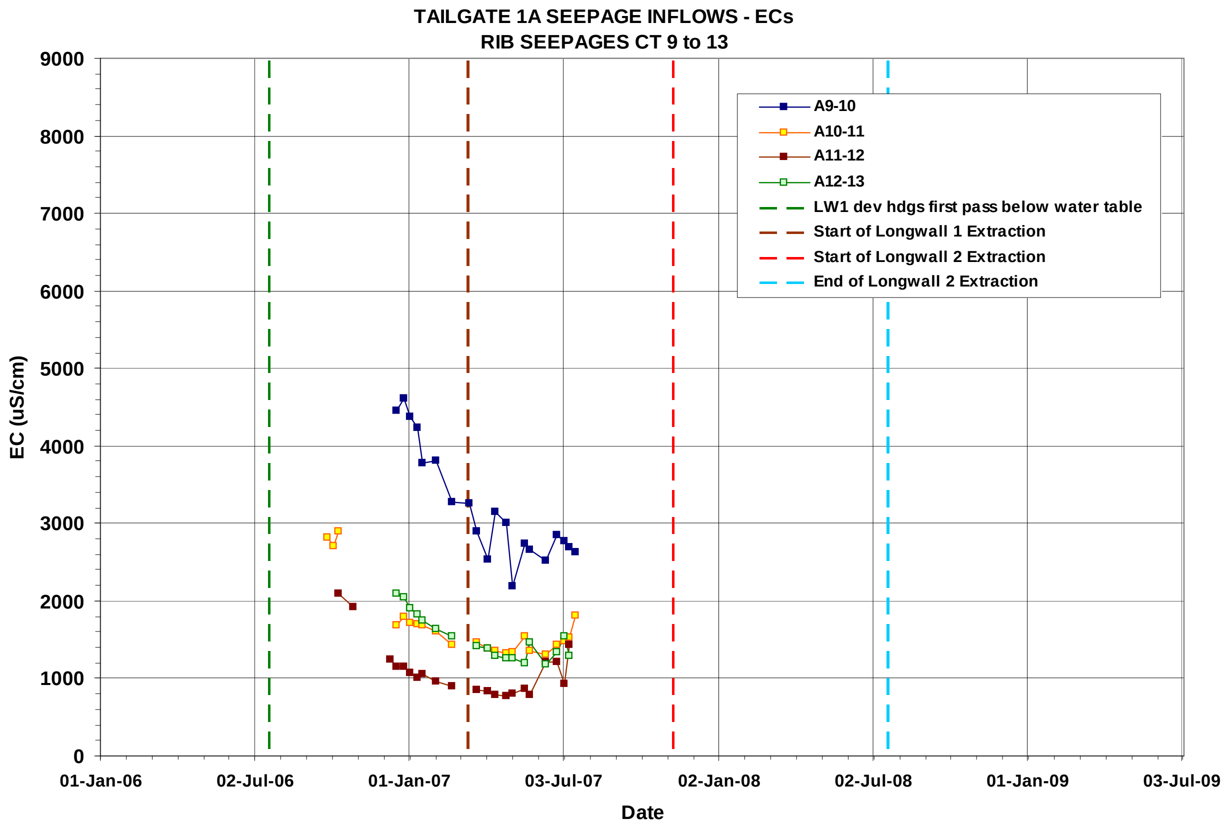
Glennies Creek

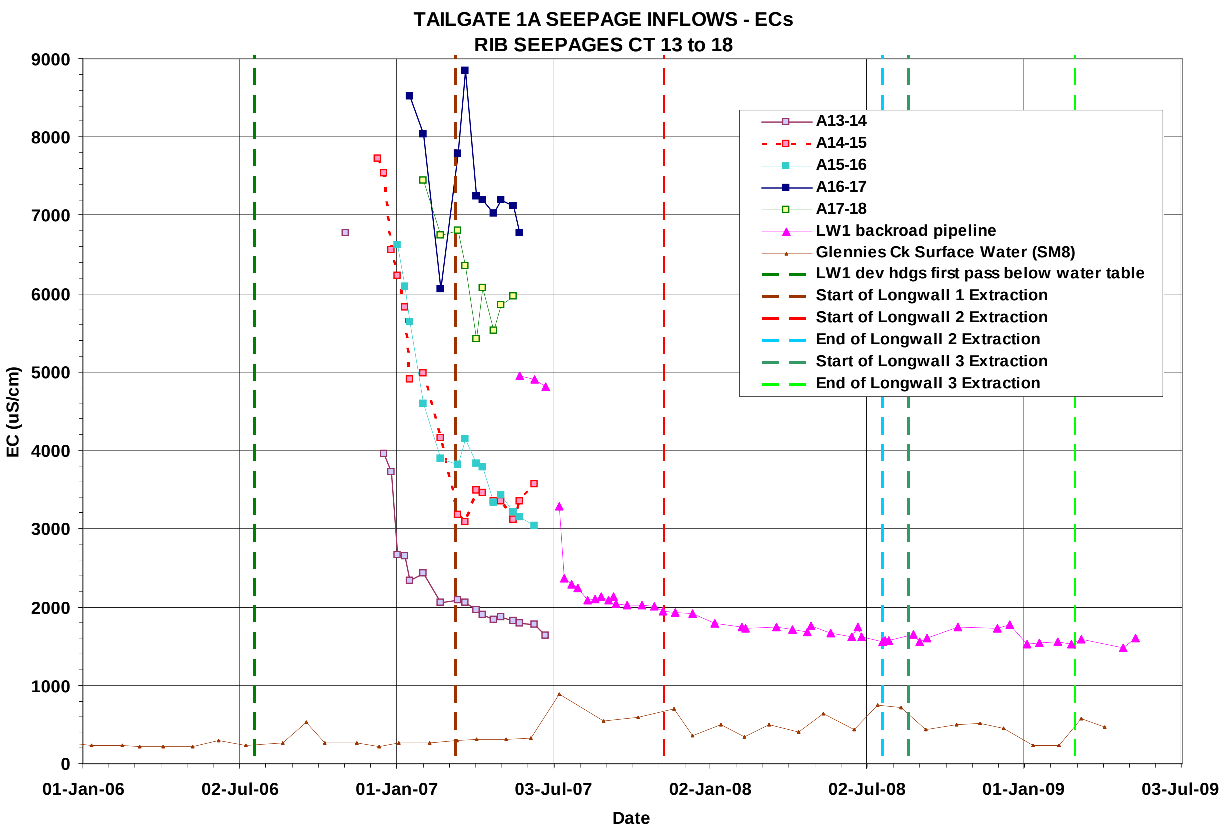
Glennies Creek is a permanent watercourse with a catchment area of several hundred square kilometres. Glennies Creek Dam is located upstream, so the flow is partly regulated by the dam releases. Glennies Creek is located outside the mining area, but approaches to within approximately 150 m of the LW1 goaf edge about halfway along the panel (Figure 4.1). The Pikes Gully seam is believed to outcrop or subcrop below the bed of Glennies Creek over part of the section closest to LW1. The overburden cover depth at the Pikes Gully LW1 goaf edge is approximately 70m at the point closest to Glennies Creek.

The Upper Liddell and Upper Lower Liddell seams are also thought to subcrop beneath the Glennies Creek floodplain (Figure 4.3), but these subcrops are several hundred metres further to the east of the Pikes Gully sub-crop, and also have a much shorter intersection with the creek than the Pikes Gully seam.



Date: 13 July 2009	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: JVDA	Job No: S55G	**ASHTON UNDERGROUND MINE GROUNDWATER INFLOWS vs EIS PREDICTIONS**
Drawing No: S55G-028	Rev: B	
aquaterra		**Figure 4.17**





Date: 23 June 2009	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: JVDA	Job No: S55G	**ASHTON UNDERGROUND MINE LONGWALL 1 TG1-A SEEPAGES ECs**
Drawing No: S55G-029	Rev: A	
aquaterra		**Figure 4.18**

Hunter River

The Hunter River is located to the south of and outside of the proposed mining area. The closest point of the longwall mining is the start corner of LW5, which is approximately 310m from the Hunter River, and 200m from the edge of the Hunter River alluvium. The Pikes Gully overburden depth at this point is approximately 150-155 m.

The southern end of LW1 is situated approximately 515m from Hunter River, and at least 480m from the edge of Hunter River alluvium. The overburden depth at the southern end of LW1 is approximately 50-80m.

Bowmans Creek

Bowmans Creek flows south-westwards across the western parts of the mining area. It comprises a river channel that is incised some 2-5m below the surrounding topography. The channel comprises a series of ponds retained behind cobble bars that are often vegetated. Some rock bars do occur within the channel, but not in the sections of the proposed creek diversions. Connectivity with the alluvium is relatively low due to the presence of the low permeability silt and clay matrix in the alluvial material. There is a significant thickness of Permian interburden between Bowmans Creek and the uppermost target coal seam – the Pikes Gully seam.

4.9 RECHARGE AND DISCHARGE

4.9.1 RECHARGE

As described previously, pre-mining regional groundwater levels indicate that the primary recharge to the Permian coal measures occurs in the sub-crop areas. Within the Ashton underground mine area, there are a series of sub-crops of the Lemington seams within the area of elevated ground between Bowmans Creek and Glennies Creek. The available data indicate that recharge to the Permian coal seam aquifers above the Pikes Gully seam occurs within these elevated sub-crop areas. Layers beneath the Pikes Gully seam also show an upward gradient, indicating recharge is similarly controlled by higher level sub-crops, generally to the east of Glennies Creek. Evidence of recharge to sub-crop areas, particularly where these are subject to natural, slope associated, stress relief, has been described in Section 4.7.2.

The large difference in pre-mining groundwater levels between the deeper Permian and the alluvium/regolith in the valleys shows that vertical connectivity is very limited in the undisturbed condition. Vertical recharge between layers is therefore very much less important than recharge by lateral flow within layers from their subcrop area.

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. It appears that recharge is entering 'zones' of more permeable Permian strata near subcrop, which fill and then slowly drain along the bedding layers to downdip areas.

The main method of recharge to the alluvium is by direct rainfall, surface runoff from less permeable areas, and in some sections of the creeks and rivers where they may periodically be 'losing' water to the groundwater. Rainfall and runoff recharge to the alluvium is generally higher than to the weathered Permian due to the low lying nature of the alluvium (which increases runoff into those areas) and the more permeable nature of the alluvial materials.

4.9.2 DISCHARGE

Natural groundwater discharge for the alluvium occurs primarily through baseflow contributions to creeks and rivers. It is also possible that there is some shallow flow that occurs within the weathered regolith above the Permian rocks, which will discharge to the river/creek alluvium. These are essentially near surface mechanisms that influence the rate of recharge to groundwater and recession curves in the streams following rainfall events, but do not represent an interaction between surface water features and the ground water table.

In the pre-mining condition, the relative groundwater levels indicated that there was potential for upward leakage from the Permian rocks to the alluvium in this area, but this would have been very limited given the low vertical permeability of the rock mass. Localised areas of saline groundwater in the alluvium have resulted from upwards seepage from the Permian. Other large scale, slow regional flow mechanisms would also have been in place within the Permian before any mining started in this area, which would have allowed groundwater to flow out of the area towards regional discharge points. Early monitoring data suggested that flow was towards the southwest. Steady state groundwater modelling, as described in Section 6, indicates that the main discharges from Permian strata now occur through open cut and underground coal mines.

4.10 GROUNDWATER QUALITY

Groundwater quality across the area is variable, both in terms of key field parameters such as salinity and pH, and also in terms of major and minor hydrochemical constituents. Summary results for all of the boreholes that have been sampled are provided in Appendix C.

Comments on groundwater quality are given below. Where relevant, comparison of results has been made to the ANZECC (2000) guideline values for freshwater ecosystem protection.

4.10.1 SALINITY

The groundwater in much of the coal measures aquifer system is saline. Typical salinities range from around 6,000 µS/cm EC (electrical conductivity) to more than 11,000 µS/cm EC within some of the less permeable Permian overburden layers. Some samples taken from shallower horizons, or near subcrop areas, can be much less saline. Samples from the Pikes Gully seam taken near subcrop were recorded at values as low as 1,100 µS/cm EC. This reflects the influence of rainfall recharge on the sub-crops and in some areas of the weathered Permian overburden.

Samples taken from the colluvium on the flanks of the hills were also generally saline, with values recorded between 8,000 and 17,000 µS/cm EC. This reflects the generally impermeable nature of the surface of the colluvium (which limits rainfall recharge), combined with the slow seepage and evaporation of groundwater from underlying Permian strata.

In comparison to the 2001 EIS, which assumed that Bowmans Creek was a high quality resource, with alluvial groundwater flowing downwards into the underlying Permian, it is now known that salinity within both the Glennies Creek and Bowmans Creek alluvium can be relatively high, resulting in poor water quality. In some areas good water quality can be found, particularly in the more permeable alluvium around Glennies Creek, which contains a higher rate of through flow from surface recharge. In these areas the salinity is generally below 2,000 µS/cm EC, and reflects the combined influence of rainfall recharge and a slow influx of more saline water from the underlying Permian and/or from the flanking colluvium. However, higher ECs (up to 6,000 µS/cm) have been recorded in some parts of the alluvium. These generally correspond to areas that are covered with low permeability clays (which reduces rainfall recharge) which have poor recharge and movement of groundwater. This is particularly prevalent within Bowmans Creek and within the margins of the alluvium on the eastern side of Glennies Creek.

4.10.2 PH

Field pH for all samples was near neutral or slightly alkaline, indicating a lack of acid forming conditions in the area. There is some correlation between higher pH and higher salinity within the Glennies Creek alluvial samples, but this is relatively weak. pH in groundwater from Permian strata, including coal seams, shows a fairly wide variation and no discernable relationship between pH and salinity.

4.10.3 DISSOLVED METALS

Comparison of the analysis results for dissolved metals against the ANZECC guideline values for Freshwater Ecosystem Protection (ANZECC, 2000) shows occasional exceedences of the guideline values as follows:

- The guideline value for **cadmium** (0.0002 mg/L) was exceeded at alluvium bores RA18, RA27, T1-A, T2-A, T3-A, T10, WML252, at colluvium bores RA8 and RA16, and in Permian bores T4-P and WML111B.

- The **copper** guideline value (0.0014 mg/L) was exceeded at alluvium bores RA10, T7, T10 and WML248, at colluvium bore RA16, and Permian bore WML110B.
- The **lead** guideline value (0.0034 mg/L) was exceeded in alluvium bore T10 and Permian bore WML110B.
- The **nickel** guideline value (0.001 mg/L) was exceeded at alluvium bore RA10.
- Many bores reported **zinc** concentrations above the guideline value (0.008 mg/L), viz alluvium bores RA14, RA17, RA18, RA27, T2-A, T10, WML248, WML249, and WML250, colluvium bore RA16, and Permian bores T2-P, T3-P and WML110B.

It is clear that these exceedences occur naturally within a range of aquifer levels and types, both within Permian and alluvium groundwaters.

4.10.4 MAJOR ION COMPOSITION

Major ion chemistry can assist with comparing natural waters to identify whether they are derived from the same or different sources, or mixtures of sources. The Piper Trilinear Diagram is useful for this purpose, as it enables each groundwater sample to be graphically plotted at a unique point on the basis of the relative concentrations of the major ions typically found in solution.

Piper Trilinear Diagrams created for the Bowmans Creek investigations (Aquaterra, 2008) and Glennies Creek SEOC investigations (Aquaterra, 2009) are shown in Appendix D. These show a general progression from sodium chloride groundwater within the Permian strata and colluvium through to a calcium bicarbonate type within the more actively recharged alluvium. This reflects a progression from old, mineralised groundwater with low rainfall recharge content in the Permian and colluvium, to more recent, rainfall recharge influenced groundwater within the alluvium that is hydraulically connected to the creeks. This supports the general observations drawn from the salinity readings described previously.

4.11 SURFACE WATER QUALITY

A summary of the surface water quality monitoring results for Bowmans Creek, Glennies Creek and the Hunter River is provided in Table 4.4. Monitoring station locations are shown on Figure 2.2.

Table 4.4: Baseline Surface Water Quality Data Summary

Water Source	Stations	pH	Electrical Conductivity (µS/cm)	
		Range	Mean	Range
Bowmans Creek	SM3, SM4, SM4a, SM5, SM6	7.29 - 8.77	1955	421 – 14400
Glennies Creek	SM7, SM8, SM11	7.20 – 8.45	375	207 - 903
Hunter River	SM9, SM10, SM12, SM13	7.62 – 8.52	613	236 - 1290

This shows that EC levels within the Hunter River and Glennies Creek are generally low. This is associated with the constant surface water supply that is released into those two rivers by the upstream dams. Water in those dams is fed by rainfall runoff and hence has a low TDS/EC.

Bowmans Creek surface flow ECs are illustrated on Figure 4.19, which shows plots of EC vs time for Ashton's surface water gauging stations SM3, SM4/4A, SM5 and SM6, as well as the DWE gauge (Foybrook 210130). Locations of the Ashton monitoring stations and DWE gauges are shown on Figure 2.2. The SM5 site is located close to the DWE gauge.

Site SM6 at the downstream end of Bowmans Creek, just above the confluence with the Hunter River, normally records an EC in the range 800-1200 µS/cm. Ashton sites SM3, SM4, SM4A and SM5 have ECs higher than SM6, generally around 1300-1800 µS/cm, but up to 14,000 µS/cm in the case of SM4.

SM3 is located upstream of New England Highway, and has a salinity essentially the same as that at SM5, which is located half way between the Highway and Hunter River. This suggests that between SM3 and SM5 there is minimal baseflow contribution from either the alluvium or the Permian (both of which have higher salinity from the streamflow)

The much higher salinity reported from the SM4 site, ranging up to 14,000 µS/cm under the low flow conditions prevailing during the 2003-2007 drought is believed to have been influenced by a small local baseflow seepage from the Permian coal measures into a pool in Bowmans Creek at the SM4 site. However, the magnitude of this seepage was only sufficient to cause a localised rise in EC, which was not reflected in higher salinity at the downstream monitoring point (SM5).

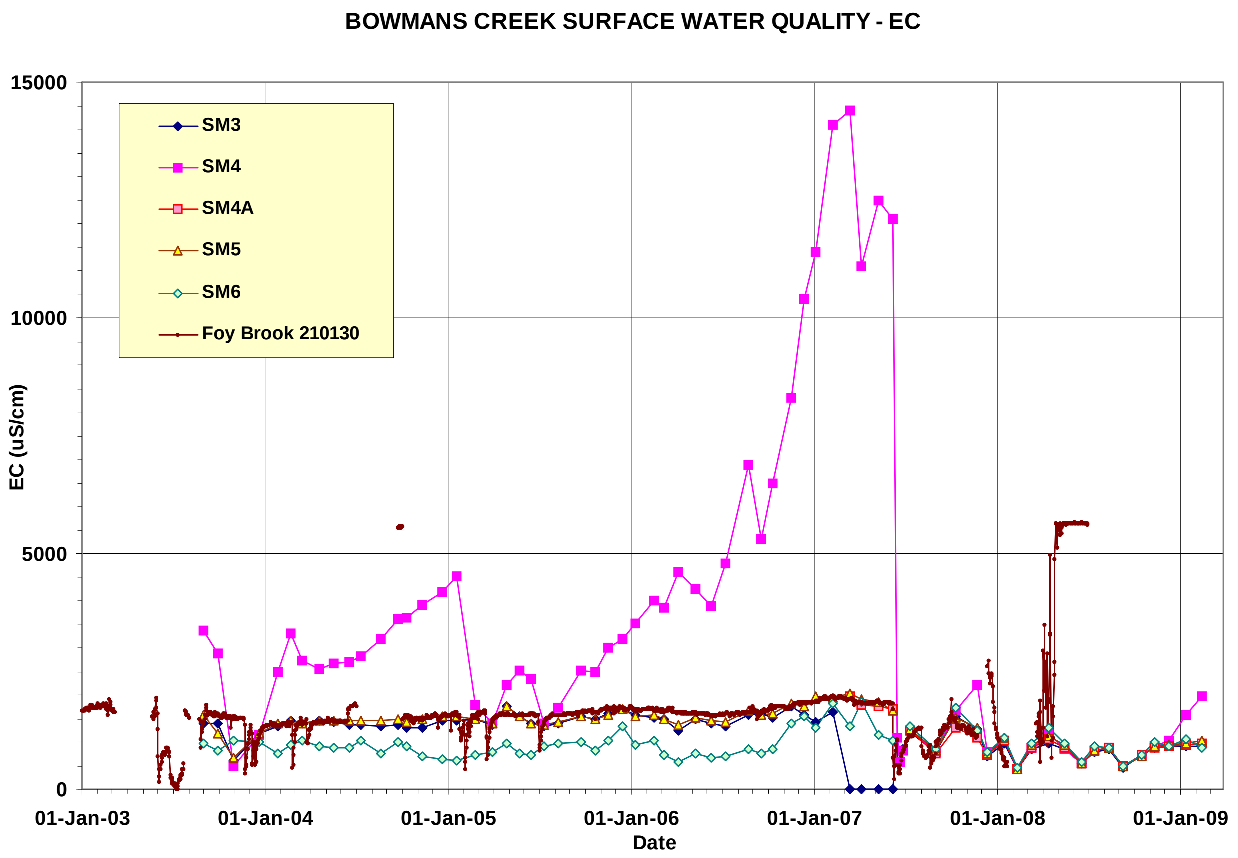
The pattern in EC fluctuations reflects the climatic conditions quite strongly. In Bowmans Creek this results in higher ECs during periods of no or reduced rainfall runoff, and lower ECs at times of high runoff. The higher ECs during times of low runoff are due to the fact that there is some influence from groundwater baseflow discharges, either locally or from higher up the catchment, during very low flow periods. Outside of drought periods, EC levels reduce significantly due to surface runoff and the presence of 'fresher' groundwater within the alluvium. During high flows and floods, the Foy Brook monitoring station on Bowmans Creek shows that EC values reduce dramatically, to around 200 - 300 µS/cm.

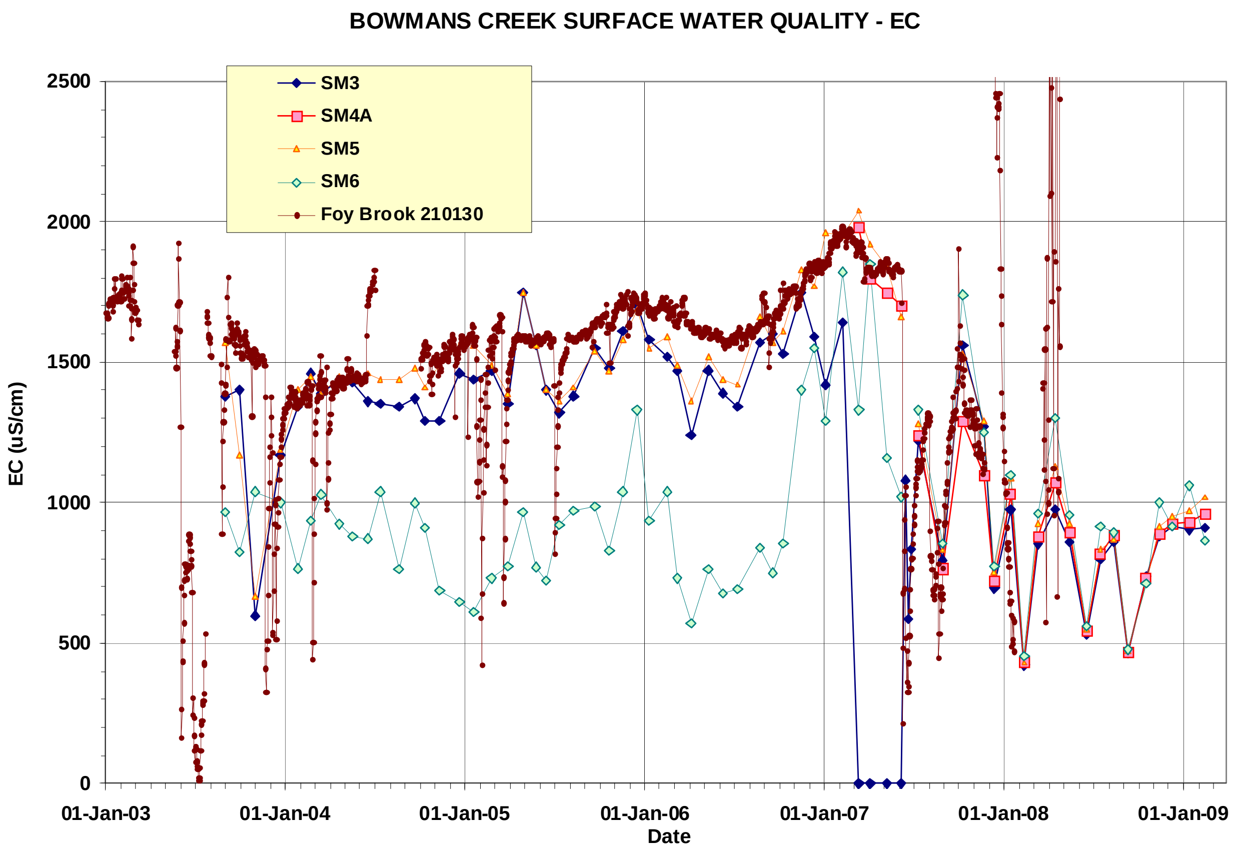
In Glennies Creek, the reverse is true, as it exhibits an increase in salinity during wet periods. It is thought that this is caused by the fact that the 'baseflow' during drier periods is actually due to the release of fresher water from the dam in the upper catchment. During wetter periods there is a proportionally greater contribution from the lower catchment, which is thought to contain some saline soils.

4.12 GROUNDWATER DEPENDANT ECOSYSTEMS

Shallow groundwater in the alluvium is utilised by trees and shrubs along the banks of Bowmans Creek and Glennies Creek. Some of the deeper pools in Bowmans Creek are also maintained throughout drought conditions by groundwater flow from the alluvium (and in some cases the Permian, as shown by the high drought salinities in SM4). Some of these pools form natural drought refuges for aquatic organisms, and are used as drinking sources by terrestrial animals such as cattle and kangaroos during drought conditions (HLA, 2001).

Two stands of River Red Gum have been surveyed alongside the southern reaches of Bowmans Creek near the confluence with the Hunter River. The exact location of these is described within the ecology specialist report.





Date: 22 August 2008	Scale: as indicated	**Ashton Coal Operations Ltd**
Initials: JVDA	Job No: S55G	**BOWMANS CREEK SURFACE WATER MONITORING EC Profiles**
Drawing No: S55G-030	Rev: 0	
aquaterra		**Figure 4.19**

5 MINING PROPOSAL

5.1 MINING SCHEDULE AND INTERACTION WITH OTHER MINES

The approximate mining schedule for the extraction of the longwall panels within the four target seams has already been shown in Figures 1.3 to 1.6. For the purposes of this assessment, a 'worst case' approach has been adopted whereby all of the panels within the 4 seams are 'stacked' directly beneath each other.

In order assess the incremental effects of mining, operational mining impacts and impacts following post mining recovery have been assessed for both the completion of the four seam project, and at a point where mining is terminated at the end of the Upper Liddell seam. At this point, mining will have progressed to the end of the mine plan shown in Figure 1.4.

The longwall panels would be extracted at the same time as continuing operations at the North East Open Cut (NEOC), and the proposed development of the South East Open Cut (SEOC) mine starting in 2010. There will also be ongoing operations at the Ravensworth underground mine (RUM) and the Narama open cut mine to the west. All of these will affect groundwater levels at the same time as the Ashton underground mine.

The NEOC will be complete by the end of 2010, and will then be progressively part backfilled by rejects and washery fines from the Ashton Coal processing plant. A summary of the schedule that has been used for the Ashton underground mine, the SEOC and those parts of the RUM mine that feature in the groundwater model (see Section 6) is provided in Table 5.1. This table includes the mining schedule for all four seams.

Table 5.1: Mine Schedules Used for the Impact Assessment

From	To	Ashton Underground Mine		Ashton SEOC	Ravensworth UG Mine	
		Development Heading	Longwall Panels		Development Heading	Longwall Panels
1/07/2006	31/12/2006	Pikes Gully (PG) LW1			Outside model	Outside Model
1/01/2007	30/06/2007		PG LW1			
1/07/2007	31/12/2007	PG LW2			PG LW3-4	
1/01/2008	31/03/2008	PG LW3	PG LW2		PG LW5	
1/04/2008	31/07/2008					PG LW3
1/08/2008	30/11/2008	PG LW4	PG LW3			PG LW4
1/12/2008	31/03/2009				PG LW6	PG LW5
1/04/2009	31/12/2009	PG LW5 & LW6	PG LW4		PG LW7	PG LW5
1/01/2010	31/12/2010	PG LW7 & LW8	PG LW5 & LW6	Mine Yr 1	PG LW8	PG LW6 & 7
1/01/2011	31/12/2011	Upper Liddell (ULD) LW1&2	PG LW7 & LW8	Mine Yr 2	PG LW9 & 10	PG LW8
1/01/2012	31/12/2012	ULD LW3&4	ULD LW1&2	Mine Yr 3	PG LW11 & 12	PG LW9 & 10
1/01/2013	31/12/2013	ULD LW5&6A	ULD LW3&4	Mine Yr 4	PG LW13 & 14	PG LW11 & 12
1/01/2014	31/12/2014	ULD LW6B,7&8	ULD LW5&6A	Mine Yr 5	PG LW15	PG LW13 & 14
1/01/2015	31/12/2015	Upper Lower Liddell (ULLD) LW1&2	ULD LW6B,7&8	Mine Yr 6	Outside Model	PG LW15
1/01/2016	31/12/2016	ULLD LW3&4	ULLD LW1&2	Mine Yr 7	Outside Model	Outside Model
1/01/2017	31/12/2017	ULLD LW5&6A	ULLD LW3&4	Backfilled plus	ULD LW 2&3	Outside Model

From	To	Ashton Underground Mine		Ashton SEOC	Ravensworth UG Mine	
		Development Heading	Longwall Panels		Development Heading	Longwall Panels
1/01/2018	31/12/2018	ULLD LW6B,7&8	ULLD LW5&6A	void	Middle Liddell (MLD) LW4&5	ULD LW 2&3
1/01/2019	31/12/2019	Lower Barrett (LB) 1&2	ULLD LW6B,7&8		MLD LW6&7A	MLD LW4&5
1/01/2020	31/12/2020	LB3&4	LB1&2		MLD LW7B&8	MLD LW6&7A
1/01/2021	31/12/2021	LB5&6A	LB3&4		MLD LW9&10	MLD LW7B&8
1/01/2022	31/12/2022	LB6B,7&8	LB5&6A		MLD LW11&12	MLD LW9&10
1/01/2023	31/12/2023	LB8	LB6B,7&8		MLD LW13&14	MLD LW11&12
1/01/2024	31/12/2024		LB8		MLD LW15	MLD LW13&14

5.2 THE PROPOSED BOWMANS CREEK DIVERSION

The Bowmans Creek diversion consists of an eastern and a western section. The eastern section diverts the creek to the east of the area affected by subsidence associated with longwall panels 6B and 7B. The western diversion has been put in place to avoid the subsidence associated with longwall panel 7A. The outline route of the proposed diversion is shown in **Figure 5.1**.

In terms of groundwater impacts, the key relevant features of the proposed assessment are as follows:

- The river stage and bed elevations for the 'low flow' part of the diversion effectively join the existing creek levels. The new creek sections lie outside of the significant subsidence zones of the proposed longwall panels.
- Interaction with groundwater will be very restricted due to the placement of a geosynthetic clay liner (GCL) during construction. Although the immediate bed of the creek will be formed of different types of material with varying hydraulic properties, the GCL will lie underneath all of these river bed materials and will form the 'effective bed' in a hydrogeological sense.
- Water will be directed down the new channels using hydraulic structures that will divert all flow up to and including a 1 in 5 year return period event. During larger return period events, some water will enter the old channel and some water will gather within the subsided area of the old channel that crosses longwall 6B.

5.3 WATER MANAGEMENT AND POST MINING CONTROLS

Groundwater inflows during operations will be managed using the existing processing and minewater management system. Predictions of groundwater inflows during mine operation are contained in Sections 6 and 7.

Because multiple seam longwall mining is proposed beneath sections of the old Bowmans Creek channel and floodplain, there is a risk that connective cracking could provide a direct link between surface flood waters and the underground mine. A number of controls are therefore proposed to mitigate the operational risks and environmental impacts that could be caused by surface water entering the old stream channel and interacting with the subsidence troughs that will form above the longwall panels under the floodplain. These include:

- During the early stages of the diversion, while mining in the Pikes Gully seam, it is proposed that environmental flows lower than a 1 in 5 year event will be allowed through to the old channel to help with establishment of the new channel and maintain the environmental benefits of the old channel. Although the risk of connective cracking through the alluvial silts and clays is low during this stage (which relates to the mining of the Pikes Gully seam), there are a number of monitoring and response measures, as discussed in Section 8, that are proposed to detect and account for the operational risks associated with the potential for such connective cracking.
- The presence of large subsidence troughs within the Bowmans Creek floodplain has the potential to cause large volumes of water to 'pond' in the subsidence troughs and drain into the mine workings if flooding occurs within the floodplain. In order to prevent this, the project includes proposals to progressively backfill the subsidence troughs to an invert level that will ensure that they are 'free draining' back to the downstream creek channel or floodplain. This applies to all of the areas of subsidence troughs created above longwall panels 6A, 7A and 7B. For longwall panel 6B, most of the trough will be backfilled to a level that allows free drainage, except for the areas associated with the old creek channel. These areas will become periodically filled with floodwater, but the volume is relatively small (maximum of 178ML).

aquaterra	Date: 4 October 2009	Scale: as shown	Ashton Coal Operations Ltd
	Initials: SRD	Job No: S55G	Proposed Mine Layout for Pikes Gully Seam & Conceptual Bowmans Creek Diversion
	Drawing No: S55G-037c	Revision: C	Figure 5.1