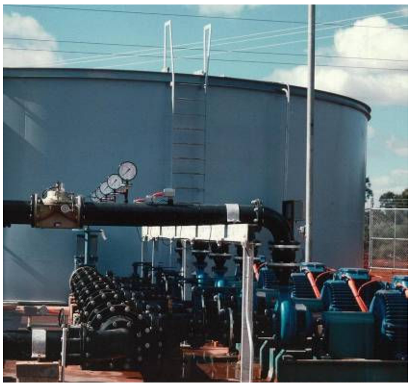
ASHTON UNDERGROUND MINE
LW6A END OF PANEL GROUNDWATER REPORT



RPS Aquaterra

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LW6A END OF PANEL GROUNDWATER REPORT

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Our ref: S55\S55D\D5 End of Longwall 6A\600\032
Date: 16 August 2011

Prepared for:

Ashton Coal Operations Pty Ltd

Document Status

	Issue Date	Purpose of Document
Revision A	25-5-2011	First Draft
Revision B	9-8-2011	Second Draft
Revision C	16-8-2011	Final

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EXECUTIVE SUMMARY

BACKGROUND

All groundwater related impacts from underground mining up to the completion of LW6A were at, or below, the levels predicted in both the EIS and the SMP groundwater assessments for this stage of mining.

The Ashton Coal Project, located 14 km west of Singleton in the Hunter Valley region of NSW, incorporates both open cut and underground mining operations in order to access a series of coal seams within the Permian Foybrook Formation.

The longwall underground mine is located south of the New England Highway. Development for the first longwall panel in the Pikes Gully Seam (LW1) commenced in July 2006. Mining of Longwall Panel 6A (LW6A) was completed on 22 November 2010 (Mining year 7). Mining is currently proceeding in LW7A in the Pikes Gully Seam.

Prior to commencement of mining, baseline studies were initiated as part of the Environmental Impact Statement (EIS) process. These were used to inform the impact assessment in that EIS, and were also used to provide a pre-mining baseline against which actual mining impacts can be compared. The monitoring network has been significantly expanded since that original EIS baseline, and has been used to provide additional information on the impacts of the underground mine development. Both standpipe piezometers and multi-level vibrating wire piezometers have been installed and monitored. The locations of Ashton monitoring piezometers are shown on Figure 2 and a summary of each piezometer is provided in Table 4.1.

In February 2011, 13 new piezometers were installed above/near the LW6A and LW6B areas, consistant with commitments made within the development consent. The piezometers were drilled into the Bowmans Creek Alluvium and Permian overburden to monitor the effects of the Bowmans Creek Diversion and to evaluate the potential issues associated with mining above LW6B.

Groundwater levels and salinity have been routinely monitored throughout the life of the mine. This has been supported by subsidence surveys and the monitoring of both total inflows to the underground workings, and inflows to the longwall panel nearest Glennies Creek.

This End of Panel Review Report for Longwall 6A (LW6A) has been prepared following consideration of all available monitoring data. Actual impacts derived from data analysis have been compared to the impacts predicted in the EIS (HLA Envirosciences, 2001), and in subsequent studies for various Subsidence Management Plan (SMP) Applications - the LW1-4 SMP groundwater report (Dundon and Associates, 2006) and the LW/MW5-9 SMP groundwater report (Aquaterra, 2008b).

The extensive network of piezometers across the Bowmans Creek floodplain has shown no evidence of any dewatering or reduction of groundwater storage in the Bowmasn Creek alluvium aquifer as a result of mining. A hydrogeological cross section produced of the inbye end of LW6A shows that the alluvium remains saturated above the SW corner of LW6, post-full subsidence (Figure 3). Likewise, no mining-related drawdown has been observed in the Hunter River alluvium, and no further drawdown in Glennies Creek alluvium during the mining of LW6A.

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1. INTRODUCTION

The Ashton Coal Project, located 14 km west of Singleton in the Hunter Valley region of NSW (**Figure 1)**, incorporates both open cut and underground mining operations accessing a series of coal seams within the Permian Foybrook Formation.

In 2003, the open cut mine, located north of the New England Highway, commenced operations. The coal is recovered from several seams of varying thickness from two open cuts: the smaller Arties Pit and the larger Barrett Pit.

The underground mine is located south of the New England Highway with the mine accessed from the northern side of the highway via a portal in the Arties pit. At the time of LW6A extraction, the approved mine plan comprised nine longwall/miniwall panels (LW/MW 1-9), which have been approved for mining the Pikes Gully seam under three SMP approvals, viz:

- Longwall panels LW1 to LW4 – SMP approved in April 2007.
- Longwall/miniwall panels LW5 - 6 MW7-8 – SMP approved in July 2009.
- Longwall/Miniwall panel (LW/MW9) – Development Consent modification approved in March 2010 and SMP in June 2010.

(Note: The Bowmans Creek Diversion EA was approved on the 24 December 2011, The mine plan has changed subsequent to this approval, however, for this report the SMP approved layout at the time of mining is used.)

Longwalls 1 to 6A were designed to mine final voids 216m wide, separated by chain pillars of a nominal 25m width rib to rib, with cut-throughs at nominally 100 to 150m centres. The extraction dates for each longwall are shown in **Table 1.1**.

Table 1.1: Longwall start and end extraction dates

Panel	Start date	End date
LW1	12/03/2007	15/10/2008
LW2	10/11/2007	21/07/2008
LW3	20/08/2008	3/03/2009
LW4	2/04/2009	15/10/2009
LW5	4/01/2010	7/06/2010
LW6A	9/07/2010	22/11/2010
LW7A	22/03/2011	In progress

Underground mine development commenced in July 2006. Five End of Panel Review reports assessing impacts from LW1, LW2, LW3, LW4 and LW5 were issued in October 2008 (Aquaterra, 2008a),May 2009 (Aquaterra, 2009a), July 2009 (Aquaterra, 2009b), April 2010 (Aquaterra, 2010a) and September 2010 (Aquaterra, 2010c) respectively. Mining of the sixth longwall panel (LW6A) began on 9 July 2010 and was completed on 22 November 2010. The progress of mining to date is shown on Figure 2. This report presents a review of groundwater impacts at the completion of LW6A.

Mining is now proceeding in LW7A in the Pikes Gully Seam. It is proposed to continue mining the Pikes Gully Seam across the rest of the underground mine area (LW6B, LW7B and LW8), and then to subsequently mine the underlying Upper Liddell, Upper Lower Liddell and Lower Barrett Seams in a multi-seam longwall operation.

Prior to the commencement of mining, baseline studies were commenced as part of the EIS process. These studies were carried out to allow predictions for the EIS, and to provide a baseline against which actual mining impacts could be compared. A number of monitoring piezometers were installed in July 2000 as part of the baseline assessment. The initial baseline monitoring programme, based on those piezometers, included quarterly monitoring of groundwater levels in piezometers and quarterly water quality sampling from piezometers and from the surface flows in the Hunter River, Glennies Creek and Bowmans Creek. The EIS groundwater investigations were reported in Appendix H of the EIS (HLA Envirosciences, 2001).

Further studies were initiated as part of the SMP Application process for LWs 1-4 (Peter Dundon and Associates, 2006) and LW/MW 5-9 (Aquaterra, 2008b). These studies included the installation of piezometers, hydraulic testing, and groundwater quality sampling. The new piezometers were added to the baseline monitoring network. Monitoring frequency was increased to weekly in selected bores, as soon as the LW1 headings first passed below the water table, and then again at the start and end of each longwall panel from LW4 to LW6A. At other times, monthly monitoring has continued as an ongoing routine monitoring program.

Once mining had advanced below the regional groundwater level in the underground mine, monitoring of groundwater inflows into the mine was established as part of the ongoing groundwater monitoring program.

- This End of Panel Review Report has been prepared following consideration of all available monitoring data, including:
- Groundwater inflows to the underground mine;
- Groundwater level records from 77 piezometers at 65 sites (see Figures 2 and 3);
- Field data on water quality from underground seepages, surface water samples and selected bore water samples; and
- Survey data from a transect across the LW3 - LW6A goafs (XL5).

Groundwater seepage into the eastern rib of tailgate heading TG1A of LW1 started as soon as the heading first passed below the water table, and has continued since that time. Analysis confirmed that some of this seepage was derived from the alluvium of the Glennies Creek floodplain, east of LW1. These inflows were monitored closely, initially by means of weirs installed along tailgate TG1A, which is the easternmost heading of the underground mine. Access to TG1A was lost during extraction of LW1. Water inflow to TG1A is now contained and conveyed along TG1A to a collection point at 18CT, where the water is piped through the goaf to the Longwall 1 backroad, which continues to be accessible (**Figure 2**). The flow rate and water quality of discharge from this pipe are monitored separately from other underground inflows to assess seepage losses from Glennies Creek alluvium into the mine.

All other groundwater inflows are collected at a number of sumps, the main sump being Borehole No 2 Sump, which is located to the south of LW6A, close to the lowest point in the mine (**Figure 2**), and another in the North West Mains. The discharge from the LW1 Backroad Pipe also flows to the Borehole No 2 Sump. All discharges are monitored by flow meters. Water pumped into the mine is monitored as well, to enable net groundwater inflows to be determined by water balance calculations.

This report includes a comparison between the actual impacts derived from analysis of the monitoring data, and the impacts predicted in both the EIS studies (HLA, 2001) and the groundwater studies for SMP applications for LW1-4 (Peter Dundon and Associates, 2006) and LW/MW 5-9 (Aquaterra, 2008b), which were undertaken in support of the mine plan that was current at the time of LW6A extraction.

The Bowmans Creek Diversion EA was approved on the 24 December 2011, The mine plan has changed subsequent to this approval, however, for this report the SMP approved layout at the time of mining is used.

A brief explanation for all figures is summarised in **Table 1.2**.

Table 1.2: Figure Explanations

Figure Reference	Explanation
Figure 1: Locality Map	Locality map of Ashton Coal
Figure 2: Ashton Coal, Underground Groundwater Monitoring Network	Monitoring piezometer location plan for the underground area
Figure 3: Groundwater monitoring network near LW6A	Monitoring piezometer location plan for the LW6A area
Figure 4: Survey Cross Lines XL5 (lateral) and CL6- (vertical) Movement	Survey cross lines, vertical movement over the inbye and outbye ends of LW6A (CL6) and horizontal movement above the LW6A goaf (XL5)
Figure 5: Groundwater Level Hydrographs - Pikes Gully Seam WML119 and WML120A	Hydrographs of Pikes Gully piezometers WML119 and WML120A located east of LW1, showing the continuation of trends established following completion of LW1 development headings.
Figure 6: Groundwater Level Hydrographs - Pikes Gully Seam East of LW1	Hydrographs of Pikes Gully Piezometers WML181-186 located east of LW1 showing the continuation of trends established following completion of LW1 development headings.
Figure 7: Groundwater Level Hydrographs - Pikes Gully Seam in Mining Area	Hydrographs of Pikes Gully Piezometers. WML106, WML189, WML191, WML20 and WML21 responded to the mining of LW1-4 development headings. No significant responses were observed during LW5 and LW6A extractions as these piezometers were dry or exhibited only small residual pressures prior to LW5 headings. WML115 and WML213 showed continuation of trends established prior to LW6A.
Figure 8: Hydrostatic Head Profiles - WML189, WML191, WML115 and WML213	Hydrostatic head profiles of vibrating wire piezometers inside the area of current mining (WML189 and WML191) and outside the area of current mining (WML115 and WML213). WML189 and WML191 show depressurisation in the Pikes Gully and overlying Lemington 15 seam, due to LW2 development headings and LW3 extraction, but no further significant response. WML115 and WML213 show steady depressurisation in the Pikes Gully Seam, with minor depressurisation response in the overlying Lemington 19 seam, due to LW extractions.
Figure 9: Groundwater Elevations – Pikes Gully Seam, June November 2010	Potentiometric contours for the Pikes Gully Seam, produced from groundwater levels measured before LW6A extraction (June 2010) and after LW6A extraction (November 2010).
Figure 10: Groundwater Level Hydrographs - Bayswater Seam and Lemington 1-7 seams	Hydrographs of the Bayswater Seam, showing receding groundwater level trends in WML113-40m and WML213-48m due probably to the adjacent Narama mine. This downward trend at WML113-40m appeared to steepen during LW6A extraction, but the piezometer has subsequently showed recovery of pressures, and may be unrelated to LW6A. The Lemington 1-7 seams, showed depressurisation as a result of increased storage (bed separation) effects in WML112, WML113,,WML213 and WML269, during the mining of LW6A.
Figure 11: Groundwater Level Hydrographs - Lemington 8-9 Seams and Lemington 10-12 Seams	Hydrographs of the Lemington 8-9 and 10-12 Seams, some showing stress induced responses (bed separation) to the mining of LW4, LW5 and LW6A
Figure 12: Groundwater Level Hydrographs - Lemington 15 and 19 Seams	Hydrographs of the Lemington 15 and 19 seams, showing temporary stress induced responses in WML111, WML112 RA16 and WML213, and an increased dewatering response in WML269 during mining of LW6A.
Figure 13: Hydrostatic Head Profiles - WML112, WML113, WML114 and WML269	Hydrostatic head profiles of vibrating wire piezometers WML112 and WML113 (outside the area of current mining), and WML114 and WML269 (inside the area of current mining) showing depressurisation effects in the Lemington seams.
Figure 14: Groundwater Level Hydrographs - Coal Measures Overburden	Hydrographs of coal measures overburden, showing head declines in T4-P (coinciding with the advancement of LW5 and LW6A) and T1-P (coinciding with the advancement of LW4), and pressure responses in T2-P, T3-P and WML111B. Stable groundwater pressures in all other piezometers.
Figure 15: Groundwater Level Hydrographs - Paired Coal Measures Overburden and Bowmans Creek Alluvium	Hydrographs of Bowmans Creek paired piezometers. Permian groundwater levels have declined in response to longwall extraction, while alluvium responses have shown no response to mining. T2-P and T3-P showed temporary pressure responses to subsidence impacts above LW4, LW5 and LW6A.

Figure Reference	Explanation
	T4-P responded sharply to LW5 and LW6A. The alluvium bore T4-A, which is located within the LW6A subsidence zone, showed a drop in groundwater level with LW6A subsidence, but when corrected for the changed datum, it showed no reduction in the saturated thickness of the alluvium at this site. T1-P revealed a groundwater drop coinciding with the passage of LW4, but no response to LW5 or LW6A.
Figure 16: Hydrogeological cross section	LW6 East - West hydrogeological cross section, showing Pre and post LW6 groundwater conditions
Figure 17: Groundwater Level Hydrographs – Bowmans Creek and Hunter River Alluvium	Hydrographs of Bowmans Creek Alluvium and Hunter River Alluvium, showing receding groundwater trends as a result of below average rainfall, and a recent rainfall recharge response. No response to mining.
Figure 18: Groundwater Level Hydrographs – Glennies Creek Alluvium	Hydrographs of Glennies Creek alluvium, showing rainfall controlled natural recharge and discharge responses.
Figure 19: Groundwater EC – Glennies Creek Alluvium and Bowmans Creek Alluvium	Groundwater EC trends for the Glennies Creek alluvium and Bowmans Creek alluvium.
Figure 20: Groundwater EC of Tailgate 1A seepages and Pikes Gully	Groundwater EC trends of the Tailgate 1A seepage and Pikes Gully, showing EC decline at LW1 backroad, WML119 and WML120A, following the development headings of LW1, and stable ECs during the extractions of LW2-6A.
Figure 21: Groundwater Inflows Versus EIS Predictions	Total underground inflows and seepage inflows from Glennies Creek alluvium, which both plot below EIS predictions.

2. SITE DESCRIPTION

2.1 LONGWALL 6A

Mining of LW6A was carried out between 9 July 2010 and 22 November 2010. Coal was recovered from the Pikes Gully Seam, which varies in thickness between 2.3m and 2.6m along LW6A. The overburden thickness above the Pikes Gully Seam along LW6A ranges from 163m at the southwestern corner to around 130m at the northeastern corner, as a consequence of the west-south-westerly dip on the coal measures strata.

Mining of LW6A stopped about 185m to the south of the oxbow bend of Bowman's Creek, at the edge of saturated alluvium (**Figure 2**). The south-western corner of LW6A underlies saturated alluvium of the Bowmans Creek floodplain. Unsaturated alluvium occurs over about half of the panel length, while the northern half of the panel lies outside the Bowmans Creek floodplain (**Figure 2**). The Pikes Gully Seam is more than 150m below the Bowmans Creek alluvium where LW6A underlies the floodplain.

The surface topography above LW6A slopes gently to the west-south-west.

2.2 RAINFALL

Monthly rainfall data measured on site from the Ashton weather station is provided in **Appendix A**. During the period of LW6A extraction, the total rainfall was 264mm, which was about 43mm above the long term average for the same time period. The area experienced above average rainfall for the months of July (65mm), October (58.6mm) and November (92.2mm), and below average rainfall for the months of August (24.5mm) and September (24.6mm).

2.3 HYDROGEOLOGY

Two main aquifer systems occur within the Ashton underground mining area:

- A hard rock aquifer system in the Permian coal measures, in which groundwater flows predominantly along cleat fractures in the coal seams; and
- A porous-medium aquifer in unconsolidated alluvial sediments associated with Bowmans Creek, Glennies Creek or the Hunter River.

Groundwater flow in the Permian rocks is dominated by fracture flow, particularly in the coal seams. The hydraulic conductivity (permeability) of the coal seams is generally low, usually two or more orders of magnitude lower than the alluvial sediments, but higher seam permeabilities are found in some areas close to outcrop. The hydraulic conductivity of the coal seams declines gradually with greater depth of cover. Because groundwater flow and storage are dominated by relatively tight, sparse fracturing, storage capacity and storativity within the Permian rocks is very low.

Hydraulic testing indicated that hydraulic conductivities in the order of 1 to 10m/d may apply to parts of the Pikes Gully Seam within the weathered zone very close to outcrop, whereas typical values for the seam in the unweathered zone are in the order of 0.001 to 0.05m/d. The results of hydraulic testing of bores in the zone between Glennies Creek and LW1 have confirmed that the higher permeabilities of the outcrop zone persist to less than 100m from outcrop (Aquaterra, 2008a).

The unconsolidated alluvial sediments comprise clay and silt-bound sands and gravel, with occasional coarser lenses or horizons where sands and gravel have been concentrated. The alluvial aquifer associated with Glennies Creek has generally been found to be moderately or poorly permeable, with hydraulic conductivity values less than 1 m/d, but with occasional coarser horizons with conductivity up to greater than 10m/d. The alluvial aquifer associated with Bowmans Creek is generally characterised by high silt and clay content, and is less permeable than Glennies Creek, with a mean hydraulic conductivity of around 0.5m/d.

2.4 GROUNDWATER QUALITY

The groundwater in the coal measures aquifer system is saline. Typical salinities range up to more than 8,000 µS/cm EC (electrical conductivity), or more than 6,000mg/L TDS (total dissolved solids).

Salinity within the Glennies Creek 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 in areas of higher EC, more 'stagnant' groundwater does exist in the poorly connected alluvial materials that mix with colluvium and fine sediments in the areas away from the creek.

Salinity within the Bowmans Creek alluvium ranges from 772 to 9,920 µS/cm EC, with an average of 2,280 µS/cm EC. Groundwater in the colluvium that exists above LW5 and parts of LW6A is more saline (4,500 to 13,800 µS/cm EC), indicating that it is not strongly connected hydraulically with less saline groundwater in the alluvium associated with Bowmans Creek.

Groundwater in both the Permian and the alluvium is more saline than the typical surface flows in Glennies Creek and Bowmans Creek.

2.5 GROUNDWATER LEVELS

Groundwater levels in the Permian Coal Measures may have been influenced to an extent by historical mining in the area, but it is considered that prior to commencement of mining at Ashton, the groundwater levels in the Permian were higher than in both the alluvium and in the streams. The higher groundwater heads in the Permian mean that under natural conditions, groundwater discharged from the Permian to the alluvium and to the surface streams. This is reflected in relatively higher salinities in the alluvium in some places, and also in the stream flow during periods of low rainfall and runoff.

At multi-level piezometer sites, groundwater levels are commonly higher in the deeper piezometers in the Permian than in the shallow alluvium and the near-surface parts of the Permian sequence, unless affected by mining activity. In some locations, Permian groundwater heads have been historically recorded at above the ground surface (i.e. artesian). Typically, there is an upward hydraulic gradient with depth below surface under natural conditions.

In areas where drawdown impacts from mining have lowered groundwater levels in the Permian, the hydraulic gradients may have been reversed, so that there is potential for water to flow from the alluvium directly into the underlying Permian. However, groundwater studies and the ongoing monitoring have indicated there is generally very poor hydraulic connection between the alluvium and the underlying Permian coal measures, and therefore flow between the two is limited.

3. SUBSIDENCE MONITORING

3.1 SURVEY CROSS-SECTIONS

Survey monitoring has continued consistent with the framework established for LW 1-5, as shown on **Figure 2**.

North-south survey line CL6 was established spanning the inbye and outbye ends of LW6A (**Figure 2**). Surveys were conducted at regular intervals during the early weeks of LW6A extraction to monitor the development of subsidence at the start of the panel. Surveys were again conducted over the final stages of LW6A extraction to monitor the subsidence as the longwall approached the finish line. The survey results from CL6 are plotted on **Figure 4**.

During the extraction of LW6A, the east-west survey line XL5 (which extends from east of LW1 across the mine area) was also resurveyed over the LW4 to LW6A panel areas, prior to and shortly after the LW6A face passed the survey line. This survey line was initially set up to monitor for any horizontal movement affecting the barrier between LW1 and Glennies Creek, but has been re-surveyed at intervals as each new panel is mined.

The plots of horizontal movement versus time on XL5 are shown on **Figure 4**, and indicate that lateral movement above LW6 was around 3mm.

Although the XL5 line has not been re-surveyed across the Glennies Creek barrier since completion of LW3, there is no evidence that mining of LW6A has caused any subsidence or lateral movement to the east of LW1, in the barrier between LW1 and Glennies Creek.

3.2 SURVEY LEVELLING OF PIEZOMETERS POST SUBSIDENCE

Several piezometers within and close to the subsidence zones above LW5 and LW6A were re-surveyed in November 2010 to establish new RLs for the ground surface and piezometer datums. The changed levels post-subsidence are as follows:

Table 3.1: Survey Levelling of Piezometers Post-Subsidence

Piezometer	RL Ground Level (mAHD)		RL Top of Casing (mAHD)		Magnitude of Total Subsidence (m)
	Pre-Subsidence	Post-Subsidence	Pre-Subsidence	Post-Subsidence	
RA8	63.21	62.16	63.98	62.93	1.05
RA12	62.15	60.02	62.92	60.79	2.13
RA16	70.33	69.71	70.91	70.29	0.62
RM02	60.60	60.47	61.05	60.92	0.13
T10	58.69	58.43	59.61		0.26
T4-A	58.58	58.10	59.46		0.48
T4-P	58.52	58.13	59.49		0.39
WML110A	63.71	62.67			1.01
WML110B	63.74	62.70	63.99		1.04
WML110C					
WML111A	58.20	56.91			1.29
WML111B	58.33	56.98	58.77		1.35
WML269	65.53	65.38			0.15
WMLP276	58.65	58.54			0.11

The monitoring data post-subsidence have been corrected for the datum changes caused by subsidence. Hydrographs for the above piezometers presented in this and other reports reflect the datum change resulting from subsidence.

3.3 SUMMARY

The survey cross-sections indicate that maximum subsidence magnitudes of around 1.35m were experienced above LW6A. Re-surveying of piezometer RA12 suggests a datum change of 2.13m, but this is inconsistent with the cross-section data, and may reflect either an error in the initial datum survey for the bore, or a change in the height of casing stick-up above ground level at some time.

The subsidence would have caused a lowering of Bowmans Creek alluvium groundwater levels (in fact a lowering of the base of the alluvium as well) in the parts of the alluvium which directly overlie the south-western corner of LW6A. These effects are discussed in the next section of the report.

Ground movement outside the LW6A goaf footprint, in the area of Bowmans Creek alluvium, was horizontally less than 3mm and vertically less than 10mm.

Note that the northern part of LW6A is overlain by unsaturated Bowmans Creek alluvium.

4. GROUNDWATER LEVELS

4.1 MONITORING NETWORK

An extensive network of monitoring bores has been installed to monitor the effects of underground mining. The locations of all monitoring piezometers for the underground area are shown on **Figure 2,** and the local monitoring piezometers around LW6A are shown on **Figure 3.** A summary of piezometer information presented in **Table 4.1**.

The monitoring network includes bores into all the main hydrogeological units (alluvium, Permian overburden, Pikes Gully Seam and deeper seams), and geographically distributed across the underground mining area. They include:

- Standpipe piezometers between LW1 and Glennies Creek, some screened in the Pikes Gully seam (WML119, WML120A, and WML181 to WML186); two in the Upper Liddell Seam (WML261 and WML262); two in the Arties Seam (WMLP301 and WMLP302); and others in the Glennies Creek alluvium (WML120B and WML129);
- Multi-level vibrating wire piezometer bores:

  WML106 (south of start of LW1);

  WML107 (south of start of LW2);

  WML108 (south of start of LW3);

  WML109 (6m inside start of LW4);

  WML110 (above southern end of LW5);

  WML111 (above southern end of LW6A);

  WML112 (above southern end of LW7A);

  WML113 (just west of southern end of LW7A);

  WML114 (above central part of LW5);

  WML115 (above northern end of LW7B);

  WML144 (east of Glennies Creek);

  WML189 and WML191 (above chain pillars between LW2 and LW3);

  WML213 (south-west corner of UG area, near confluence of Bowmans Ck and Hunter River);

  WMLC248 (installed east of LW1); and

  WML269 (installed in the main gate chain pillar at the southern end of LW5).

- Deep standpipe piezometers *WML20* and *WML21* (screened in the Pikes Gully Seam);
- Shallow standpipe piezometers WML107B to WML115B (located adjacent to vibrating wire piezometers WML107 to WML115, and screened in the uppermost part of the Permian coal measures);
- Shallow standpipe piezometers RM2-3, RM5-6, RM8, T1-P to T4-P, T9, RA16-17 and RA2, screened in the top of the coal measures overburden and regolith above the LW 5-8 area;
- Shallow piezometers WML110C, WML112C, WML113C and WML115C (adjacent to vibrating wire piezometers WML110 to WML115, and screened in alluvium);A network of shallow standpipe piezometers above the LW 5-8 mining area, screened in the Bowmans Creek alluvium (T1-A to T4-A, T5-10, RA10, RA14, RA11, RA15, RM4, RM9, PB2, WML275-276, WML299-300) and colluvium (RA8, RA9, RA12, RA16-17); and

  Shallow standpipe piezometers, RA27 and WML277-280 (south of LW4-LW7A, adjacent to Hunter River, and screened in Hunter River alluvium).

Italics indicates piezometer no longer functional (failed or dry due to subsidence or depressurisation).

In February 2011, the groundwater monitoring network was expanded above/near the LW6A and LW6B areas. They include:

- Three nested monitoring sites, installed in the Bowmans Creek alluvium and the Permian overburden units, to the southwest of LW6A (WMLP326 and WMLP327), above the northern end of LW6B (WMLP311 and WMLP325), and above the southern end of LW6B (WMLP323 and WMLP324). These piezometers were drilled in accordance with the Bowmans Creek EA Section 13 Commitments and were used to evaluate the potential of flows entering the old creek channel and entering the workings via connective cracking above LW6B.
- Standpipe piezometers which target the Bowmans Creek alluvium near the Bowmans Creek Divern areas (WMLP308, WMLP312, WMLP314-316, and WMLP320). These piezometers were installed to verify the hydraulic properties of the Bowmans Creek alluvium and monitor any effects of the Bowmans Creek Diversion.
- Standpipe piezometer WMLP328, which targets the Bowmans Creek Alluvium, and was drilled as a replacement bore for RA20. As this piezometer had either partly collapsed or accumulated sediment.
- As these piezometers were installed following LW6A extraction, data that has been collected from these piezometers has been excluded from this report.

The majority of bores have been installed to monitor regional impacts, and to monitor any impacts on the Glennies Creek or Bowmans Creek alluvium. The monitoring bores located along the bank of the Hunter River, south of the underground mining area, are intended to monitor any impacts on the Hunter River alluvium. Various shallow exploration bores have been installed within the alluvial flats on the eastern side of Glennies Creek. These bores monitor groundwater levels in the Glennies Creek alluvium and/or colluvium.

Table 4.1: Groundwater Monitoring Piezometers

Piezometer	Location	Aquifer	Installation Date
WML189-49	Located in chain pillars between LW1 and LW2	Lem15	-
WML189-93		Arties	
WML189-101		Pikes Gully	
WML191-52		Lem15	-
WML191-100		Pikes Gully	
WML191-132		Upper Liddell	
WML191-155		Upper Lower Lower Liddell	
WML191-200		Lower Barrett	
WML106-32	Located outside southern end of LW1	Lem15	July-06
WML106-68		Lem19	
WML106-84		PG	
WML107A -38	Located outside southern end of LW2	Lem11	May-06
WML107A -69		Lem15	
WML107A -98		Lem19	
WML107B		Lem8-9	Sep-06
WML108A-53	Located outside southern end of LW3	Lem11-12	Apr-06
WML108A-80		Lem15	
WML108B		Lem8-9	
WML109A-36	*Located inside southern end of LW4*	*Lem8-9*	Apr-06

WML109A-65		*Lem11-12*	Apr-06
WML109A-84		*Lem15*	
WML109B		*Lem7*	
WML110A-36	Located inside southern end of LW5	*Lem6*	May-06
WML110A-64		*Lem8-9*	
WML110A-90		*Lem10-12*	
WML110A-110		*Lem15*	
WML110B		*Lem6 OB*	
WML110C		BC Colluvium/Alluvium	
WML111B	Located inside southern end of LW6A	CM Overburden	May-06
*WML111A-24**		*Lem4*	
*WML111A-54**		*Lem7*	
*WML111A-90**		*Lem11-12*	
*WML111A-118**		*Lem15*	
WML269-24*	Located in maingate chain pillars close to LW5 start line	Lem5	-
WML269-56*		Lem7	
WML269-64*		Lem8-9	
WML269-92*		Lem11-12	
WML269-122*		Lem15	
WML269-142*		Lem19	
WML112C	Located near start line of LW7A	BC Alluvium	July-06
WML112B		Bayswater 1-2	
WML112A-43*		Lem2-3	
WML112A-72*		Lem6-7	
WML112A-101*		Lem8	
WML112A-130*		Lem15	
WML113C	Located just west of southern end of LW7A	BC Alluvium	May-06
WML113B-18*		Bayswater 1	
WML113A-40*		Bayswater 2	
WML113A-65*		Lem9	
WML113A-95*		Lem10-12	
WML113A-124*		Lem15	
WML114A-68	*Located south of the Bowmans Creek oxbow inside LW5*	*Lem10-12*	*May-06*
WML114A-88		*Lem15*	
WML114A-108		*Lem19*	
WML114B		*Lem6-9*	
WML115A-40	Located inside northern part of LW7B	Lem7	-
WML115A-72		Lem8-9	
WML115A-93		Lem15	
WML115A-120		Lem19	
WML115A-144		Pikes Gully	
WML115B		CMOB & Lem3-4	-
WML115C		BCA	

WML213-48	Located south west of LW7A	Bayswater	-
WML213-110.5		Lem8-9	
WML213-169.5		Lem15	
WML213-185.5		Lem19	
WML213-205		PG	
WML213-247		Upper Liddell	
WML213-276		Upper Lower Lower Liddell	
WML213-300		Lower Barrett	
RA8	Located within maingate chain pillars of LW5	Colluvium	-
RA9	*Located within the southern part of LW6A*	*Colluvium*	-
RA10	Located above maingate chain pillar of LW7A	BC Alluvium	-
RA11	*Located at southwest corner of LW7A*	*BC Alluvium*	-
RA14	Located above LW7A	BC Alluvium	-
RA15	Located west of LW7A	BC Alluvium	-
RA16	Located within maingate chain pillars of LW5	Colluvium	-
RA18	Located just outside northern end of LW6A	BC Alluvium	-
RM02	Located within maingate chain pillars of LW5	Colluvium/CM	-
RM04	West side of Bowmans Creek, west of mid-point of LW7A	BC Alluvium	-
RM06	Located in oxbow between LW7A and LW7B	BC Alluvium/CM	-
RM07	Located in oxbow between LW6A and LW6B	BC Alluvium/CM	-
RM09	Located in the northern section of Bowmans Creek	BC Alluvium	-
T5	Located above northern part of LW7B	BC Alluvium	-
T6		BC Alluvium	-
T7		BC Alluvium	-
RA30		BC Alluvium	-
WMLP299	Located between LW4 and LW6B, adjacent to proposed northern diversion of Bowmans Creek	BC Alluvium	Jun-10
WMLP308		BC Alluvium	Feb-10
WMLP300	Located west of LW7A, adjacent to proposed southern diversion of Bowmans Creek	BC Alluvium	Jun-10
WMLP314		BC Alluvium	Feb-11
WMLP315		BC Alluvium	Feb-11
WMLP320		BC Alluvium	Feb-11
WMLP320		BC Alluvium	Feb-11
WMLP311	Located between LW4 and LW6B, adjacent to proposed northern diversion of Bowmans Creek	BC Alluvium	Feb-11
WMLP323	Located between LW4 and LW6B, adjacent to proposed northern diversion of Bowmans Creek	BC Alluvium	Feb-11
WMLP324	Located between LW4 and LW6B, adjacent to proposed northern diversion of Bowmans Creek	CM Overburden	Feb-11
WMLP325	Located between LW4 and LW6B, adjacent to proposed northern diversion of Bowmans Creek	CM Overburden	Feb-11
WMLP326	Located southwest of LW6A	BC Alluvium	Feb-11
WMLP327	Located southwest of LW6A	CM Overburden	Feb-11
T8	Located within / near main gate pillars between LW6A and LW7A	*BC Alluvium*	-
T9		*BC Alluvium*	-

T10		BC Alluvium	-
WML275	Located within/close to southern end of LW6A	BC Alluvium	-
WML276		BC Alluvium	-
RA27	Located to the south of LW5-LW7A, along the bank of Hunter River.	HR Alluvium	-
WML277		HR Alluvium	-
WML278		HR Alluvium	-
WML279		HR Alluvium	-
WML280		HR Alluvium	-
T1-A	Located between LW4 and LW6B, adjacent to proposed northern diversion of Bowmans Creek	BC Alluvium	-
T1-P		CM Overburden	-
T2-A	located within LW7A, 200m from LW6A goaf edge, and 440m from LW5 goaf edge	BC Alluvium	-
T2-P		CM Overburden	-
T3-A	located within southern part of LW7A, 65m from LW6A goaf edge	BC Alluvium	-
T3-P		CM Overburden	-
T4-A	located within the southern part of LW6A, about 155m from the start line	BC Alluvium	-
T4-P		CM Overburden	-
RA12	Located mid-panel within LW5	Colluvium	-
WML110C	Located inside southern end of LW5	Colluvium	May-06
WML119	Located in the barrier east of LW1	Pikes Gully	Jun-06
WML120A		Pikes Gully	Jun-06
WML120B		GC Alluvium	Jun-06
WML129		GC Alluvium	-
WML181		Pikes Gully	Mar-07
WML182		Pikes Gully	Mar-07
WML183		Pikes Gully	Mar-07
WML184		Pikes Gully	Mar-07
WML185		Pikes Gully	Mar-07
WML186		Pikes Gully	Mar-07
WML187		Pikes Gully	Mar-07
WMLP301		Arties	Jul-10
WMLP302		Arties	Jul-10
WML261		Upper Liddell	Oct-09
WML262		Upper Liddell	Oct-09

Italics denotes piezometer no longer functional – either dry, or affected by subsidence

The bores have been monitored routinely since underground mining commenced, or earlier in some cases.

A number of the piezometers were equipped with dataloggers set to record water levels/pressures at hourly or 6-hourly intervals in order that any impacts related to subsidence effects can be detected and related precisely to the position of LW6A or other specific site activities occurring at the time. These were:

- WML111A and WML111B
- WML112A
- WML113A
- WML114A and WML114B
- WML269A
- WMLP299 and WMLP300
- RM09, RA16, RA18 and RA27
- T1-P.

Water levels/pressures were manually measured weekly in all other piezometers close to LW6A, during the early and final stages of LW6A extraction. At other times, piezometers have been monitored monthly.

Groundwater quality is monitored in selected bores, which are sampled for field and laboratory analysis in accordance with the monitoring frequencies specified in the GWMP (Groundwater Management Plan).

Water level hydrographs relevant to the LW1 to LW6A extraction are shown on **Figures 5, 6, 7, 9, 11, 12, 14, 15, 17** and **18.**

4.2 OBSERVED EFFECTS

4.2.1 PIKES GULLY SEAM

Composite plots of all Pikes Gully Seam piezometers are presented in **Figure 5** and **Figure 6**. They include the following piezometers (see **Figure 2** for locations):

- Standpipe piezometers to the east of LW1 – WML119, WML120A, WML181, WML182, WML183, WML184 and WML186;
- Multi-level vibrating wire piezometers WML106-84m, WML189-93m, WML191-100m, WML115-144m and WML213-205m; and
- Standpipe piezometers WML20 and WML21, located within the underground mining area.

Groundwater level responses east of LW1

Piezometers east of LW1 (between LW1 and Glennies Creek) have not indicated any response attributable to the mining of LW6A (**Figure 5**). The trends observed in the piezometers are continuations of trends established during the mining of LW1 development headings. Consequently, all the seepage impact occurred during LW1 development, and the actual extraction of LW1 to LW6A has not caused any further drawdown impact.

Groundwater levels in WML120A, and WML184 to WML186 have continued to show steady recovery of approximately 0.7 m/y, so that about 90% of the initial 3.0 m drawdown has now been recovered (**Figure 6**). The almost complete recovery in water levels in these bores, despite the hydraulic gradient between the Glennies Creek area and LW1, suggests a steady reduction in the hydraulic conductivity of the Pikes Gully Seam within the barrier, possibly due to delayed response to the in-seam grouting carried out in 2007. As discussed below in Section 6, the gradual recovery in water levels has been accompanied by a gradual reduction in the rate of underground seepage inflows.

Aside from a number of isolated rainfall recharge events, water levels in WML119, WML181 and WML182 were showing a steady drawdown trend of approximately 0.2 m/y since the mining of

LW1 began (**Figure**s **6**), which was consistent with below average rainfall occurring during that period. Since mid 2009 (mid LW4 extraction), these bores have all showed a reversal of trend, and water levels were rising throughout the mining of LW5 and LW6A, consistent with the increased rainfall recharge during that time.

Groundwater level responses in the underground SMP area

Piezometers which monitor the Pikes Gully Seam in the underground SMP area have all shown responses to underground mining (**Figure 7**).

Piezometers located inside the LW1 - 4 area responded during the mining of LW1 to 4. No significant responses were observed during the subsequent LW5 and LW6A extractions, as these were already dry or exhibit only small residual pressures by this time. The groundwater responses observed to date are summarised as follows:

- WML106-84m and WML20 responded to LW1 development headings, with WML20 responding further to LW2 headings. WML20 became dry during the nearby mining of LW3 maingate headings.
- Vibrating wire piezometer WML191-100m located in the chain pillar between LW2 and LW3 showed dramatic depressurisation in response to the mining of LW3, but showed no response to the earlier passage of the LW2 development headings. WML189-93m, which is also located in the chain pillar to the north of WML191, showed marked drawdown as the LW2 development heading passed and no further responses during the extraction of LW3.
- WML21, located in the northern part of LW5, responded strongly to the advance of the North West Mains and LW4 development headings past this point. The water level had fallen more than 100m below surface and could no longer be monitored before LW6A started. The Pikes Gully seam is 105m below surface at WML20, and is believed to be essentially dry at this location.

Whilst most responses were observed during the mining of LW1 to LW4, continuing depressurisation responses have been observed during the mining of LW5 and LW6A in piezometers outside of the area of current mining, viz:

- WML115-144m is located closer to the North West Mains than to any of the extracted LW panels, and has responded mainly to the NW Mains development. The continued drawdown response observed during the mining of LW5 and LW6A is believed to be due primarily to drainage into the nearby NW Mains and development headings for LW6A-B and LW7A-B. By the end of LW6A, the Pikes Gully Seam was essentially fully dewatered at the WML115 site, with the latest measured water pressure being around -73mAHD.
- WML213 is remote from both LW1 – 6A and the North West Mains. The steady drawdown observed in WML213 during LW3 to LW6 is believed to be due to the combined effect of Ashton's underground operations and mining activities on neighbouring mine sites. The measured pressure in the Pikes Gully seam at the end of LW6A extraction was around 29 mAHD. The seam is at around -140mAHD at the WML213 site.

The drawdown responses discussed above are also shown on hydrostatic head profiles, developed 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 of current longwall extraction (**Figure 8**).

The plots represent a snapshot of groundwater pressures in relation to the elevation for each piezometer prior to LW1 development (baseline levels), and following each of the LW1 to LW6A extractions.

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.

Marked deviations from the hydrostatic line were first noted at WML189 and WML191 due to the depressurisation effects of LW2 development headings and LW3 extractions (**Figure 8**). Note that a significant depressurisation effect in both WML189 and WML191 is observed to have occurred at the Lemington 15 Seam level, approximately 45 m above the Pikes Gully Seam, during the mining from LW3.

Steady deviations from the hydrostatic line have continued in WML213 and WML115 for the reasons outlined above, however unlike the piezometers inside the area of current mining (WML189 and WML191), only limited depressurisation or stress induced effects have been noted in the Lemington 15 and 19 seams, while no significant effects have occurred in the higher Lemington Seams (**Figure 8**).

Potentiometric contours for the Pikes Gully Seam have been produced from groundwater levels measured in June 2010 and November 2010 (**Figure 9**). A comparison of potentiometric surfaces for these periods enables an assessment to be made of the depressurisation impacts before and after LW6A extraction. The potentiometric contours show:

- A tight "cone" of depression around the LW1-7 longwall panels, showing the recent expansion of the cone from the influence of the LW7 main headings which were developed during the LW6A extraction. Note that water levels in the Pikes Gully Seam usually respond to mining of the development headings, with only limited additional drawdown occurring in response to subsequent longwall extraction.
- A secondary depression in the north-western part of the underground mining area. The water level impacts in WML21 and WML115-144m are believed to be due to the nearby North West Mains and development headings up to LW7.
- A drawdown effect at WML213, in the south western part of the Ashton underground mining area (see both **Figure 8** and **Figure 9**), which is almost certainly responding to the combined effects of LW1-7 headings and the North West Mains, and possibly also to dewatering at neighbouring mines to the west and/or south.

Piezometers remote from the Pikes Gully Seam outcrop have not shown any response to the recharge events which has been observed in bores east of LW1.

4.2.2 PERMIAN OVERBURDEN UNITS

Varying drawdown impacts have been observed in piezometers that monitor the overlying Lemington seams, Bayswater seams and shallow coal measures overburden. Hydrographs for these are presented in **Figure**s **10, 11, 12** and **14**. The drawdown effects that have occurred are also apparent on the hydrostatic head profiles (**Figure**s **8** and **13**).

Lemington Seams

Aside from WML115B, WML115-40m and WML112-43m which monitor the shallow Lemington 1 to 7 seams outside the area of current mining, all piezometers have now shown recognisable drawdowns in response to mining of LW1 to LW6A. Generally, drawdowns occur over a relatively broad area in the Pikes Gully seam in response to the development headings, whereas in the overburden, responses are only seen once longwall extraction occurs, and then only within the area of subsided strata or the immediately adjacent areas.

Hence, the magnitude of response in each overburden piezometer has varied according to the proximity of the piezometer to the nearest active or extracted longwall.

Whilst most piezometers had already responded during mining of LW1-5, further pressure responses were detected during the mining of LW6A (**Figure**s **10** to **13**). The horizons that showed recognisable drawdowns in response to LW6A were:

- WML269 – Lem5, Lem7, Lem8-9, Lem10-12, Lem15 and Lem19 (within main gate pillars, south of LW5);
- WML111 – Lem1-3, Lem4 and 7, Lem11-12, Lem15 (southern end of LW6A);
- WML112 – Lem6-7, Lem 8 and Lem15 (above start line of LW7A);
- WML113 – Lem9 (outside southern end of LW7A), and
- WML213 – Lem8-9, Lem15 and Lem19 (SW of LW7A).

VW piezometer responses in WML111A, which monitors the Lemington 4 to 15 seams indicate that there was significant disturbance of the strata around the period of 2-10 August 2010. However, all WML111A vibrating wire piezometers were lost, presumably due to ground movements severing the communication cables. Although, all piezometers were still pressurised at the time they ceased recording.

However, standpipe bore WML111B is screened in the uppermost part of the Permian coal measures, and showed some fluctuation in water level during the LW6A extraction, but with an overall decline in level of 1.1 m, followed by more than full recovery between the 23 September 2010 and January 2011 to a higher water level than at the start of LW6A extraction. Although this piezometer was undermined, there is still more than 8 m of water in the bore above the base of the screen at 18m below ground level, indicating continuing saturation in the upper Permian (**Figures 11** and **12**).

All piezometers in WML269 continued to show positive pressures throughout the extraction of LW6A. This bore is located just inside the goaf edge at the start line of LW5.

Shallow Lemington seams (Lemington 1-12) in the south west part of the underground mining area (WML112, WML113, WML269 and WML213) showed marked drawdown responses to the mining of LW4, LW5 and LW6A (**Figure 10** and **Figure 11**). It is thought that this drawdown represents the lateral expression of bed separation effects above the extracted panels, not dewatering. Similar effects associated with longwall mining elsewhere in the world have been reported in literature (Booth, 2006; Karaman et al, 2001), and are related to subsidence/storage response in the unconnected (tortuous and surface) fracture zones above the longwall panel. This effect does not lead to increased mine inflows, and is a transient pressure response that occurs in upper layers in the vicinity of the subsidence zones above longwall panels in a deeper seam. This effect and its implications for impact predictions are explained in the previous End of Longwall 4 report (Aquaterra, 2010a).

Bayswater seams

Two Bayswater seam piezometers have shown definite drawdown, viz WML113-40m and WML213-48m (**Figure 10**). These are believed to be responding to mining at the adjacent Narama mine, not the Ashton operation, as they have been on a consistent downward trend throughout the period of monitoring until after completion of LW6A extraction, after which both have shown recovery possibly in response to rainfall starting in late 2010. The responses cannot be related to any specific activities on the Ashton site.

The Bayswater Seam standpipe piezometers WML112B and WML113B have not shown any response to Ashton's mining, and remain generally consistent with pre-mining groundwater conditions. Both have shown recharge responses from late 2010, similar to that seen in WML113-40m and WML213-48m.

Top of the Coal Measures

Hydrographs of paired standpipe piezometers which monitor the uppermost water-bearing horizon in the Permian (T1-P, T2-P, T3-P and T4-P) and overlying Bowmans Creek Alluvium (T1-A, T2-A, T3-A and T4-A) are presented on **Figure 14** and **Figure 15**.

At all four sites, differences in water level were found to exist between the alluvium and Permian. At Sites T1 and T4, the Permian groundwater level was initially higher than the alluvium groundwater level, while at sites T2 and T3 the alluvium groundwater level was higher.

The temporary pressure responses observed in WML111B (located centrally within the LW6A goaf) were also seen in T4-P, which monitors the uppermost part of the Permian coal measures near the western edge of the LW6A goaf. Following a small temporary pressure response to LW4, groundwater levels in T4-P responded sharply to the passage of LW5 (which is located 220m away), with a permanent water level drop of around 1m between 20 and 28 January 2010, and then further steady decline throughout the mining of LW5. The most recent responses in T4-P and WML111B are both interpreted to be temporary pressure responses to subsidence above LW6A. Both have displayed partial recovery followed by a second head decline, although some or all of this apparent recovery may be due to the fact that the surface elevation is now up to 1.3m lower than pre-mining.

Much smaller responses were observed in T2-P and T3-P during the mining of LW6A Both showed some fluctuation during LW6A extraction, but no significant pressure reduction overall. This fluctuation pattern has been repeated a number of times previously during LW4 and LW5 extraction, but with a gradual overall downward trend in pressures.

In all cases where there has been a decline in pressure in the upper part of the coal measures (T1-P to T4-P), there has been no water table decline in the alluvium (T1-A to T2-P). Instead, the water table has shown an overall rise through the period of LW6A extraction, attributed to above average rainfall over the extraction period.

Even at T4-P, where the ground surface subsided 0.6 m following LW6A extraction, the groundwater level dropped, but by less than the magnitude of subsidence. Therefore, the alluvium saturated thickness was actually greater at this subsided site at the end of LW6A extraction than before.

4.2.3 ALLUVIUM AND COLLUVIUM

Bowmans Creek Alluvium

LW6A extraction has occurred largely beneath saturated colluvium. A small section, the south-western corner of panel, is overlain by saturated Bowmans Creek alluvium (**Figure 2**). The northern end of the panel approaches close to saturated alluvium, but was terminated at the interpreted edge of saturated alluvium.

Figure 16 shows an east to west cross section near the inbye end of LW6A. Groundwater conditions in the alluvium/colluvium prior to commencement of LW6 are shown. Groundwater levels of piezometers depicted in the cross section have risen since the completion of LW5, due to recent rainfall recharge. It shows that the alluvium remains saturated above the SW corner of LW6A, post-full subsidence.

Piezometers which monitor the alluvium near the southern end of LW6A - T4-A (which lies inside the subsidence trough) and RA10 (which lies outside the subsidence trough), and near the northern end - RA-18 (located just beyond the LW6A finish line), showed no response to LW6A extraction or earlier LWs. Instead they showed an upward trend in response to rainfall recharge, since the start of LW6A, similar to alluvium piezometers more distant from the LW6A subsidence zone, including WML275, RM6 and RM7 (**Figure 17**).

Bore T-10, located above the chain pillar of LW6A and LW7, had previously gone dry in March 2010, which was attributed to below average rainfall rather than mining. However, it once again contains water, suggesting that the alluvium has re-saturated in the area, following recent higher rainfalls.

Piezometers which are screened in the Bowmans Creek Alluvium and the upper most part of the coal measures to the north and west of LW6A (RM06, RM07, RM10, PB1) have shown no responses to LW6A or earlier LWs (**Figure 17**). Instead they reveal rainfall recharge responses.

RA02 has also revealed a small recharge response and reported a saturated thickness of 2.98m above the original base. This piezometer had previously been dry, due to the fact that the piezometer was about 2m shallower than when first drilled, as it had either partly collapsed or accumulated sediment in the base of the bore.

As discussed above, the absence of any mining-related responses in the alluvium across all monitored piezometers, while all piezometers show some depressurisation responses in the Permian, indicates a clear lack of hydraulic connection between the alluvium and underlying Permian coal measures.

Colluvium

RA8 and RA16 which are located above chain pillars between LW5 and LW6A, and screened in colluvium, showed small responses to LW5 and LW6A and have since recovered, indicating a temporary change in storage rather than dewatering. Recent recharge responses are evident in

RA8. Bore RM2 (also located above the chain pillars between LW5 and LW6A) had previously gone dry following subsidence associated with LW6A, but once again contains water, suggesting that the colluvium has re-saturated in that area, following recent rainfall. Following the recharge event, this bore has reported a saturated thickness of 0.84 m, consistent with pre LW6A levels.

Hunter River Alluvium

Piezometers which monitor the Hunter River Alluvium have shown no response to mining. Instead the water table reflects the rainfall controlled natural recharge and discharge patterns (**Figure 17**).

All piezometers have shown a recent upward trend in response to rainfall recharge. Prior to this a gradual recession following a small recharge event in April 2009 was evident across all piezometers. The recession of the water table was associated with a reduction in rainfall recharge over the period, rather than underground mining, and there has been no discernable response to mining (**Appendix A**).

Glennies Creek Alluvium

As reported in the LW1 End of Panel Report (Aquaterra, 2008a), a small drawdown of 0.4m was observed in alluvium monitoring bore WML120B, between June 2006 and December 2006, coinciding with the advance of TG1A past the bore location (**Figure 18**). No further drawdown occurred in the alluvium bores during subsequent extractions of LW1 to LW5, or during LW6A. All drawdown impacts occurred during the development heading stage of LW1.

Water table responses in Glennies Creek alluvium to the east of Glennies Creek are consistent with the rainfall controlled natural recharge and discharge responses also observed in the Hunter River and Bowmans Creek alluvium (**Figure 18**).

4.2.4 RECHARGE

Monthly rainfall measured at the Ashton weather station is provided in **Appendix A**. A total of 264mm of rainfall was recorded during the extraction of LW6A, which was about 43mm above the long term average for the same period.

A number of rainfall recharge events are evident in the hydrographs of piezometers which monitor the Glennies Creek, Bowmans Creek and Hunter River alluvium (**Figure**s **15** and **17-18**). Aside from the most recent upward trend in response to above average during LW6A extraction, groundwater levels have been mostly on a natural recession trend since early 2009. This was a period of below average rainfall, and the recession trend was due to the natural discharge process, and was not a function of mining, as piezometers distant from current mining activities also exhibited the same trends.

It was reported in Aquaterra (2009b) that recharge events were also evident in piezometers which monitor the Pikes Gully Seam close to outcrop (WML119 and WML120A – **Figure 5**). Bores distant from outcrop showed no response to these recharge events (e.g. Pikes Gully Bores WML181-186 - see **Figure** 5; and the deeper Lemington Seam bores - see **Figure 12**).

Similar responses to rainfall were apparent in the paired alluvium and Permian bores T1 - T4. T1 and T2 piezometers (both alluvium and the top of the Permian) show a strong and large response to rainfall recharge, where as the T3 and T4 piezometers were less responsive to rainfall, and showed an attenuated and smaller magnitude recharge response to rainfall events (**Figure 14**). The two southern sites (T3 and T4) are considered to be in an area where the alluvium is more clayey/silty, and therefore is characterised by slower infiltration of rainfall, than the alluvium in the northern part of the Bowmans Creek floodplain, where the T1 and T2 sites are located, and where the alluvium is less clayey/silty and permits more rapid infiltration of rainfall.

4.2.5 POST EXTRACTION RECOVERY IN WATER LEVELS

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 12**), which showed drawdowns during LW1 development headings, and again at the start of LW2 and LW3 extraction. Following each initial drawdown, the groundwater level has risen by several metres, although each rise represents only partial recovery. This pattern was not repeated in this bore after LW4, LW5 or LW6A.

Similar responses were observed during the mining of LW4 to LW6A at piezometers WML110-65m, WML110-90m, WML110-110m, WML111-118m, WML112-130m and WML269-112m (**Figure 12**).

As previously discussed, recent and greater understanding of rock stress impacts from long wall mining suggests that the drawdown and partial recovery seen in the Lemington seams at distance from the longwall panels is at least in part a pressure response associated with changes in storage in the rock mass above the longwall panels, rather than being only a drainage response related to mine dewatering and inflows. The physical movement of coal seams within caved areas can also cause a hydraulic disconnection between coal seams directly above the goaf and the same seams outside of the goaf area. These effects are described in detail in Aquaterra (2010a). It should be noted that the sudden depressurisation noted in piezometers close to LW5 (WML110, WML111 and WML269) was not accompanied by an increase in underground inflow, which supports the evidence of a storage/pressure response, rather than a solely dewatering response.

Standpipe piezometers WML120A and WML183 to WML186, located within the Pikes Gully Seam between LW1 and Glennies Creek, have shown steady recovery post LW1 extraction (**Figure 6**). These responses are significant, as the water levels in these bores are controlled by the head difference between Glennies Creek alluvium to the east and TG1A to the west, and the hydraulic conductivity of the Pikes Gully Seam between the two. As the head difference between Glennies Creek alluvium and TG1A has remained essentially unchanged during the period of ongoing mining, the water level recovery can only have occurred as a result of a progressive reduction in the hydraulic conductivity of the Pikes Gully Seam between the creek alluvium and the mine. This may be due to progressive silting up of the cleat fractures by fines deposited from the through-flowing water, or a delayed benefit from the TG1A rib-grouting measures that were implemented to reduce inflows during LW1 extraction. The reduction in observed inflow rates to TG1A (see Section 6), and the fact that this occurs at the same horizon as the mining, indicates that this is definitely due to changes in permeability within the barrier between the mine and the Glennies Creek floodplain, and not the storage/pressure response discussed above.

5. GROUNDWATER AND SURFACE WATER QUALITY

5.1 MONITORING PROGRAMME

Monitoring of groundwater quality in the Glennies Creek alluvium, Bowmans Creek alluvium, Coal Measures Overburden and Pikes Gully Seam was undertaken prior to the commencement of mining to establish baseline conditions.

Key monitoring piezometers are listed in **Table 5.1**. Further water quality sampling of the bores has taken place periodically since underground mining commenced.

Data from an extensive underground water quality monitoring program was collected throughout the mining of LW1 and has been previously reported by Aquaterra (2008a). Initially, while access was available to the TG1A development heading, samples were collected separately from several locations along the eastern rib of TG1A, and from various other underground locations. As access to TG1A was progressively lost due to the longwall advance, water quality monitoring of seepages from the eastern rib of TG1A was maintained by monitoring the discharge from the LW1 Backroad Pipe (**Figure 2**), as explained earlier in Section 1. This discharge comprises the total of all seepage into TG1A, not just seepage through the eastern rib.

EC monitoring of the LW1 Backroad Pipe discharge from TG1A has continued through the extraction of LW6A.

5.2 MONITORING RESULTS

A summary of all available EC measurements from the monitoring bores is detailed in Table 5.1, together with selected readings from underground seepages and surface water sampled from Glennies Creek and Bowmans Creek.

Graphs of measured EC values from the TG1A seepages and monitoring bores are indicated on **Figures 19** and **20**.

On the basis of the water quality monitoring data, the typical pre-mining salinity (EC) of the water sources was as follows:

- Pikes Gully Seam:
- 6,000 to 6,500 µS/cm (north of LW1 CT13)
- 8,000 to 9,000 µS/cm (south of LW1 CT14),
- Glennies Creek alluvium - 500 to 2,200 µS/cm,
- Bowmans Creek alluvium - 1,000 to 2,000+ µS/cm,
- Colluvium – 4,000 to 13,500 µS/cm,
- Uppermost water zone in coal measures overburden above LW5 to LW6A - 320 to 2,000 µS/cm,
- Glennies Creek surface water - 250 to 350 µS/cm (increases to 800 to 900 µS/cm during high runoff), and
- Bowmans Creek surface water - 600 to 1,000 µS/cm (increases to 2,000+ µS/cm during low flow).

Groundwater EC from piezometers that monitor the Pikes Gully Seam and the Glennies Creek alluvium have shown responses to mining, most of which occurred during the development headings of LW1. Piezometers that monitor the Bowmans Creek alluvium have only responded to climatic variability. The pattern of responses observed to date is summarised below.

Significant decrease in EC was observed during the development headings stage and mining of LW1, viz:

- Pikes Gully piezometers WML120A and WML119 yielded progressively less saline water as a result of induced water flow from the Glennies Creek alluvium towards the mine through the Pikes Gully Seam;

- Glennies Creek piezometers WML120B and WML129 showed smaller reduction in salinity due to elimination of some of the upward leakage of saline groundwater from the underlying Permian coal measures, as the groundwater levels in the Pikes Gully Seam are now lower than in the alluvium in this area as a result of the dewatering associated with the underground mine; and
- LW1 Backroad Pipe (total TG1A seepage) showed steady decline in salinity, and then stabilised at a moderately low salinity level intermediate between alluvium and Permian groundwater salinity levels, as a result of induced water flow from the Glennies Creek alluvium towards the mine through the Pikes Gully Seam.

After some EC decline during the development headings stage of LW1 and mining of LW1-LW2, the EC of monitored alluvium bores, Pikes Gully bores and LW1 Backroad Pipe have generally remained steady during LW3 to LW6A panel extractions.

Salinities in the Bowmans Creek alluvium mostly fluctuate from a minimum of 1,000 to a maximum of 2,000 µS/cm EC, although at some sites, salinities up to 6,000+ µS/cm EC have been recorded. The steady decrease in EC over the LW1 to LW6A mining period is attributed to dilution from rainfall recharge.

The alluvium close to the northern end of LW6A contains relatively fresh groundwater (1140 µS/cm EC as observed at bore RA18), South of RA18, the alluvium is mostly unsaturated, and the colluvium that exists above LW5-LW6A may periodically contain groundwater, but is generally saline (4,500 to 13,800 µS/cm EC, as observed at RA8, RA12, RA16 and RM2).

A dramatic decrease in reported groundwater salinity from 1,820 µS/cm to 86 µS/cm EC was observed in WML119 during the mining of LW3. This bore was found to have been damaged apparently after being hit by a vehicle and has since been repaired. The very low EC was caused by ingress of local rainfall runoff into the bore hole while it was damaged. The measured EC is still relatively low, as the bore has not been purged since being repaired.

Table 5.1: Groundwater and Surface Water EC Values (µS/cm)

Source	Location	Aquifer	Pre- Mining	During LW1 Extraction		During LW2 Extraction		During LW3 Extraction	During LW4 Extraction	During LW5 Extraction	During LW6A Extraction
			Jun - Sep 2006	Jan-2007	May - Jun 2007	Nov 2007 - Feb 2008	Mar - Jun 2008	Aug 2008 - Mar 2009	May - Nov 2009	Jan - Jun 2010	July - Nov 2010
Monitoring Piezometers											
WML 20	Chain Pillar LW3-LW4	Pikes Gully	6240	-	6030	-	-	-	-	-	-
WML 21	North of LW5	Pikes Gully	8140	-	8530	-	-	-	7550	-	7070-7500
WML 119	East of LW1	Pikes Gully	6470	4940	3090	2320	-	86-1820	87-126	139	87 - 155
WML 120A	East of LW1	Pikes Gully	6350	1470	742	828	-	810-1140	919 - 935	1050	600 - 1020
WML 181	East of LW1	Pikes Gully	-	-	4920	-	-	2460-2680	2600-2640	2670	2600
WML 182	East of LW1	Pikes Gully	-	-	4220	8680	-	6510-6950	6390-6760	7900	6760-8400
WML 183	East of LW1	Pikes Gully	-	-	8570	8180	-	5310-5950	5310-5950	5570	5310-5440
WML 184	East of LW1	Pikes Gully	-	-	-	4560	-	4400-5140	4940-5270	5440	1790-5210
WML 185	East of LW1	Pikes Gully	-	-	-	4430	-	2900-2940	2310-2710	2650	2710
WML 186	East of LW1	Pikes Gully	-	-	-	463	-	-	933-1300	1550	1140-1640
WML 120B	East of LW1	Glennies Creek Alluvium	1930	1260	1020	1220	-	915-992	903	639	574-839

Source	Location	Aquifer	Pre- Mining	During LW1 Extraction		During LW2 Extraction		During LW3 Extraction	During LW4 Extraction	During LW5 Extraction	During LW6A Extraction
			Jun - Sep 2006	Jan-2007	May - Jun 2007	Nov 2007 - Feb 2008	Mar - Jun 2008	Aug 2008 - Mar 2009	May - Nov 2009	Jan - Jun 2010	July - Nov 2010
WML 129	East of LW1	Glennies Creek Alluvium	571	522	396	577	-	458-571	490	433	430-570
RA8	Maingate chain pillars of LW5	Bowmans Creek Alluvium							6800-7660	7490	7330
RA10	Located within/ close to MW7	Bowmans Creek Alluvium		1780					1940-2010	1950	1670
RA18	Maingate chain pillars of LW6/7	Bowmans Creek Colluvium							1650-1690	1620	1140
RA16	Located within LW6	Bowmans Creek Colluvium							11500-12300	13800	11500
T1A	Located within northern end of LW5	Bowmans Creek Alluvium		2040					1080-1160	2230	1490
T1P		CMO							2740-8510	1990	2270
Glennies Creek Surface Flow											
SM7	Glennies Creek		235-518	268	319-325	347-643	402-652	235-727	270-774	366-393	
SM8			235-527	267	318-328	339-699	400-644	239-754	264-764	287-408	
SM11			238-542	268	320-329	335-686	410-650	476-768	277-769	293-436	

Source	Location	Aquifer	Pre- Mining	During LW1 Extraction		During LW2 Extraction		During LW3 Extraction	During LW4 Extraction	During LW5 Extraction	During LW6A Extraction
			Jun - Sep 2006	**Jan-2007**	**May - Jun 2007**	**Nov 2007 - Feb 2008**	**Mar - Jun 2008**	**Aug 2008 - Mar 2009**	**May - Nov 2009**	**Jan - Jun 2010**	**July - Nov 2010**
Bowmans Creek Surface Flow											
SM3	Bowmans Creek		598-1750	1420	dry	420-1270	531-976	730-917	930-160	916-992	
SM4			478-4510	11400	12100-12500	428-2220	531-1170	470-1980	954-1790	2240-2680	
Underground Seepages – TG1A											
CT9-10			-	3770	3010	-	-	-	-	-	-
CT10-11			2820	1680	1390	-	-	-	-	-	-
CT11-12			2100	1060	1200	-	-	-	-	-	-
CT12-13			-	1740	1500	-	-	-	-	-	-
CT13-14			5600	2340	1470	-	-	-	-	-	-
CT14-15			-	4910	3050	-	-	-	-	-	-
CT15-16			-	5630	2950	-	-	-	-	-	-
CT16-17			-	8520	7190	-	-	-	-	-	-
CT17-18			-	7450	5960	-	-	-	-	-	-
LW1 BR Pipe	Southern end of LW1		-	-	2830	1726-1950	1620-1760	1554-1772	1579-1666	1580-1718	1770-1938

6. GROUNDWATER INFLOWS

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. Total groundwater inflow rate is determined by a water balance approach, using flow volumes recorded at water meters on the discharge pipelines and the imported water pipeline.

Water is exported from the mine either via a borehole pump direct to the mine water supply circuit, or via pipelines along the gate-roads to the sump in Arties Pit near the mine portal. Prior to May 2010, a sump borehole situated at the south west corner of LW1 (shown on **Figure 2** as the Backroad Sump Borehole) was used, but since that date, a new sump borehole (Sump Bore No 2) located to the south of LW6A, has been used.

The main contributions to groundwater inflow are seepage into TG1A (the eastern gate road of LW1), small inflows to the North West Mains, and broadly distributed goaf seepage into the LW1 to LW6A goafs. Typically, no other persistent areas of seepage are seen.

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 LW6A it varied between about 0.25 and 0.51 ML/d, i.e. between 2.9 and 5.9 L/s with an average of around 3.9 L/s (0.34 ML/d) (**Figure 21**).

The total inflow rate includes all the groundwater seepages into TG1-A, all goaf inflows from LW1 to LW6A, seepages into maingate headings of LW7A and LW7B, all inflows to the North West Mains, and other miscellaneous seepages. The figures are conservative, as they may also include a component of recycled water derived from seepage losses back into the North West Mains from the storage dam in Arties Pit beside the mine portal.

The flow rate of total seepage into TG1A (easternmost heading of LW1) is monitored separately from other inflows, to allow determination of the relative percentages of groundwater from Glennies Creek alluvium and the coal measures aquifers. The TG1A seepage inflow rate as measured from the LW1 Backroad Pipe (**Figure 2**) reached a peak rate of 3.4 L/s in July 2007, but has since declined to an average rate of 1.4 L/s over the period of LW6A extraction (July 2010 to November 2010). Based on EC comparisons with both the Pikes Gully Seam and Glennies Creek alluvium in-situ salinities, it has been estimated that approximately 70% of the total seepage is derived from the Glennies Creek alluvium, i.e. an average of 0.86 L/s (0.07 ML/d). Since completion of LW1, the EC of the discharge from the Backroad Pipe had stabilised at around 1500 µS/cm by the start of LW6A (**Figure 18**).

A further reduction in TG1A seepage inflow rate and a gradual increase in water salinity (from 1570 to 1940 µS/cm) was observed during the extraction of LW6A. Combined, these observations suggest that the seepage rate from the Glennies Creek alluvium has also continued to decline as a percentage of the total seepage rate.

7. COMPARISON WITH EIS AND SMP PREDICTIONS

7.1 EIS PREDICTIONS

The predicted groundwater impacts as a result of the Ashton underground mine included in the EIS were outlined in the report Groundwater Hydrology and Impact Report (HLA Envirosciences, 2001). This was included in full as Appendix H of the EIS. The main parameters of predicted impacts were:

- Total rates of groundwater inflow to the underground mine – Section 5.2 (page 17) and Figure 11 of the EIS Appendix H,
- Total rates of seepage losses from the Glennies Creek, Bowmans Creek and Hunter River alluvial aquifer systems – Section 5.3 (pages 17-18) and Figure 13 of the EIS Appendix H, and
- Groundwater level drawdowns – Section 5.4 (page 18) and Figures 14-16 of the EIS Appendix H.

Each of the above parameters is addressed in turn in the following sections.

The predicted impacts were derived from HLA Envirosciences's groundwater flow model set up for the Ashton project investigations. The model description and modelling results are presented in Appendix F of the EIS (HLA Envirosciences, 2001).

The mine plan utilised as the basis for the groundwater simulation modelling in the EIS involved the commencement of underground development in Year 2, and the commencement of longwall extraction in Year 4. In the HLA model, drain cells were enabled across the full extent of LW1 and the North West Mains from the start of Mining Year 4.

Underground development actually commenced in December 2005 and first intersected the water table in July 2006. LW1 commenced on 19 March 2007. Based on these dates, it is considered that the year July 2007 - June 2008 is equivalent to Mining Year 5 in the EIS simulation modelling. This has been assumed for comparative purposes. On this basis, the extraction of LW6A occurred mostly during Mining Year 7 as modelled in the EIS.

7.1.1 GROUNDWATER INFLOW TO UNDERGROUND MINE

The measured/calculated total groundwater inflow rates to the underground mine since the commencement of monitoring are plotted on **Figure 21**, for comparison with the inflow rates predicted in the EIS for the equivalent stage of the mining operation.

The EIS predicted a progressively increasing total inflow rate, from zero in Years 1 and 2, increasing to 0.20 ML/d in Year 3, 0.45 ML/d in Year 4, 0.91 ML/d in Year 5, 1.2 ML/d (14 L/s) in Year 6, and 1.5 ML/d (17 L/s) in Year 7. Thereafter inflow rates to the underground mine were predicted to increase to a maximum of 1.7 ML/d (20 L/s) in Year 12. The predicted inflow rates for Years 1 to 8 as reported in the EIS are plotted on **Figure 21** in this report.

Figure 21 shows that the actual inflow rate during the extraction of LW6A was in the range 2.9 to 5.9 L/s (0.25 to 0.51 ML/d), well below the rate predicted for this stage of mining in the EIS (i.e. 18 L/s or 1.55 ML/d).

The total inflow rate includes all the groundwater seepages into TG1-A, all goaf inflows from LW1 to LW6A, seepages into maingate headings of LW7A and LW7B, all inflows to the North West Mains, and other miscellaneous seepages. The figures are conservative, as they may also include some recycled water, derived from seepage losses back into the North West Mains from the sump in Arties Pit beside the mine portal.

7.1.2 SEEPAGE LOSSES FROM ALLUVIUM

Seepage from Glennies Creek Alluvium

The total seepage inflows to the eastern gateroad of LW1 (TG1A) have been closely monitored separately from other mine inflows since the first appearance of seepage as the LW1 development headings passed below the water table. Monitoring has continued to the present time through the installation of the collection system and LW1 Backroad Pipeline described in Section 1. In addition to flow rates, the EC and pH are monitored.

The seepage into TG1-A includes groundwater from storage within the Pikes Gully Seam, as well as water seeping through the barrier from the Glennies Creek alluvium, and possibly small flows from the roof and floor sediments. Through an assessment of the water quality of TG1-A seepages in comparison to the in-situ groundwater quality of the Pikes Gully Seam and the Glennies Creek alluvium respectively, it was calculated that approximately 70% of the total TG1-A seepage is derived from Glennies Creek alluvium. The balance comes from storage in the Pikes Gully Seam and other Permian strata. The derivation of this proportion was detailed in Peter Dundon and Associates (2007).

The actual seepage from Glennies Creek alluvium into the underground workings, calculated using the above analysis, is plotted on **Figure 21** together with the alluvium seepage inflow rates predicted in the EIS. Furthermore, the actual seepage inflow rates during LW6A extraction (approximately 0.66 - 1.2 L/s) are well below the EIS predictions (3.2 L/s) for this stage of the mining operation.

No increase in measured seepage rate was observed during the extraction of LW6A. Rather, the plot of seepage inflows is showing a downward trend with time, which is consistent with the gradual recovery in water levels at WML120A and other bores described in **Section 4.2.5**.

Seepage from Bowmans Creek Alluvium

Although it was reported in the EIS that seepage from the Bowmans Creek alluvium was predicted to occur during this stage of mining (2.5 L/s), and LW6A did undermine saturated alluvium in its southwestern corner (**Figure 2**), there has nevertheless been no observed mining-induced reduction in alluvium saturated thickness, and hence no seepage loss from the alluvium, as a result of mining.

The extraction of LW6A has caused part of the alluvium aquifer to subside (ie the sections situated above the southwestern corner of LW6A. Hence there is likely to be fracturing both extending up from the goaf and near surface at the base of the alluvium. There is no visible sign of fracturing at the ground surface in the alluvium area within the subsidence trough.

Despite the likely presence of subsidence induced fracturing in the Permian beneath the alluvium in the southwestern corner, there has been no loss of groundwater storage in the alluvium in that area. The multi-level vibrating wire piezometer bore WML111A, which is located mid-panel just outside the area of saturated alluvium, was affected by the subsidence, and the cables to all piezometers in that bore were severed shortly after subsidence occurred. However, the shallow standpipe bore WML111B, which is screened at 11-18m depth in Permian Coal Measures, including one of the thin upper Lemington Seams. Despite the subsidence, this bore has continued to report a water level above the screen, indicating that this part of the sequence remains saturated, and therefore any fracturing at that site is not providing a direct hydraulic connection between the goaf and the base of the alluvium.

Accordingly, the impact on Bowmans Creek alluvium is less than predicted in the EIS studies.

7.1.3 GROUNDWATER LEVEL DRAWDOWNS

Predicted drawdown impacts on the Permian coal measures were only presented in the EIS for the completion of mining, not for intermediate stages of mine life. Hence it is not possible to compare actual impacts with the predicted impacts for the present stage of mining.

However, hydrographs of predicted drawdown in the Glennies Creek alluvium were presented as Figure 18 in the EIS (HLA Envirosciences, 2001). Two prediction hydrographs are shown, one denoted “North Bore” coinciding with registered bore GW064515 in Camberwell village (**Figure 2**), and another denoted “South Bore” at a location “within the alluvium overlying the sub-crop of the Upper Liddell Seam adjacent to the underground mine”. Locations of the North Bore and South Bore are shown on Figure E1 of the Groundwater Assessment Report for the EIS (HLA Envirosciences, 2001).

Ashton has a network of monitoring bores located in the general vicinity of these two notional sites:

- G3B in Camberwell village (i.e. near "North Bore"); and
- WML120B and WML129 (alluvium bores on western side of Glennies Creek) and exploration bores AP242, WML249, WML239 and WML240 (on the eastern side of Glennies Creek) adjacent to the underground mine (i.e. near "South Bore"). The location of HLA's "South Bore" shown on their Figure E1 (HLA Envirosciences, 2001) it is situated very close to bores WML120B, AP242 and WML249 (see **Figure 2**).

Bore G3B has been dry through most of the period of underground mining, and has not been able to identify any impact. Monitoring of bore WML120B commenced before underground seepage started. It initially showed a drawdown of approximately 0.6m, and by the completion of LW6A extraction, the groundwater level at WML120B had recovered slightly to be only 0.4m below the pre-LW1 level. The EIS had predicted a 1.3m drawdown in Year 3, increasing to 2.2 m drawdown by Year 7, coinciding with the present state of underground mining. Hence actual drawdown is very much less than predicted in the EIS.

The hydrographs of bores on the eastern side of Glennies Creek (**Figure 18**) indicate no suggestion that any mine-related drawdown has occurred at all in the alluvium east of Glennies Creek.

Likewise, hydrographs of bores in Bowmans Creek alluvium and Hunter River alluvium (**Figure**s **17** and **18**) reveal no evidence of any drawdown impact as a result of underground mining. In fact, some piezometers that were previously dry (RA02, RM02 and T-10), became re-saturated during the mining of LW6A, and have retained saturation following LW6A.

The total impact has continued to be well below the EIS prediction.

7.2 SMP PREDICTIONS

The Groundwater Assessment Report (Aquaterra, 2008b) prepared in support of the SMP Application for LW/MW5-9 stated that inflow rates and seepage rates would be 40% lower than those predicted in the EIS until January 2011 during the Mining of MW8-9 when the predicted mine inflow rates are similar to the EIS predictions, as described in Section 7.1.

7.2.1 TOTAL GROUNDWATER INFLOWS COMPARED WITH SMP PREDICTIONS

As indicated in Section 7.1.1, actual inflows (2.9 – 5.9 L/s, average 3.9 L/s) during the extraction of LW6A have been well below the SMP prediction (14 L/s) for this stage of mining.

The LW1-4 SMP Groundwater Assessment report (Peter Dundon and Associates, 2006) as a precautionary measure, also calculated possible increased inflows to the underground workings due to increased recharge from rainfall following surface cracking over the longwall goaf areas. Several major and minor rainfall events occurred during the extraction of LW1 to LW6A, but these were not accompanied by a measurable increase in goaf inflow rates. Hence, the subsidence cracking has not led to an increase in recharge rate.

7.2.2 SEEPAGE FROM GLENNIES CREEK, BOWMANS CREEK AND HUNTER RIVER ALLUVIAL AQUIFERS COMPARED WITH SMP PREDICTIONS

Glennies Creek Alluvium

Actual Glennies Creek alluvium seepage inflow rates during LW6A extraction (approximately 0.66 – 1.2 L/s) are well below the SMP prediction of 2.5 L/s for this stage of the mining operation.

No increase in measured seepage rate was observed during the extraction of LW6A. Rather, the plot of seepage inflows is indicating a downward trend, consistent with the gradual recovery in water levels at WML120A and other bores described in Section 4.2.5.

The actual seepage rates have therefore continued to be less than the maximum rates contained in the both LW1-4 and LW/MW 5-9 SMP predictions (Peter Dundon and Associates, 2006; Aquaterra, 2008b).

Although it was reported in Peter Dundon and Associates (2006) that seepage was expected to occur during the development of LW1, the rate of seepage was not expected to increase during the mining of subsequent panels. Simple calculations based on Darcy's Law predicted that the seepage rate during LW1 extraction would be around 2 L/s, with no increase during extraction of LW2 to LW6A or subsequent longwall panels.

The End of Longwall 1 Report (Aquaterra, 2008a) concluded that there was no evidence of any increase in permeability in the barrier between LW1 and Glennies Creek as a result of subsidence impacts.

This situation has not altered with the extraction of LW2 to LW6A. Subsidence impacts have been limited to areas immediately above each longwall panel, generally within the 20 mm subsidence line defined by the 26.5° angle of draw from the goaf edge (SCT, 2006). As no change in barrier hydraulic conductivities has occurred, seepage rates from the Glennies Creek alluvium through the Pikes Gully Seam into the alluvium are related to the natural prevailing hydraulic conductivities in the barrier.

As indicated in Section 7.1.2, the Glennies Creek alluvium seepage inflow rate has been declining, while lowered groundwater levels in the barrier have been steadily recovering. This suggests a likely reduction in the permeability of the Pikes Gully seam within the barrier, possibly due to clogging by suspended fines, or a delayed benefit from the TG1-A rib grout injection program implemented during 2007.

Bowmans Creek Alluvium

The LW/MW5-9 SMP groundwater report (Aquaterra, 2008) predicted small seepage losses (0.4-0.5 L/s) from the Bowmans Creek alluvium during the mining of LW6A. However, no reduction in alluvium storage occurred during LW6A extraction, and hence no seepage loss from the Bowmans Creek alluvium. The impact on Bowmans Creek alluvium has therefore been less than the SMP predictions.

Hunter River Alluvium

The LW/MW5-9 SMP groundwater report (Aquaterra, 2008) predicted very small seepage losses (0.1 L/s) from the Hunter River alluvium during the mining of LW6A. However, no reduction in alluvium storage occurred during LW6A extraction, and hence no seepage loss from the Hunter River alluvium. The impact on Hunter River alluvium has therefore been less than the SMP predictions.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

Mining of Pikes Gully Seam LW6A was carried out between 9 July 2011 and 22 November 2011. Monitoring data from this period continues to show that the groundwater in the coal measures aquifer system is saline, with salinities ranging to more than 8,000 µS/cm EC. Salinity of the groundwater in the Glennies Creek and Bowmans Creek alluvium varies, but it is generally less saline than the coal measures. Alluvium salinity is generally less than 1,000 µS/cm EC, but can be as high as 6,000+ µS/cm EC.

There is abundant evidence that prior to commencement of mining at Ashton, groundwater levels in the Permian coal measures were higher than both groundwater levels in the alluvium and the stage level of the streams. Under natural conditions, groundwater discharged from the Permian to the alluvium and to the surface streams. This is still occurring in some places. Mixing of saline coal measures water with lower salinity water derived from local rainfall recharge is responsible for the salinity variability seen in both the alluvium groundwater and occasionally in the stream flow.

As underground mining is progressing closer to Bowmans Creek, subsidence survey monitoring is continuing to be undertaken directly above the longwall workings. As with LW5, a new survey line LW6CL was established along the axis of LW6A, which spans the start and end sections of the panel. The survey line does not extend across Bowmans Creek, but negligible subsidence was reported well short of the creek on this section.

The lateral survey line XL5 which started east of Glennies Creek and spans the full underground area was surveyed across the LW6A panel area, and showed that lateral and vertical displacements outside of the panel area are negligible. The survey was not repeated across the barrier zone east of LW1 following LW6A extraction, but there is no evidence for any further ground movement in that area, hence the barrier between Glennies Creek and the underground mine remains unaffected by mining. Seepage inflows to the TG1A tailgate continue to decline as they have done over the period of mining LW1-LW5.

There has been no significant increase in total mine inflows following mining of LW6A. Calculated total groundwater inflow rate during LW6A ranged between 2.9 and 5.9 L/s (i.e. 0.25 to 0.51 ML/d). The majority of mine water inflow is apparently coming from (or through) the Pikes Gully Seam.

Subsidence effects are expected to have substantially dewatered the Permian strata above each panel area within the zone of subsidence at least across the LW1-LW4 area. The monitoring results at LW269 showed that the Permian strata remain saturated and only partially depressurised over the south-west corner of LW5. Likewise, the continuing saturation of the uppermost part of the Lemington sequence as displayed by standpipe piezometer VW111B, shows that the Permian sequence has not been fully affected above the southern part of LW6A.

Some of the highly confined, low storativity strata layers within the Permian to the south and west of the longwall panels have shown clear pressure-storage responses, consistent with that described in international research into longwall mining. This effect results from the subsidence and strata movement above the longwall panel. It is related to the creation of additional storage caused by fracture and bedding plane dilation. It is not related to dewatering by means of continuous cracking and direct hydraulic connection to the underground workings. The pressure-storage response can result in large piezometric responses at some distance from the mine workings, but these impacts are always transient, generally only occur in horizons with low storativity, and do not affect the longer term dewatering trends caused by the longwall mining. They are not therefore significant in terms of impacts to water resources around the Ashton Mine area.

The extensive network of piezometers across the Bowmans Creek floodplain has shown no evidence of any dewatering or reduction of groundwater storage in the Bowmasn Creek alluvium aquifer as a result of mining. Likewise, no mining-related drawdown has been observed in the Hunter River alluvium, and no further drawdown in Glennies Creek alluvium during the mining of LW6A.

A comparison of observed impacts with the EIS and SMP predictions has led to the following conclusions:

- Actual groundwater inflows have been below the EIS and SMP predictions at all stages of mining to date. Total groundwater inflows into the underground mine averaged approximately 0.34 ML/d (3.9 L/s) during the extraction of LW6A, compared with the EIS and LW/MW5-9 SMP predicted inflow rate for this stage of mining of around 1.55 ML/d (18 L/s) and 1.2 - 1.4 ML/d (13 - 16 L/s), respectively.
- Actual seepage rates from the Glennies Creek alluvium have been at, or below, the EIS and SMP predictions at all stages of mining to date. Calculated rates of actual Glennies Creek alluvium seepage into the underground mine during the LW6A extraction were approximately 0.66 – 1.2 L/s, well below the EIS prediction (3.2 L/s) and consistent with the LW/MW5-9 SMP prediction.
- Groundwater level drawdown in the Glennies Creek alluvium has been significantly less than predicted in the EIS. Groundwater levels in bore WML120B indicated a residual net drawdown of about 0.4 m by the completion of LW6A - well below the EIS prediction of 2.2 m for this locality by this stage of mining. There is no evidence of any drawdown in the alluvium east of Glennies Creek.
- Hydrographs of bores in Bowmans Creek alluvium and Hunter River alluvium reveal no evidence of any drawdown impact as a result of underground mining and as such there have been no seepage loses from the Bowmans Creek or Hunter River alluvium into the underground mine.
- Monitoring suggests that the possibility of increased mine inflow from higher rates of rainfall recharge due to the subsidence fracturing is likely to be significantly less than that considered in the LW1-4 SMP groundwater report. No measurable increase in mine inflows occurred following significant rainfall events during mining of LW1, and more recently during the above average rainfall events which fell during the mining of LW6A.

In summary, all groundwater-related impacts from underground mining up to the completion of LW6A (November 2010) were at, or below the levels predicted in the EIS (HLA Envirosciences, 2001), and in the LW1-4 SMP and LW/MW5-9 SMP Groundwater Assessments (Peter Dundon and Associates, 2006; Aquaterra, 2008b).

Most of the impacts relating to Glennies Creek alluvium had stabilised prior to the end of LW1, and no significant incremental impact or influence from mining of LW2 to LW6A has been observed. Impacts on inflows and groundwater levels in alluvium associated with Glennies Creek have generally continued to decline over time. There have been no observed impacts to date in relation to Bowmans Creek or its alluvium, either in terms of drawdown or mine inflow rates.

8.2 RECOMMENDATIONS

It is recommended that all piezometers located in the LW goafs are resurveyed after maximum subsidence is reached.

There are no additional recommendations.

9. REFERENCES

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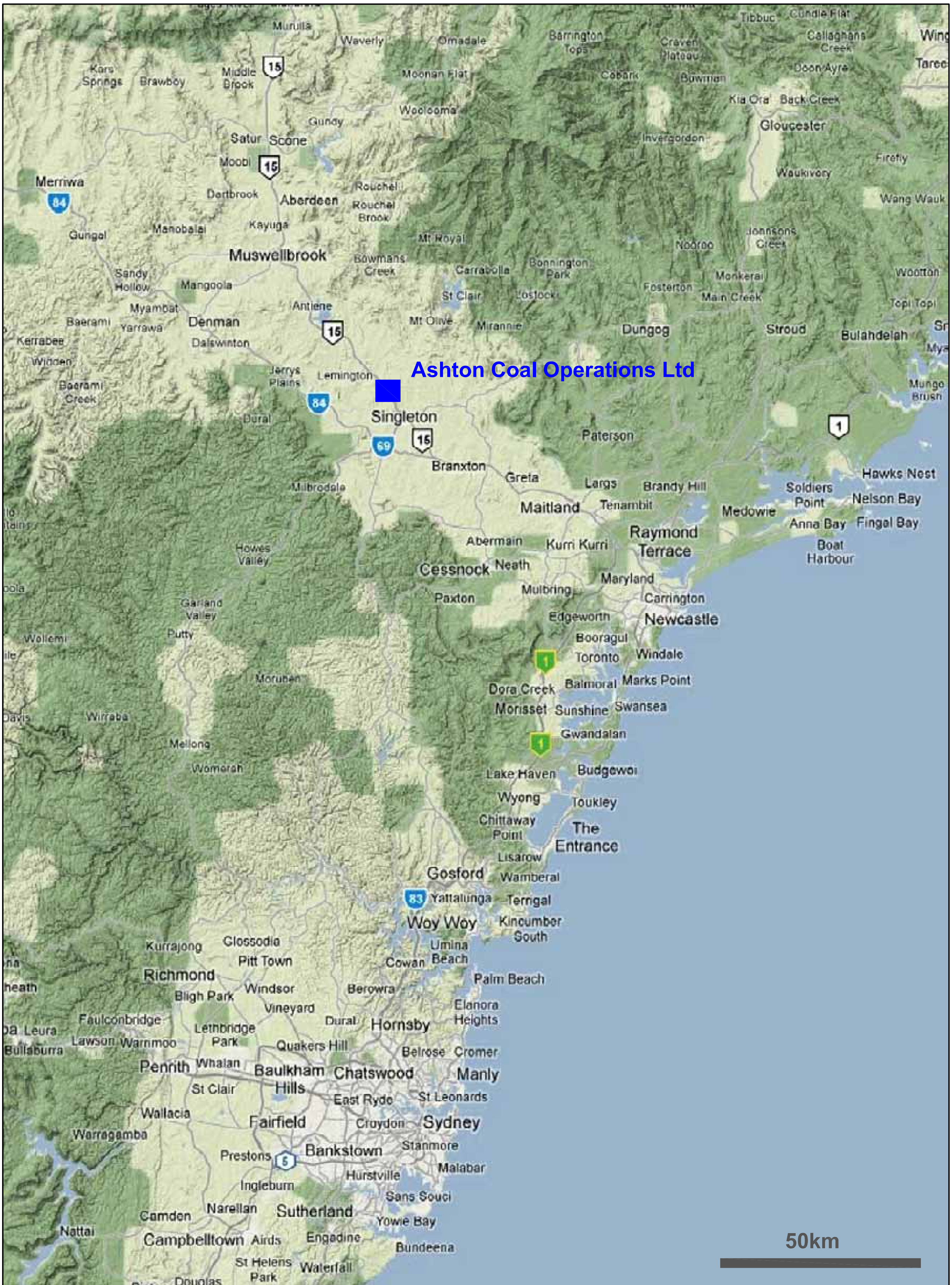


Date: 30 September 2009	Scale: as indicated	Ashton Coal Operations Ltd
Initials: HZ	Job No: S55D	PROJECT LOCATION PLAN ASHTON COAL OPERATIONS
Drawing No: S55G-001	Rev: A	
RPS Aquaterra		Figure 1

LEGEND

Monitoring Bores

Type

- Stand pipe
- Test bore
- Vibrating wire
- Well
- Pikes Gully mining completed
- Mine Plan (Pikes Gully)
- Alluvium boundary
- Saturated alluvium boundary
- Survey Cross Lines

Note: The BCD DC Modification and associated mine plan change had not occurred until Dec 2010

N

0 0.2 0.4 0.8 Kilometers

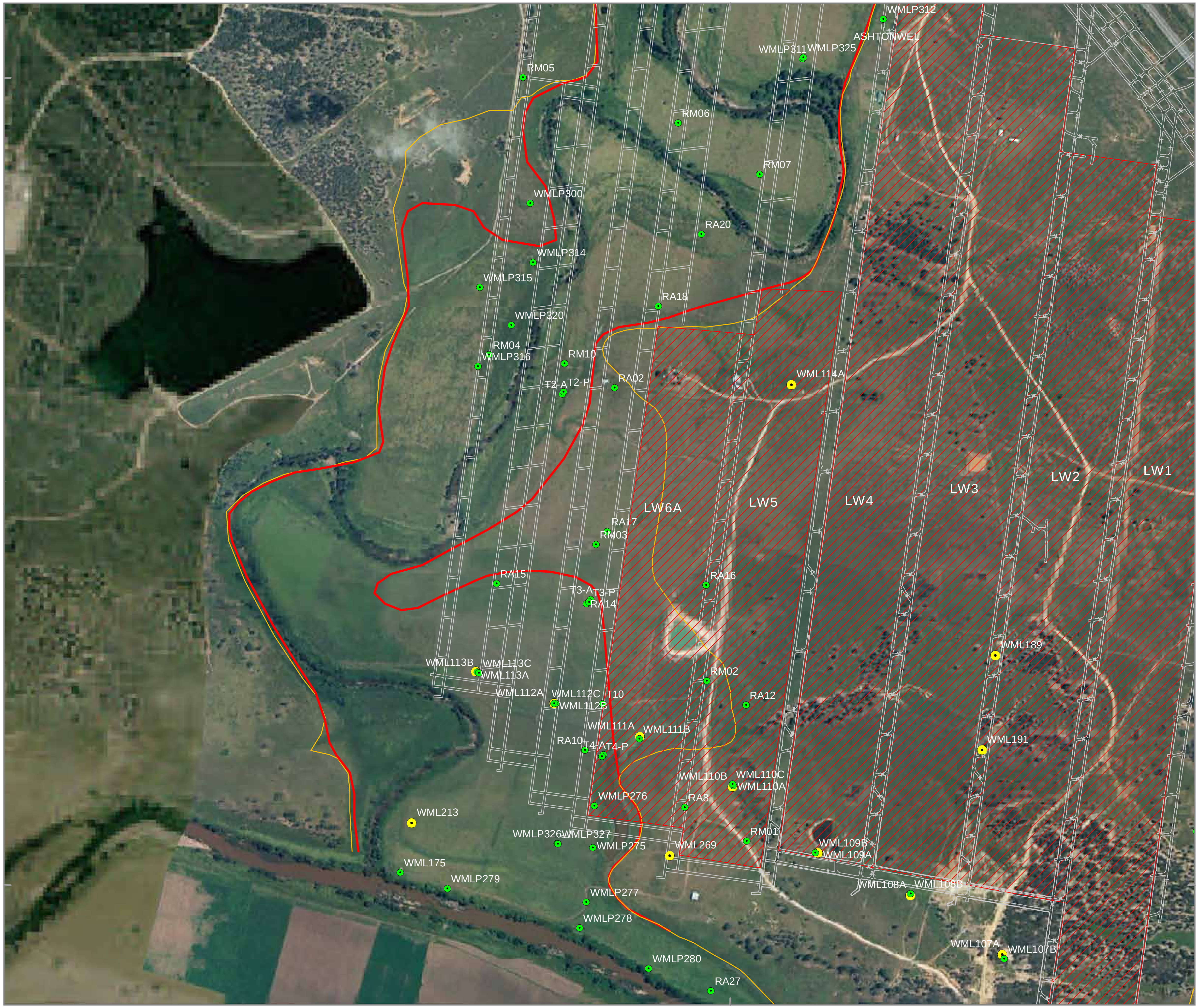
RPS Aquaterra

FIGURE 2

Ashton Coal
Groundwater Monitoring Network

AUTHOR	JVDA	PROJECT NO	S55D
CHECKED BY		REVISION	A
DATE	08/08/2010	DRAWING NO	002

318000



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LEGEND

Monitoring Bores

Type

- Stand pipe
- Test bore
- Vibrating wire
- Pikes Gully mining completed
- Mine Plan (Pikes Gully)
- Alluvium boundary
- Saturated alluvium boundary

Note: The BCD DC Modification and associated mine plan change had not occurred until Dec 2010

N

0 0.15 0.3 0.6 Kilometers

6404000

RPS Aquaterra

FIGURE 3

Groundwater Monitoring Network Near LW6A

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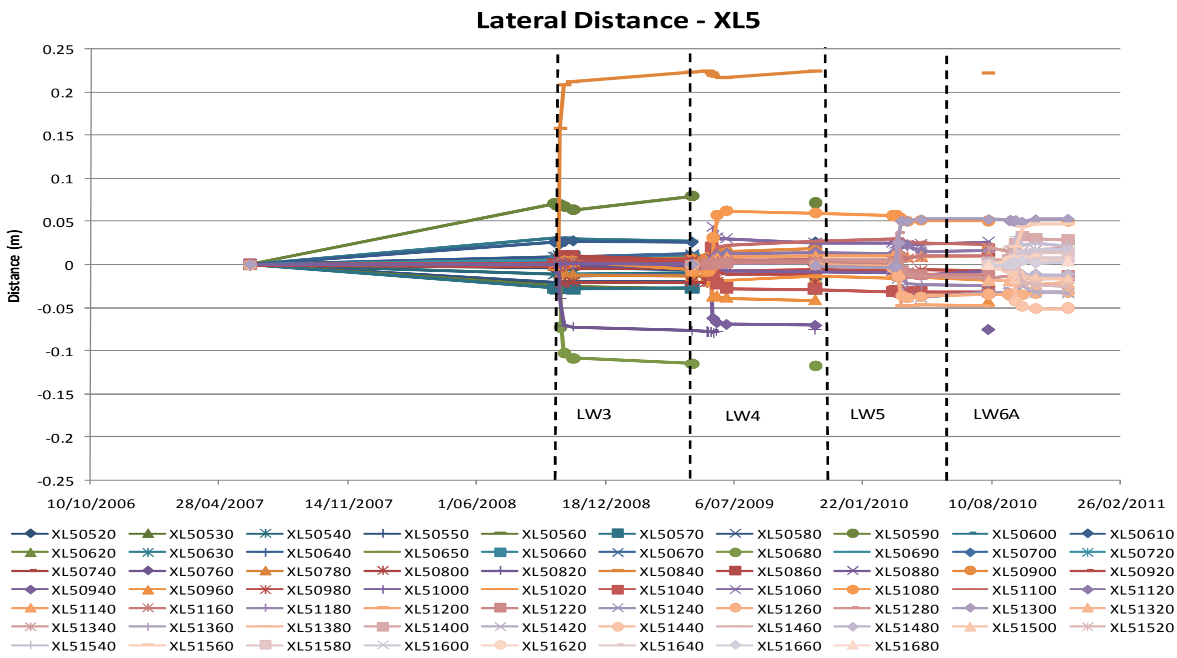
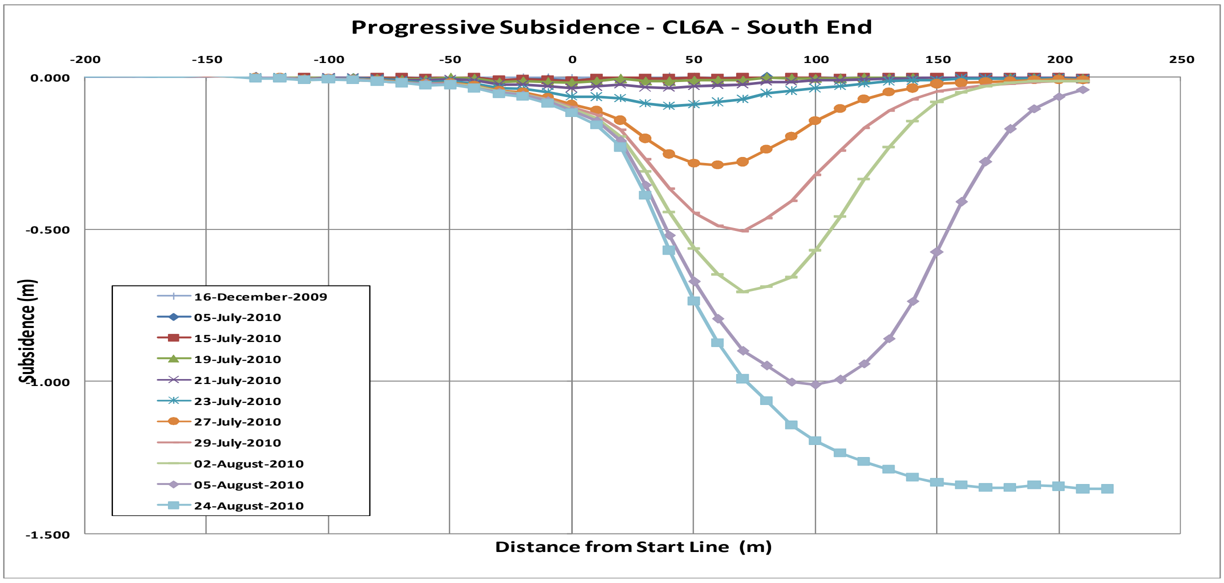
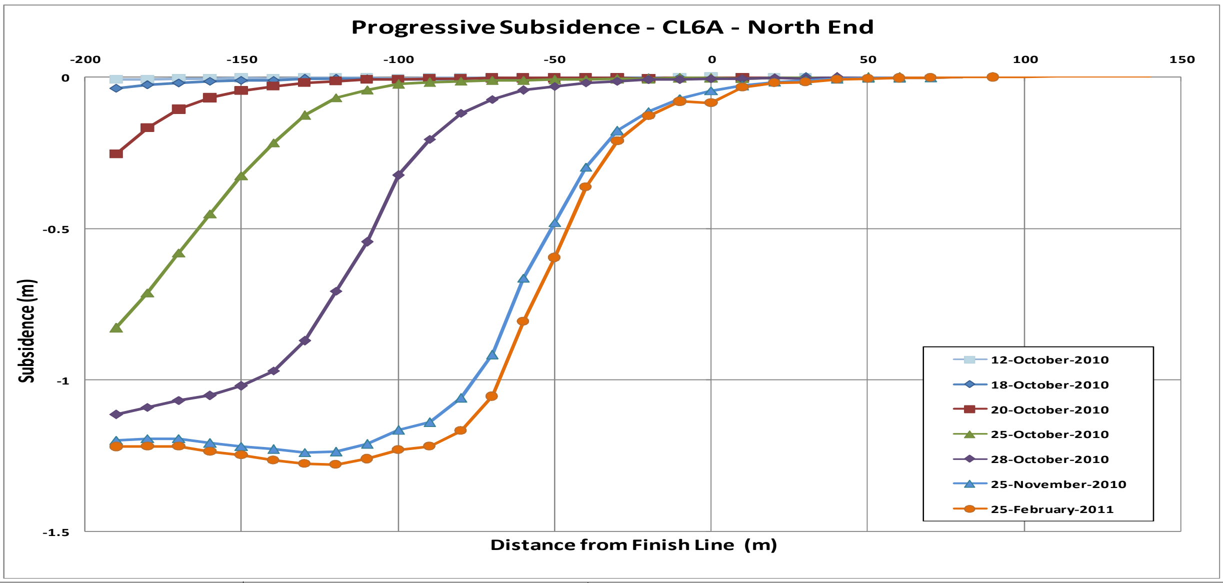
CHECKED BY		REVISION	A
DATE	08/08/2010	DRAWING NO	003







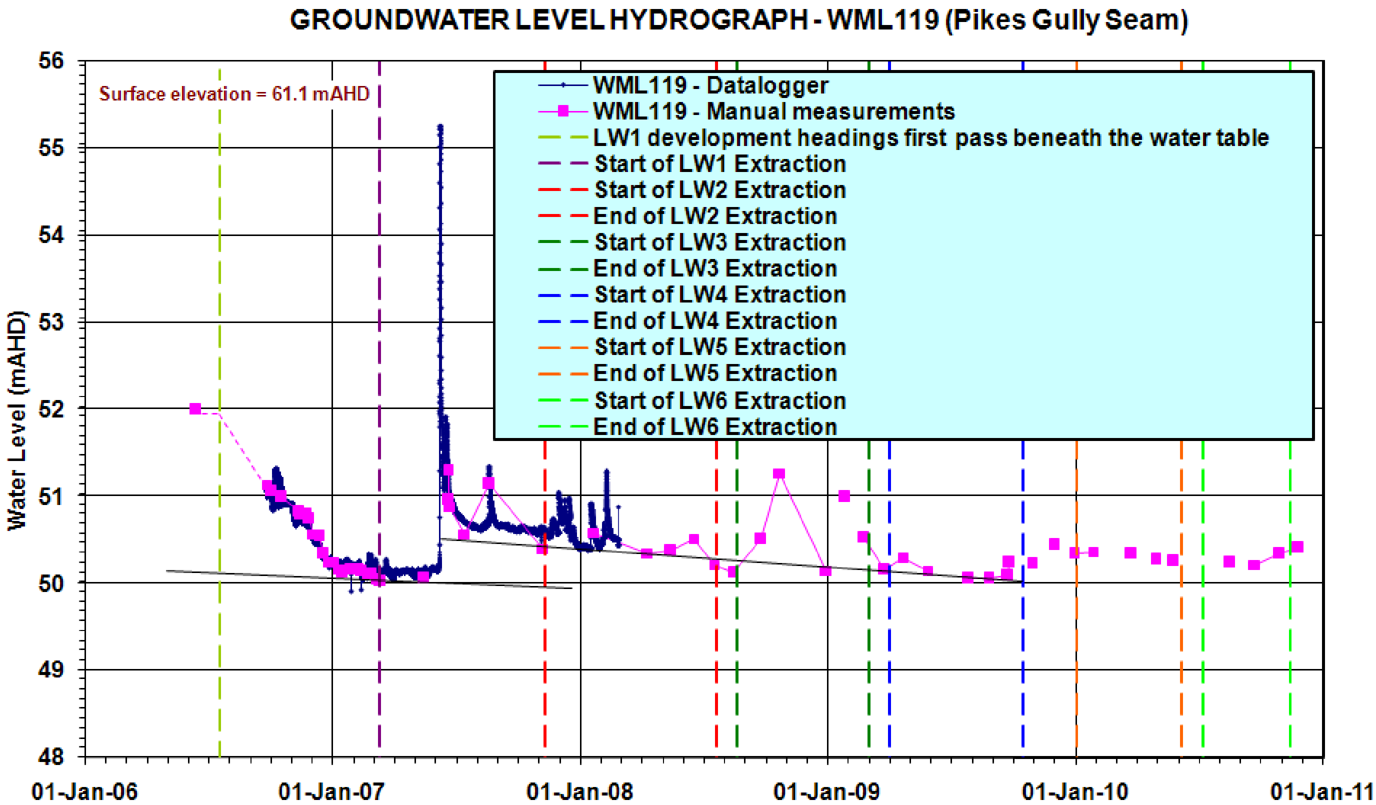
Date	23 May 2011	Scale	
Initials	JVDA	Project	S55 D5
Drawing Number	srf-029a	Revision	C

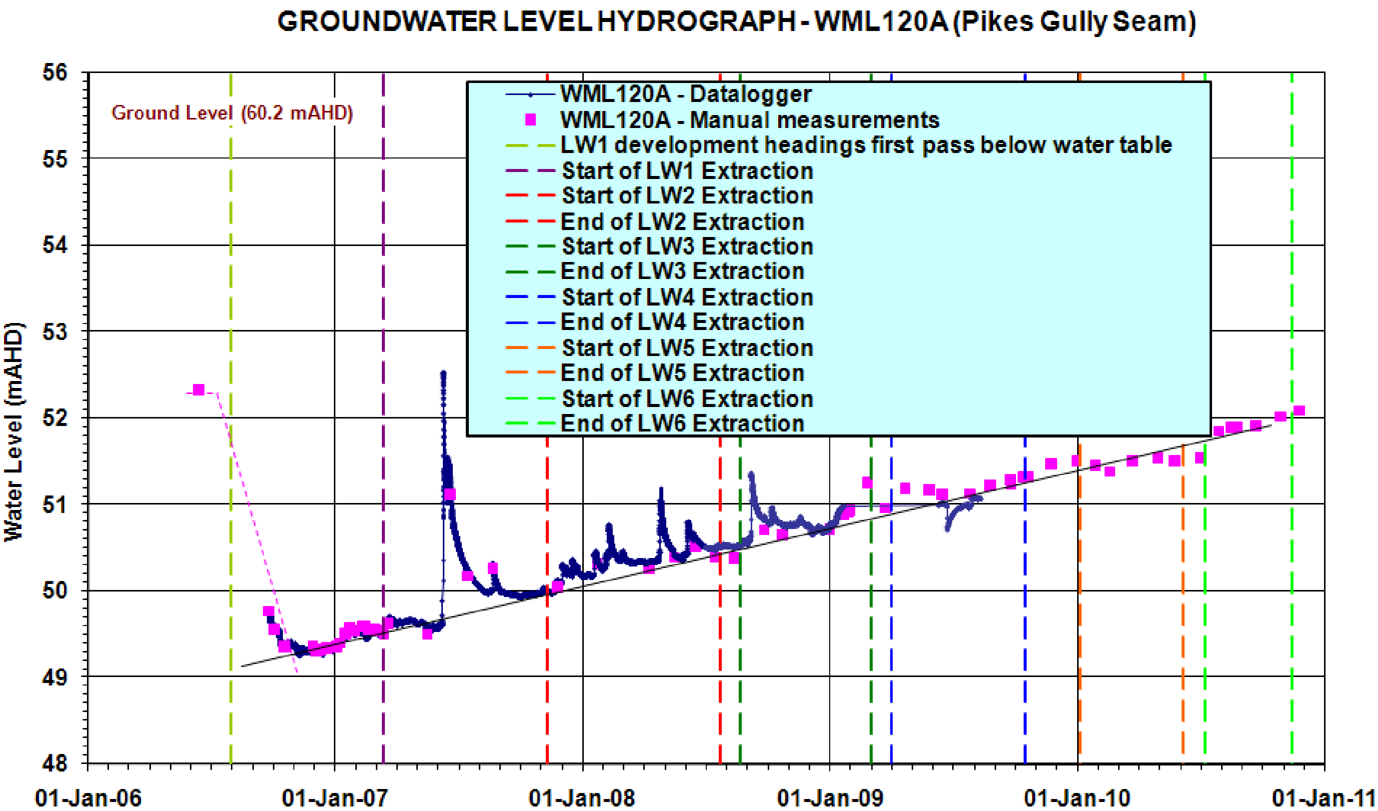
RPS Aquaterra

Ashton Coal Operations Ltd

SURVEY CROSS LINES
LATERAL (XL5) AND VERTICAL (CL2)
MOVEMENT

Figure 4





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Drawing Number srf-022	Revision C	
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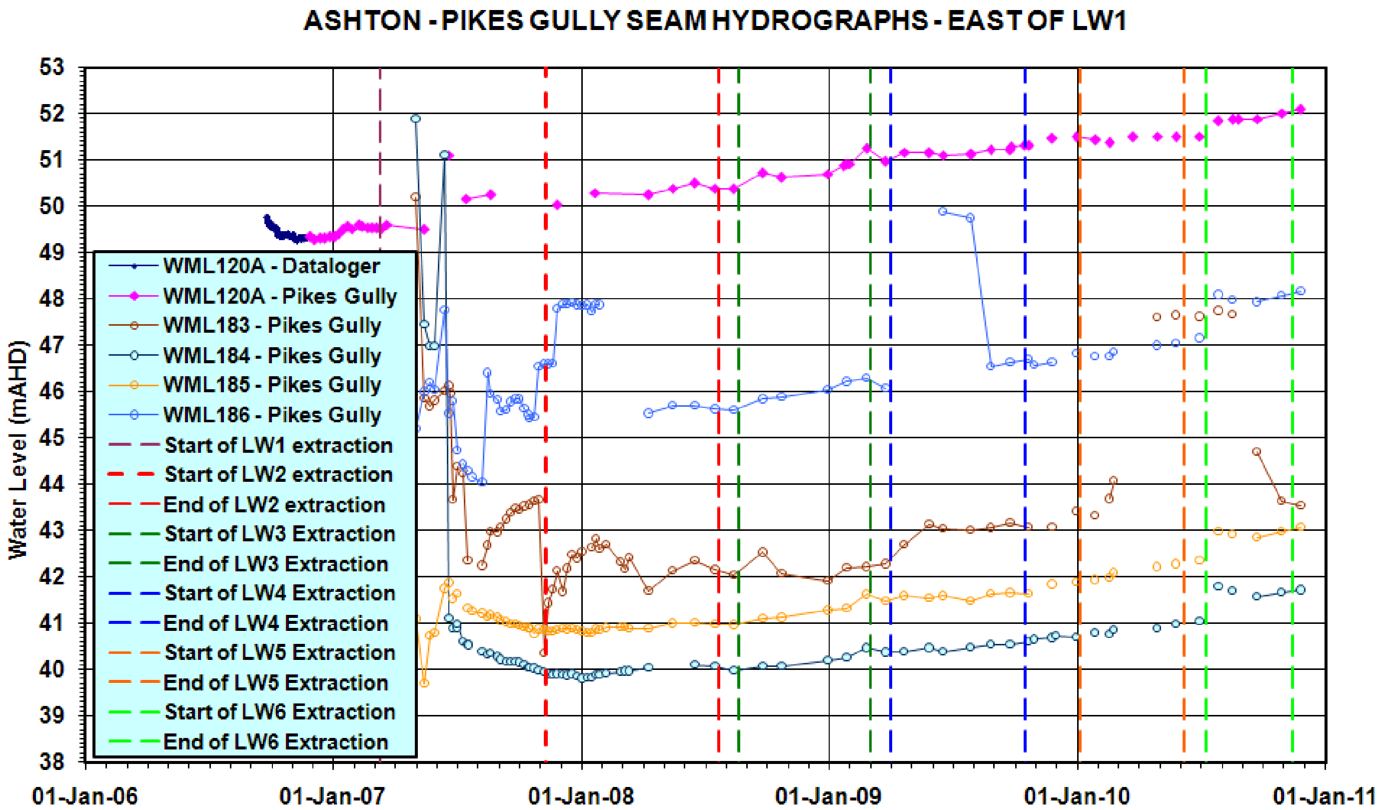

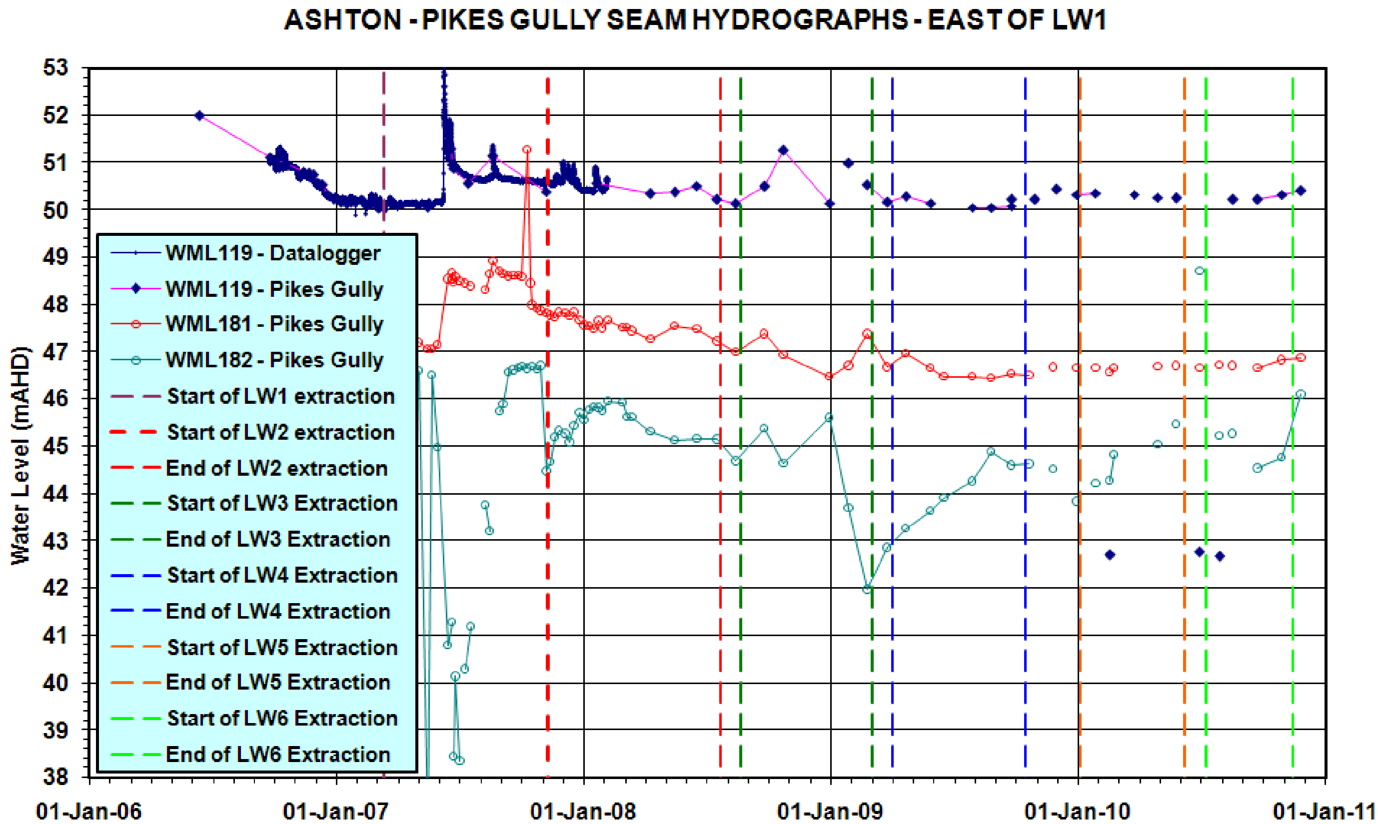

Date 13 January 2011	Scale	**Ashton Coal Operations Ltd**	
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Drawing Number srf-024	Revision B		
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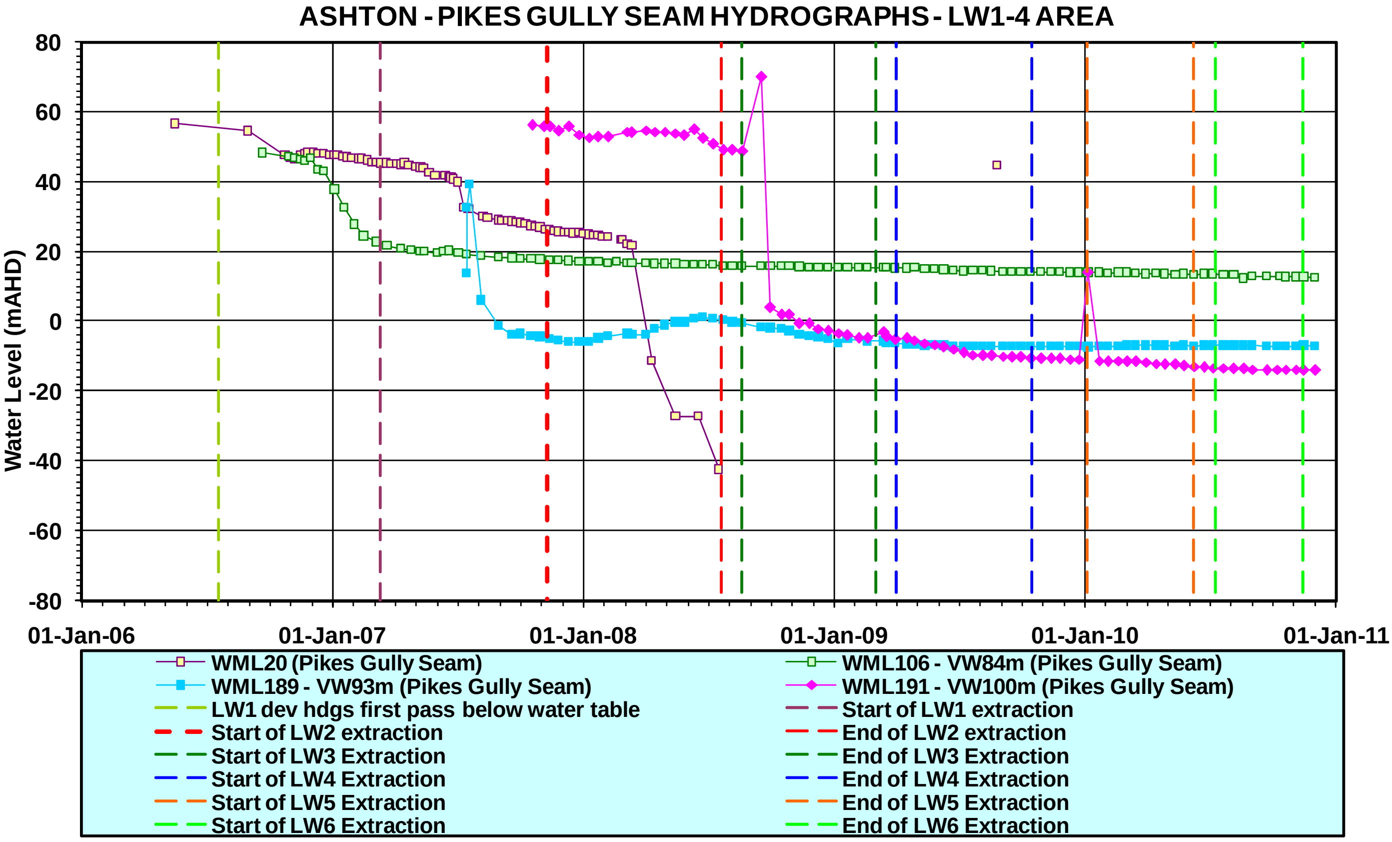

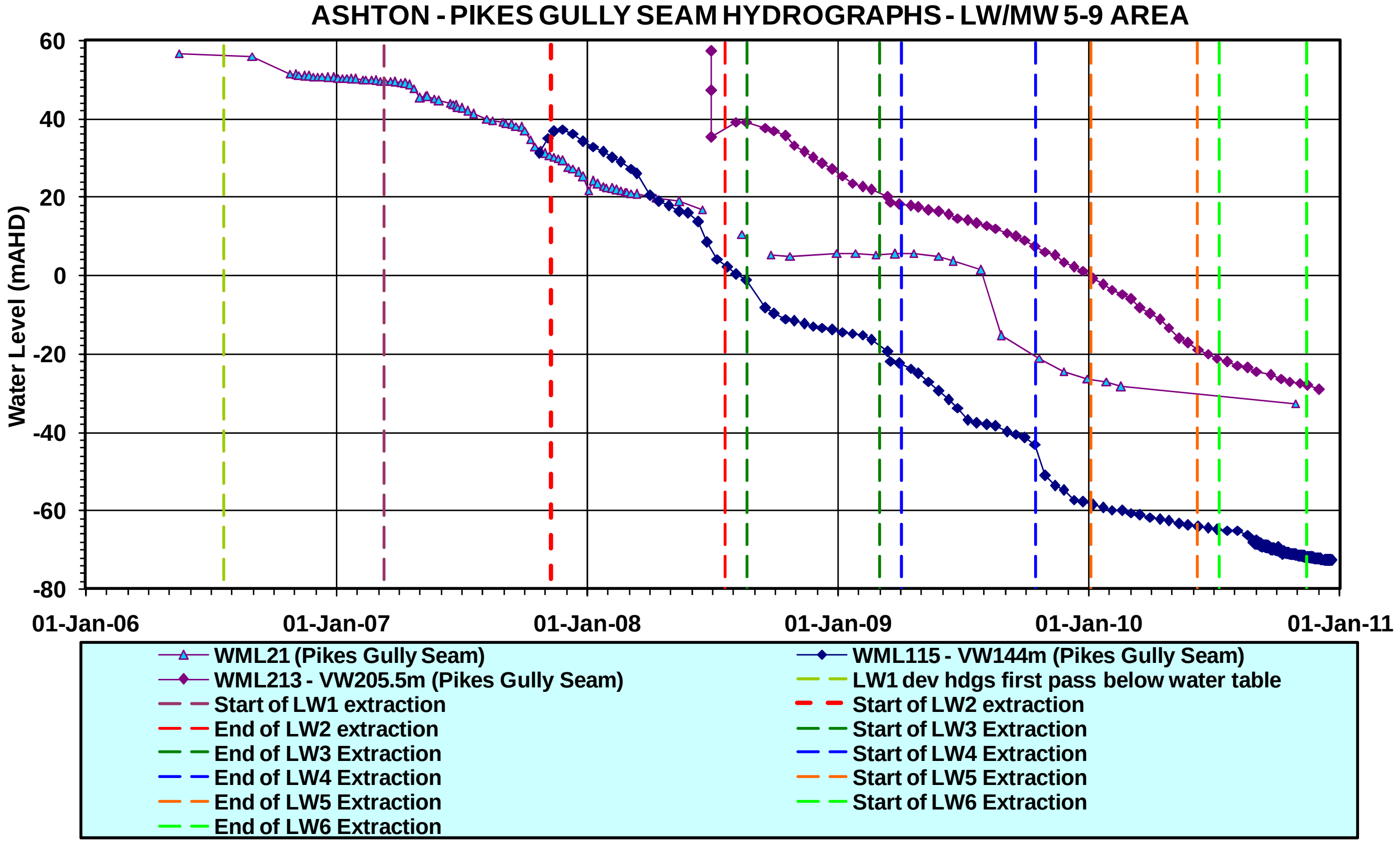

Date 13 January 2011	Scale	Ashton Coal Operations Ltd
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Drawing Number srf-026	Revision B	
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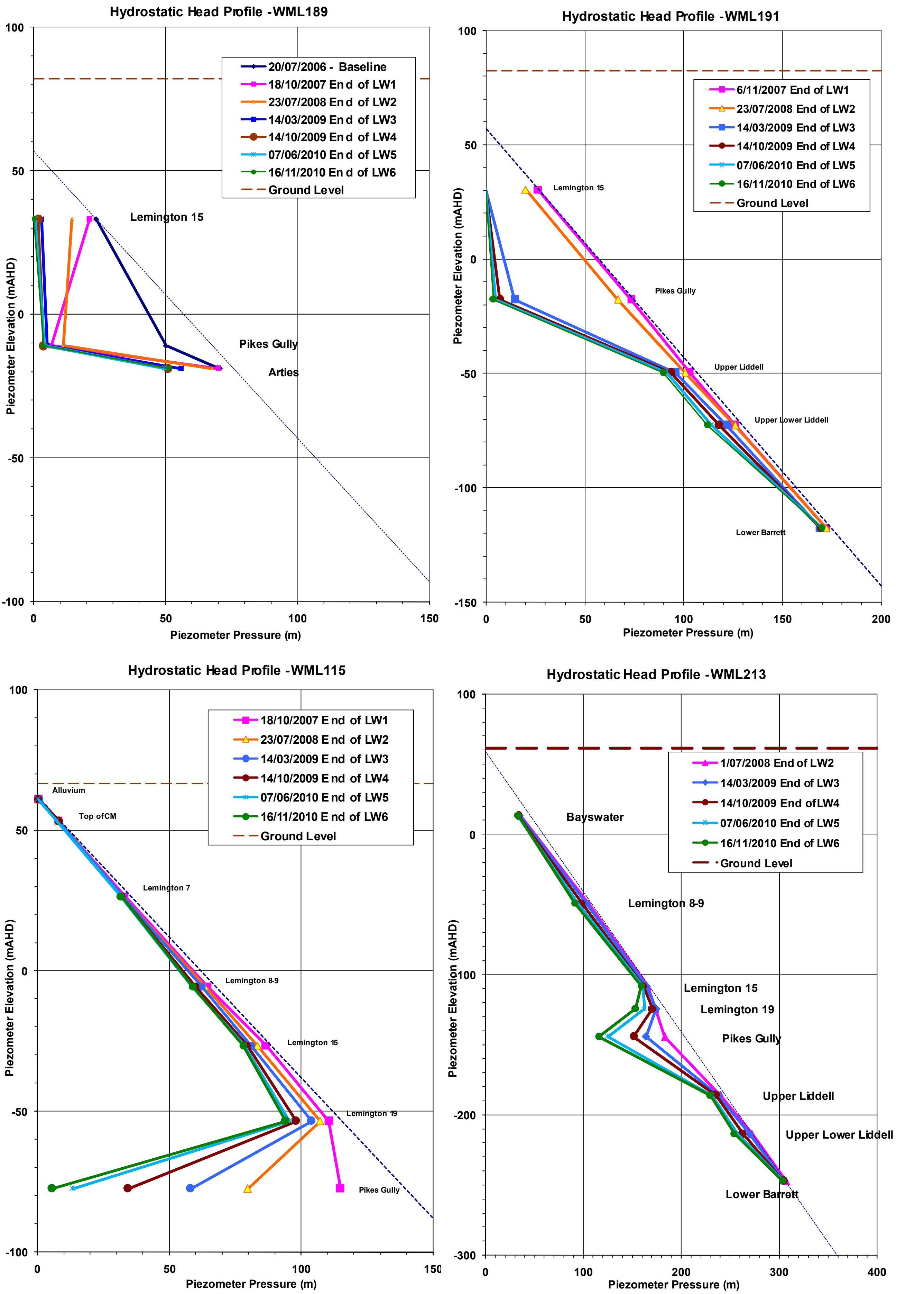


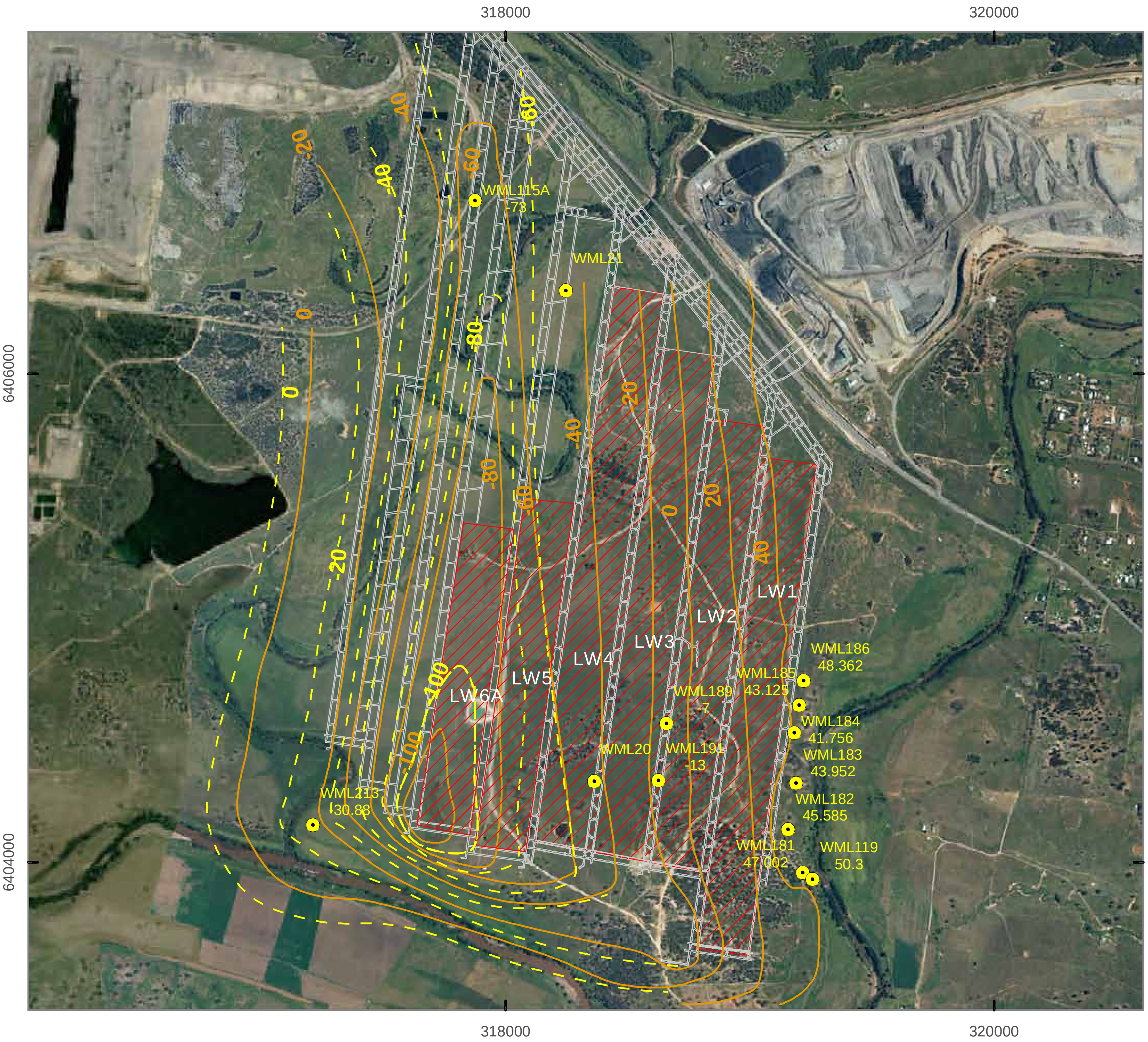
Date	13 January 2011	Scale	
Initials	TL	Project	S55 D5
Drawing Number	srf-027	Revision	B

RPS Aquaterra

Ashton Coal Operations Ltd

HYDROSTATIC HEAD PROFILES
PIKES GULLY SEAM
(WML189, WML191, WML115 and WML213)

Figure 8



LEGEND

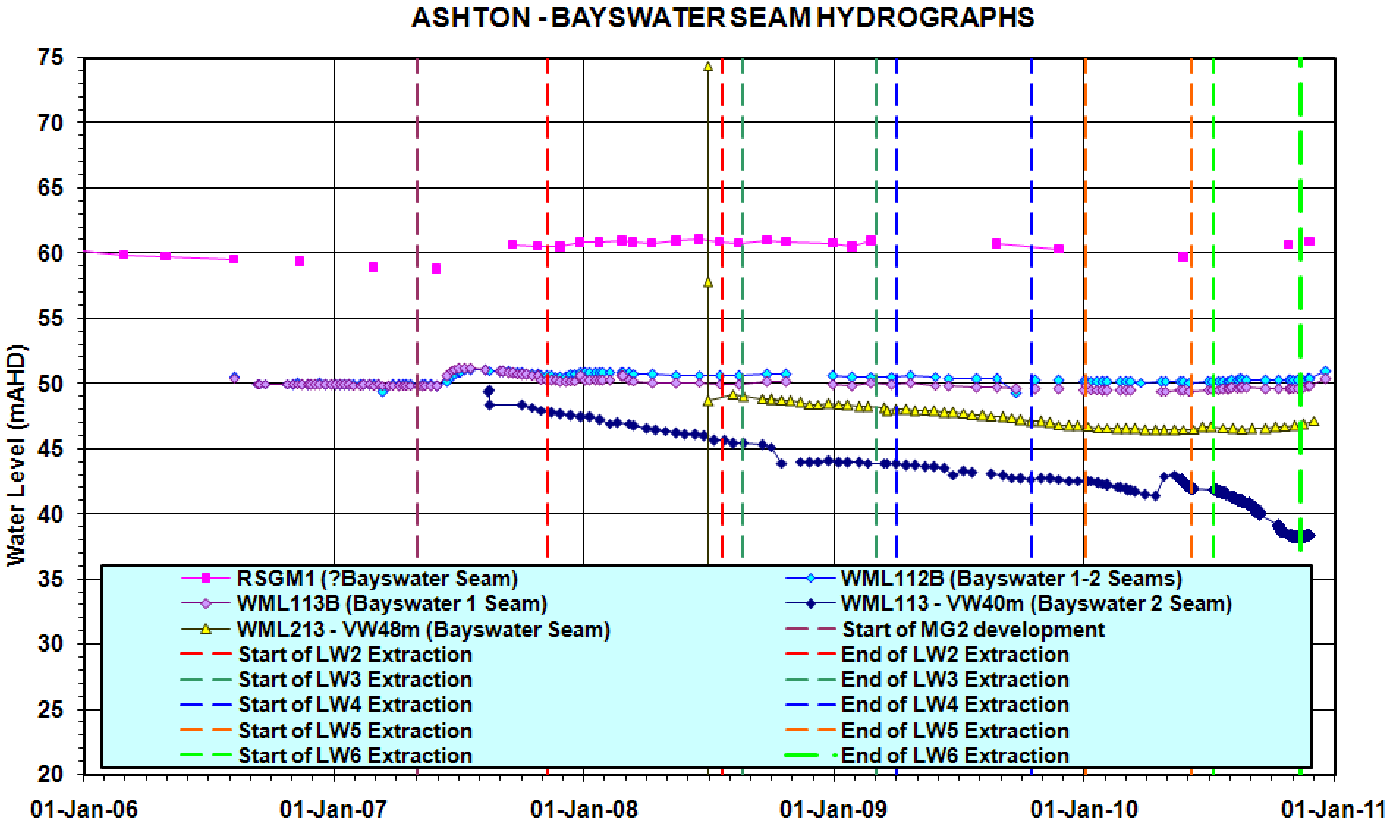
- Pikes Gully Piezometers and GWL (mAHD)
- Groundwater level contour November 2010
- Groundwater level contour June 2010
- Pikes Gully Mine Plan
- Pikes Gully mining completed

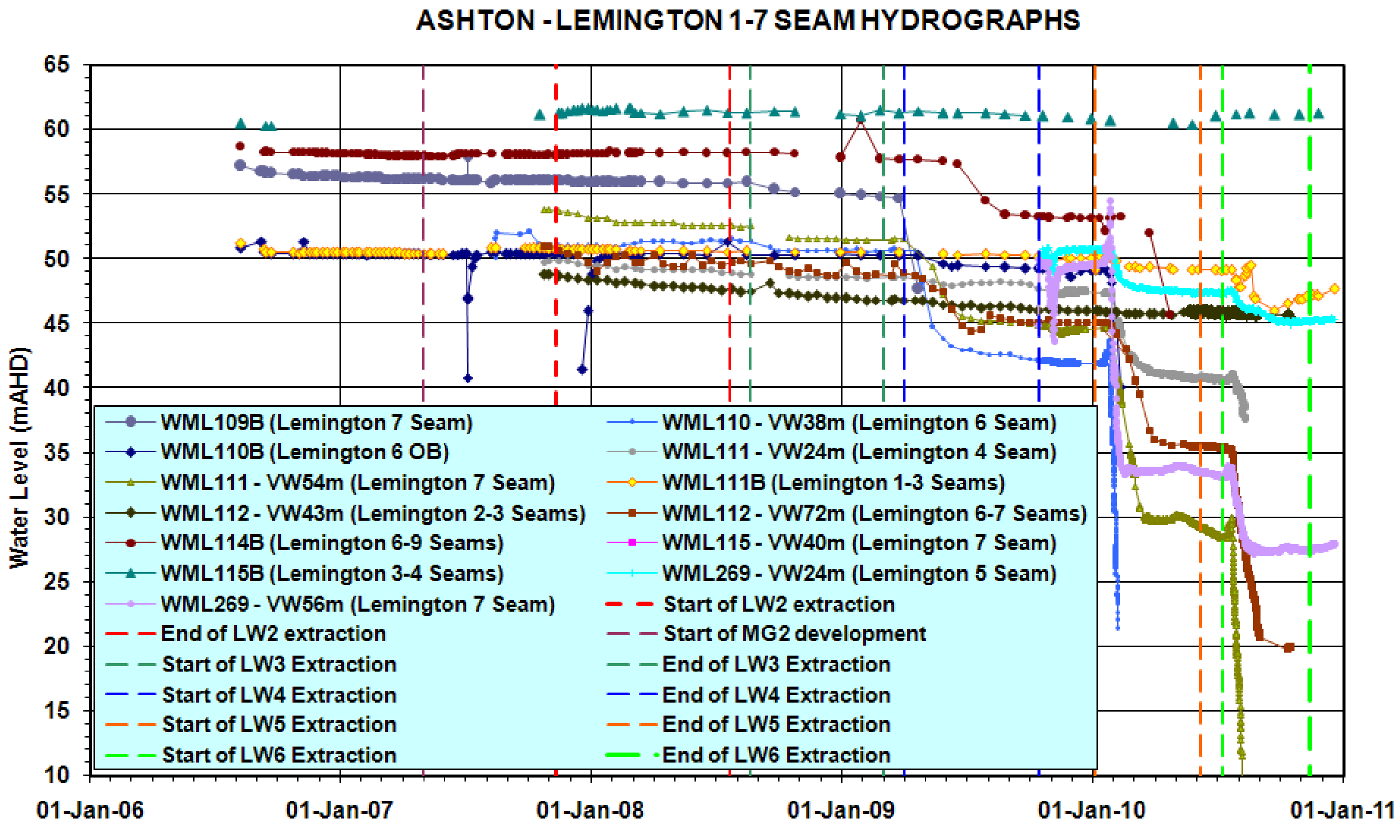
RPS Aquaterra

FIGURE 9

Groundwater Elevations -
Pikes Gully Seam, June 2010

AUTHOR	JVDA	PROJECT NO	S55D
CHECKED BY		REVISION	A
DATE	08/08/2011	DRAWING NO	001b





Date 1 December 2010	Scale	**Ashton Coal Operations Ltd**
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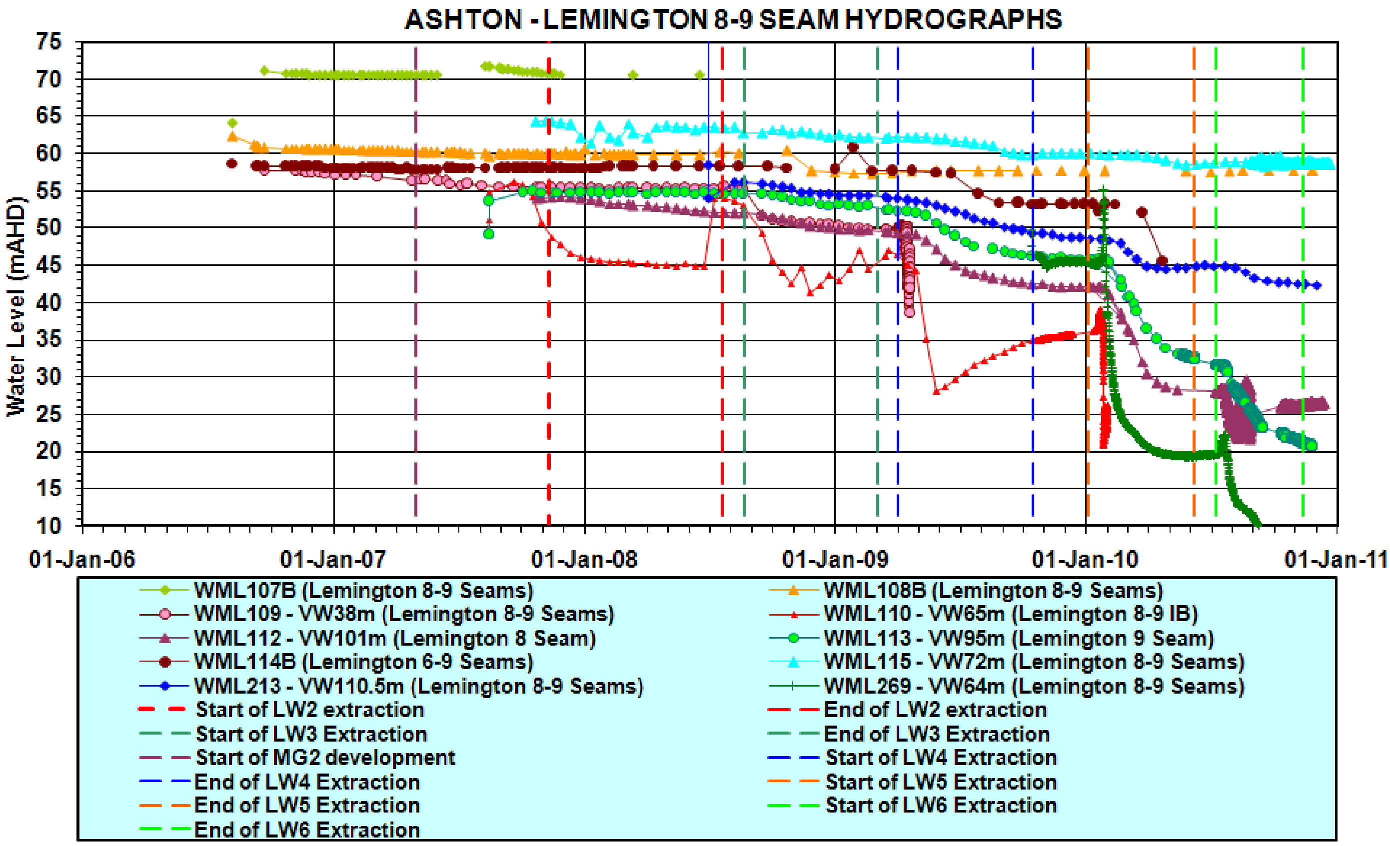
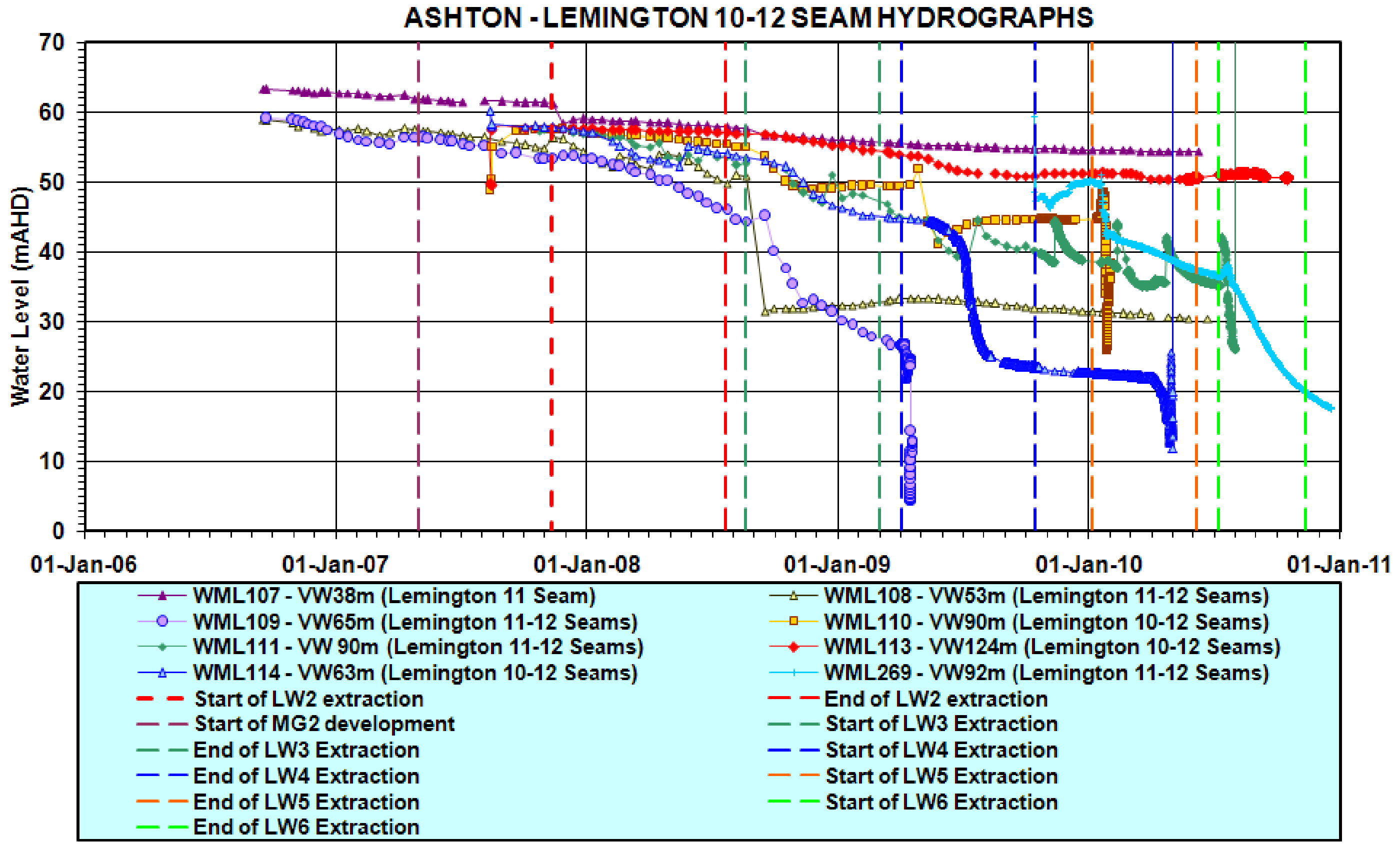
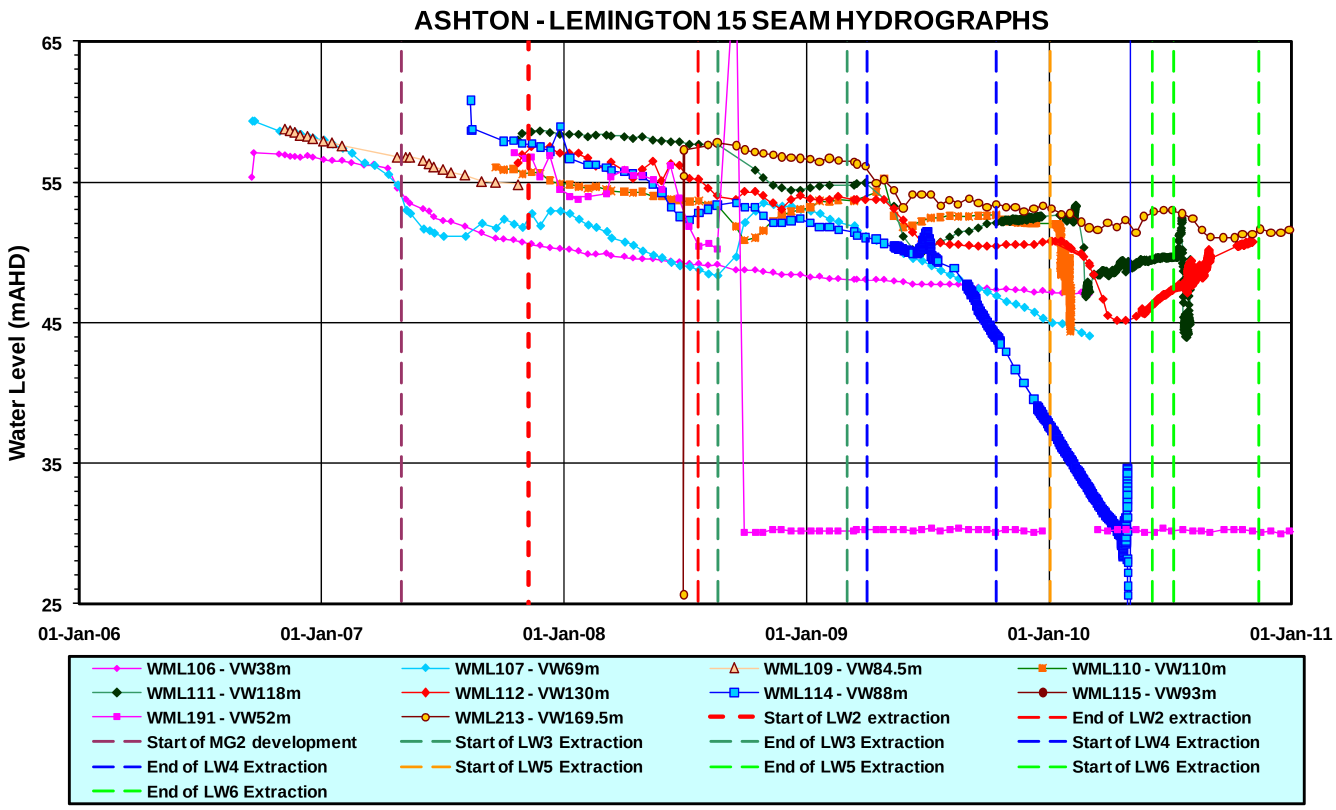
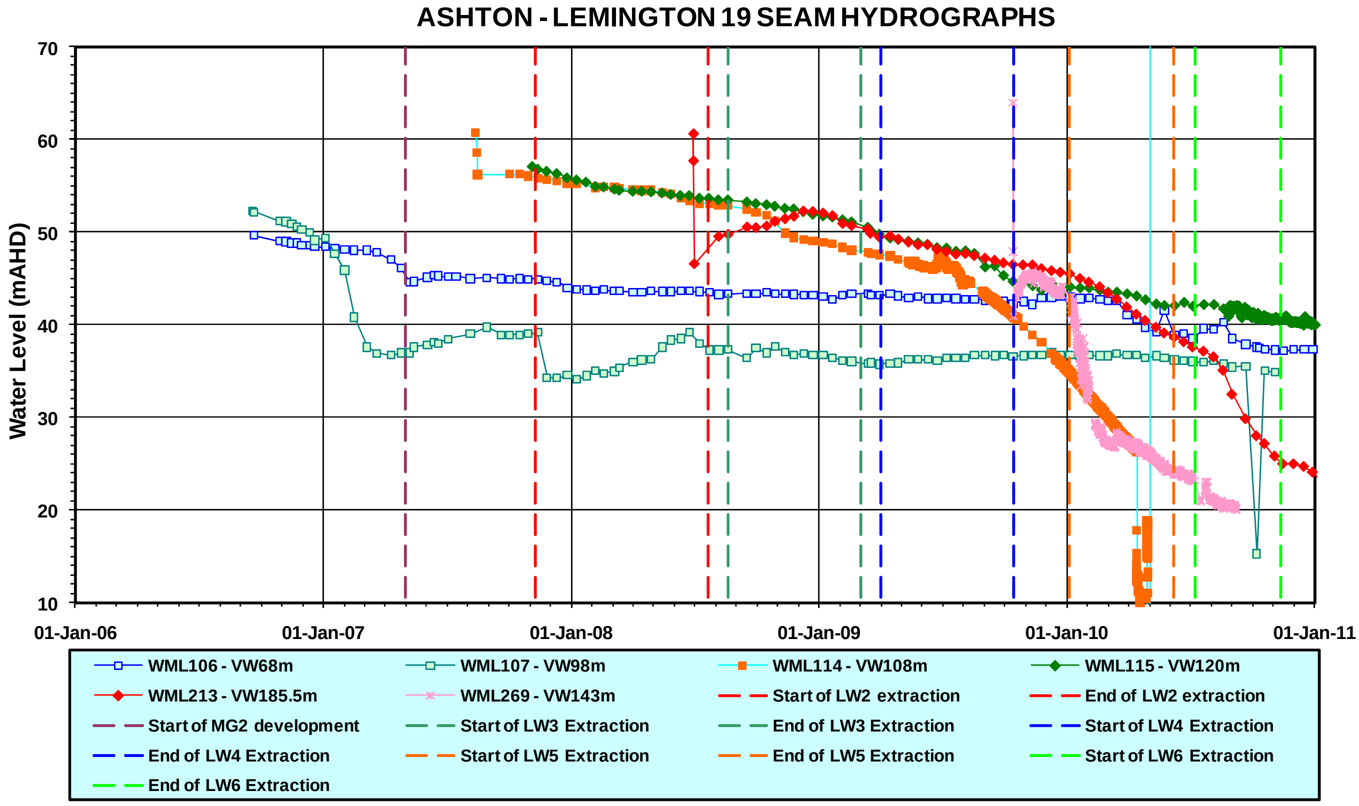
Drawing Number srf-019	Revision A	
RPS Aquaterra		Figure 10





Date 13 January 2011	Scale	**Ashton Coal Operations Ltd**
Initials TL	Project S55 D5	GROUNDWATER LEVEL HYDROGRAPHS LEMINGTON 8-9 SEAMS LEMINGTON 10-12 SEAMS
Drawing Number srf-020	Revision C	
RPS Aquaterra		**Figure 11**





Date 08 August 2011	Scale	**Ashton Coal Operations Ltd**
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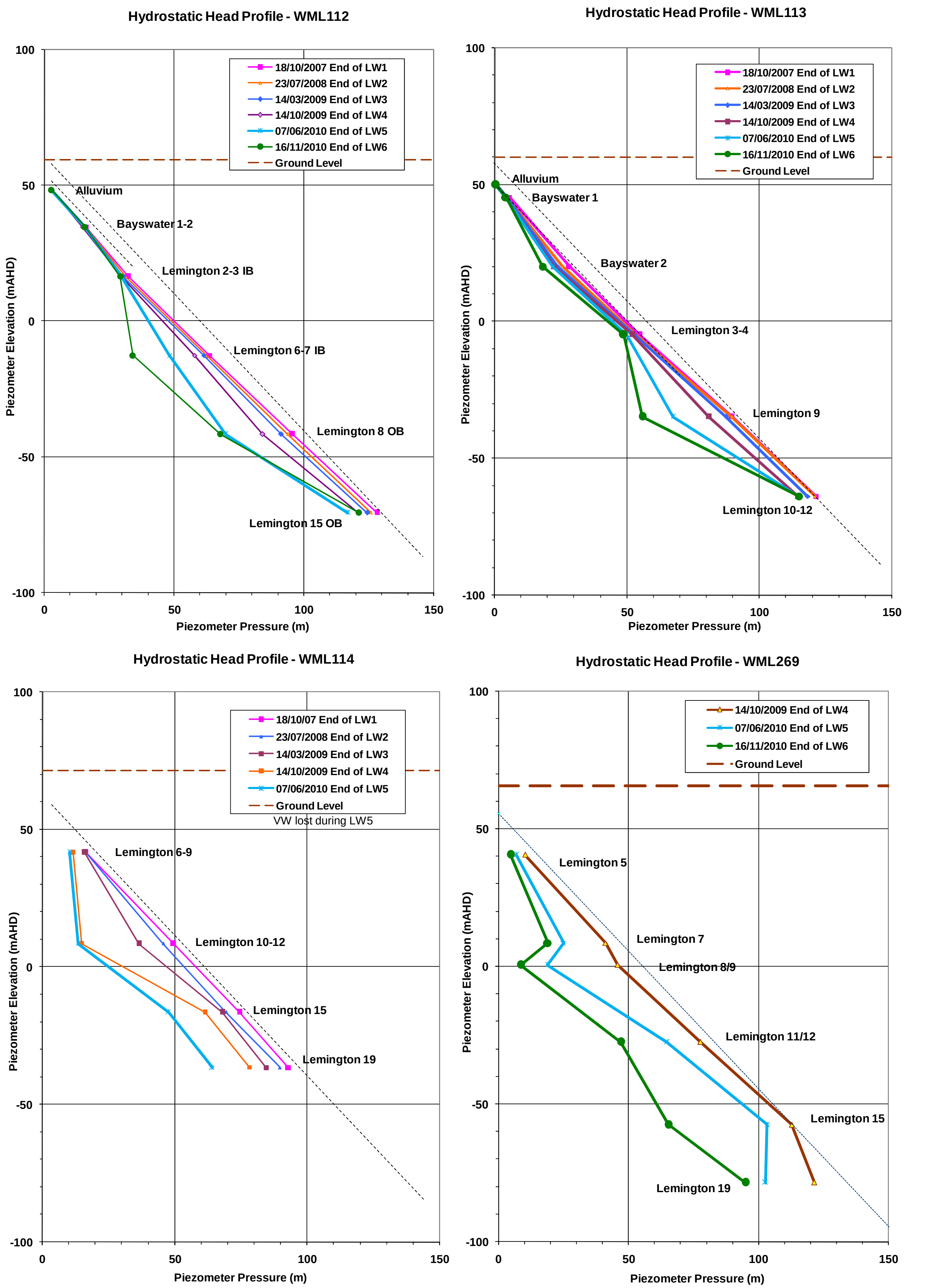
Drawing Number srf-021	Revision C	
RPS Aquaterra		**Figure 12**



Date 13 January 2011	Scale	**Ashton Coal Operations Ltd**
Initials TL	Project S55 D5	HYDROSTATIC HEAD PROFILES LEMINGTON SEAMS (WML112, WML113, WML114 and WML269)
Drawing Number 028	Revision B	
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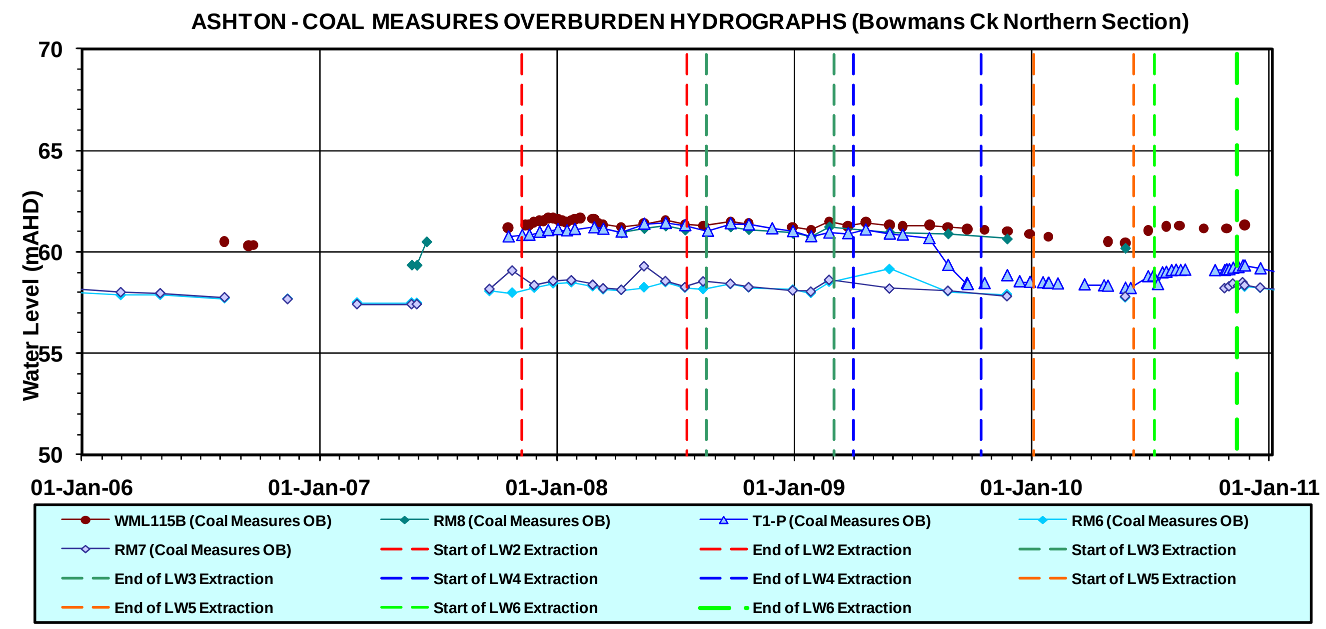

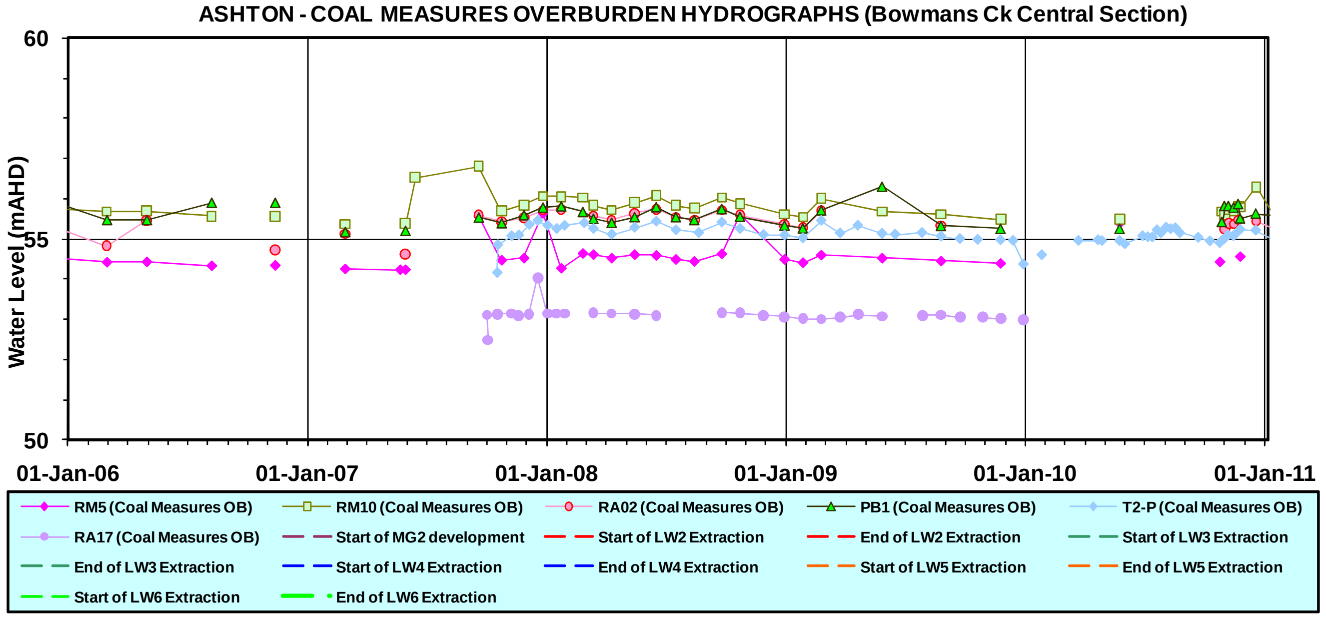

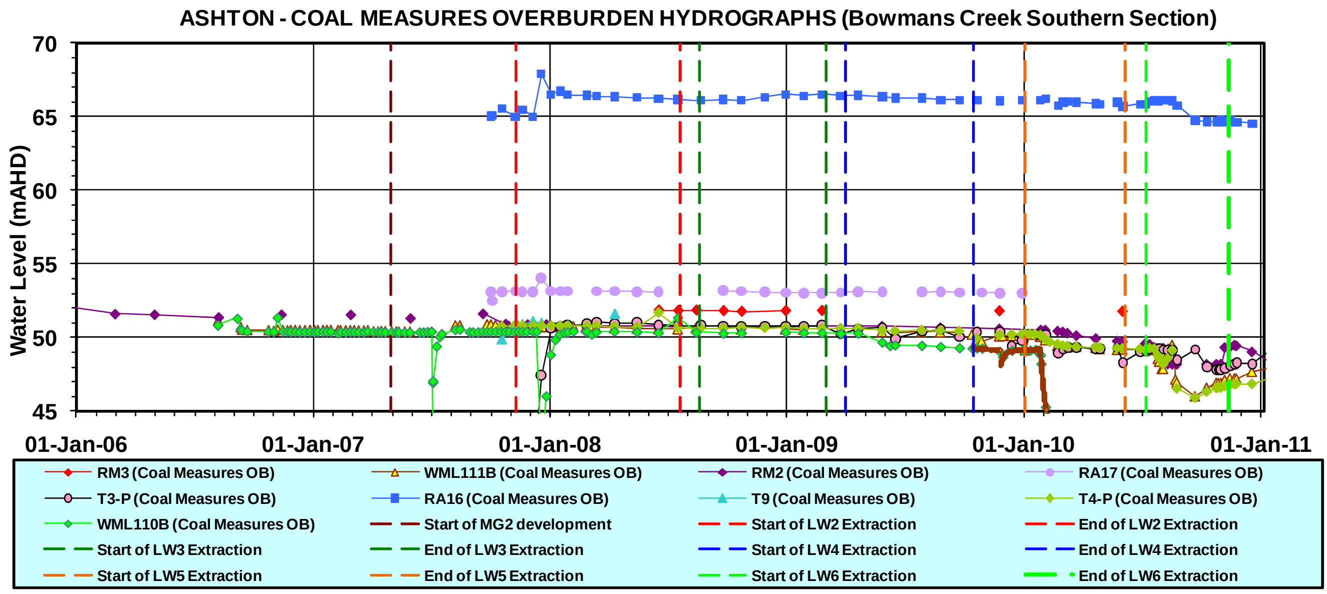

Date 13 January 2011	Scale	**Ashton Coal Operations Ltd**
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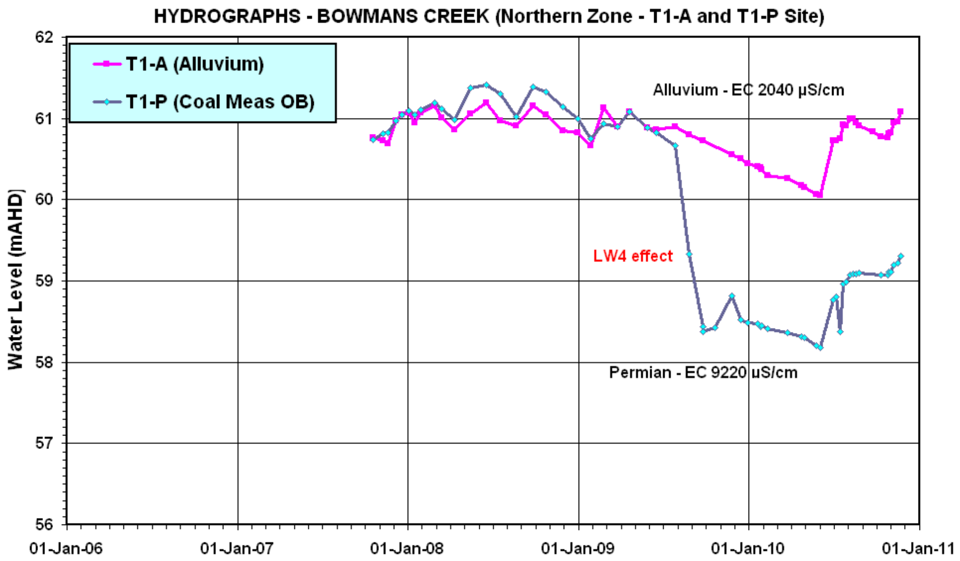
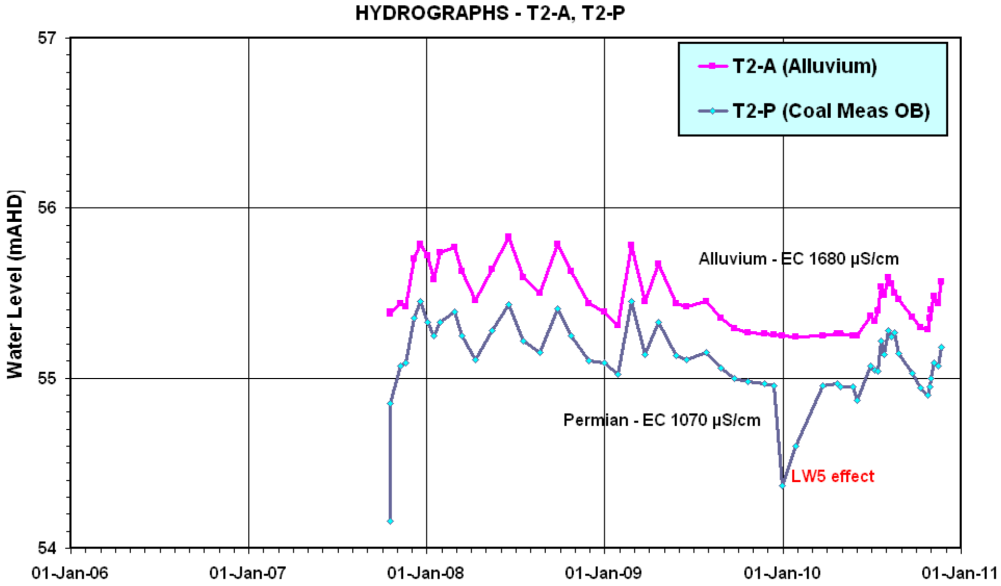
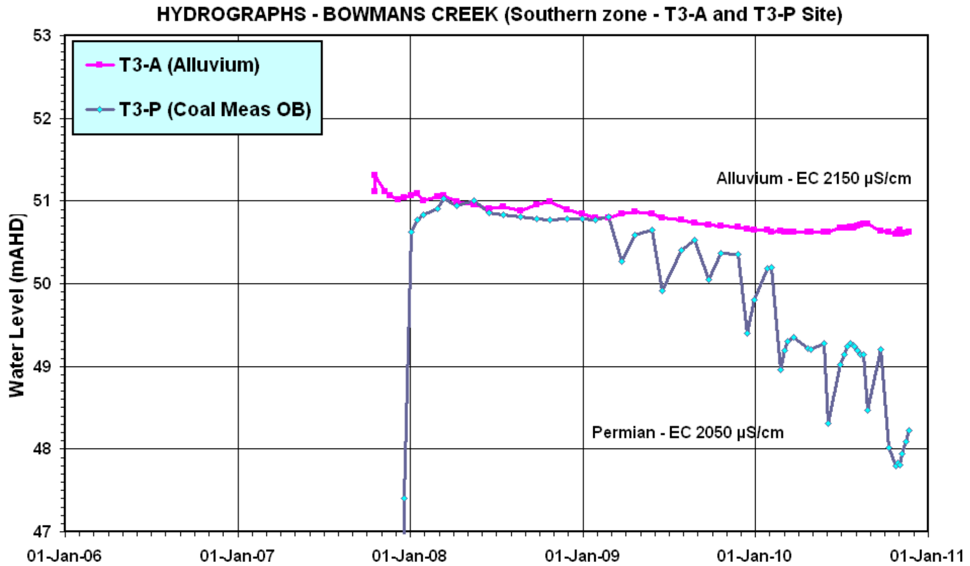
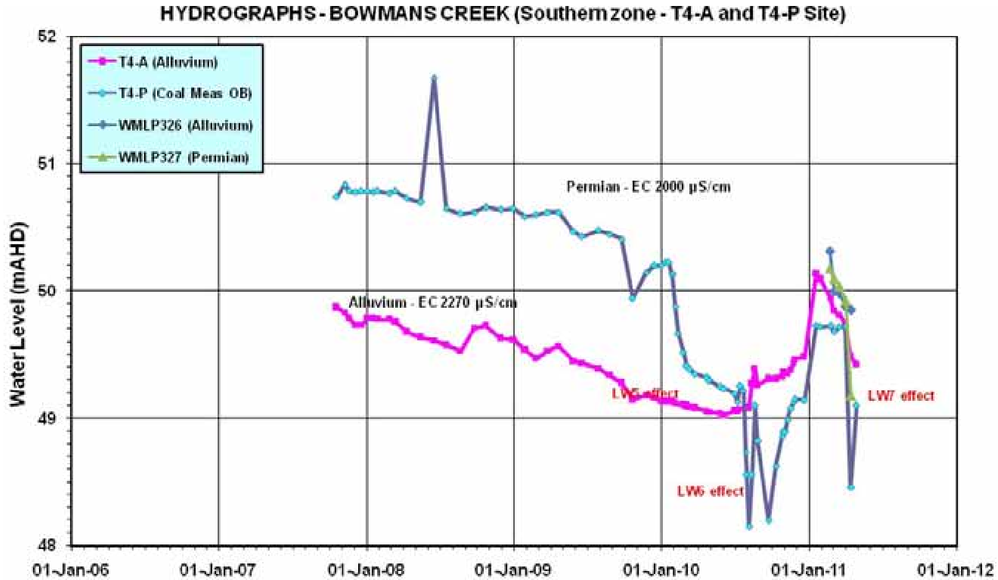
Drawing Number srf-018	Revision C	
RPS Aquaterra		**Figure 14**









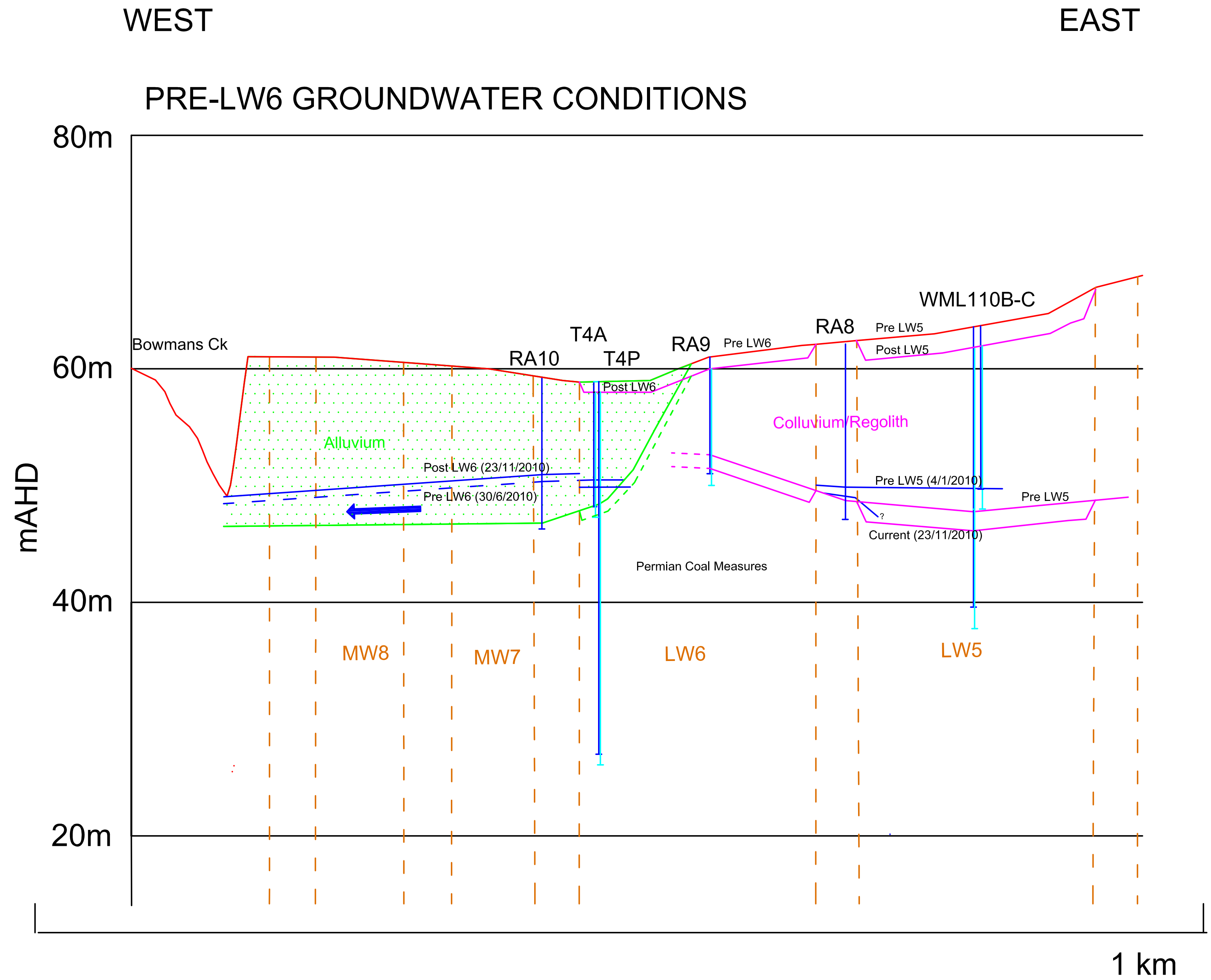
Date	2 December 2010	Scale	
Initials	TL	Project	S55 D5
Drawing Number	srf-025	Revision	A

RPS Aquaterra

Ashton Coal Operations Ltd

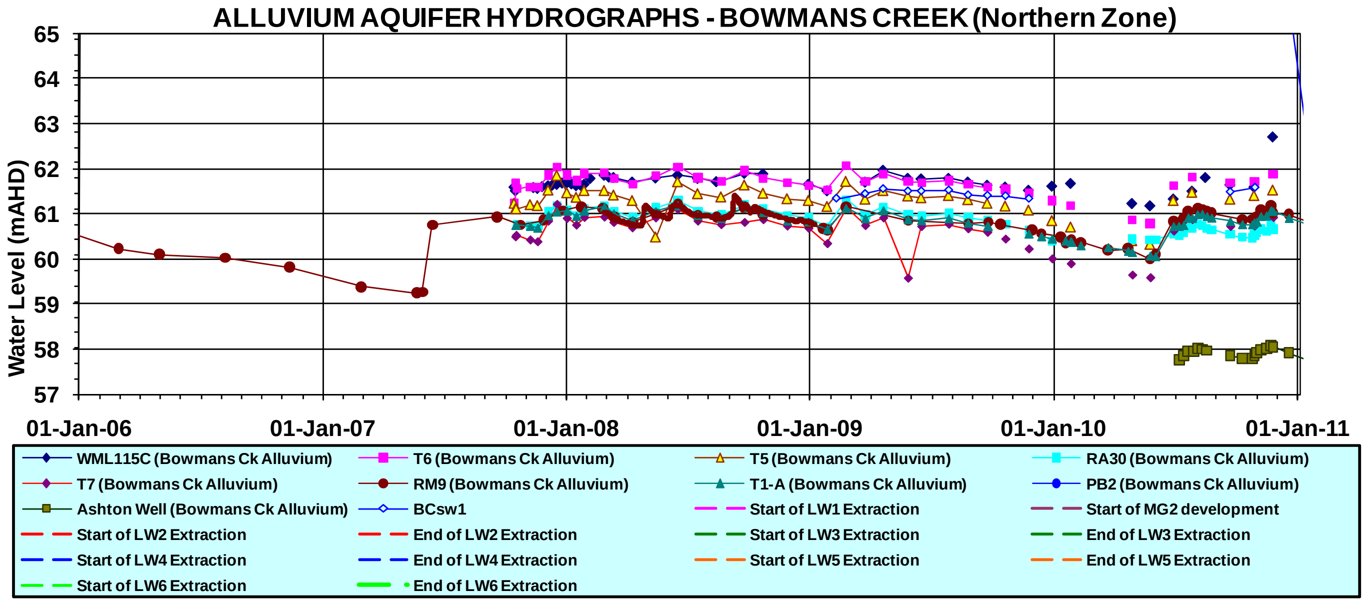
GROUNDWATER LEVEL HYDROGRAPHS
BOWMANS CREEK ALLUVIUM

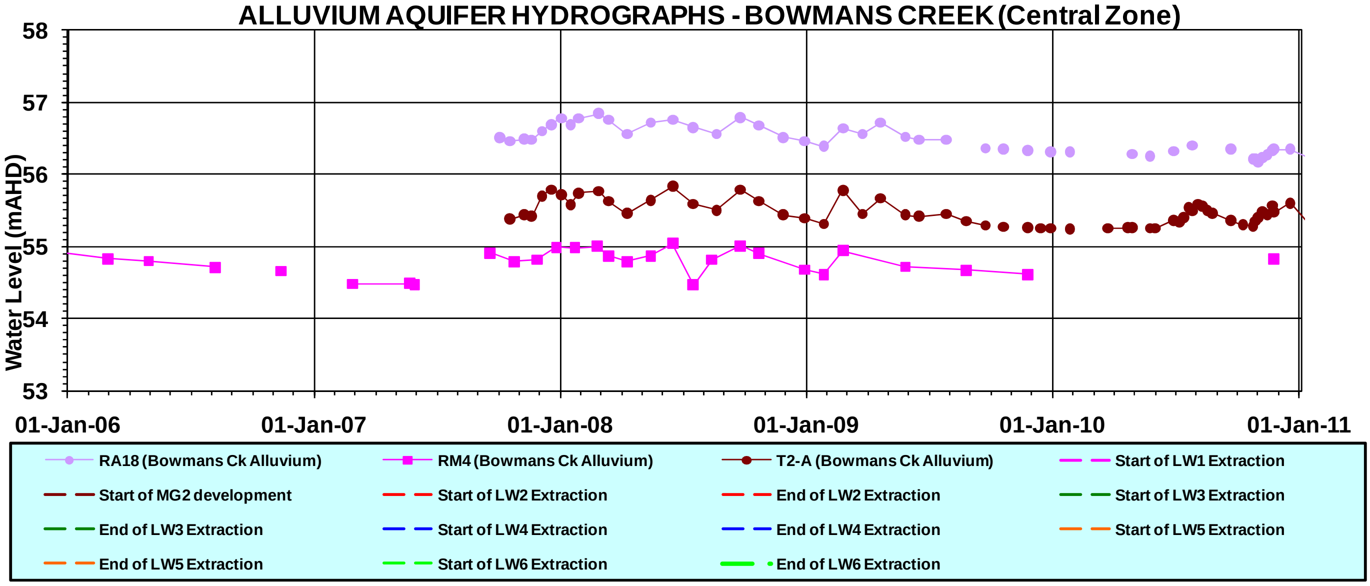
Figure 15

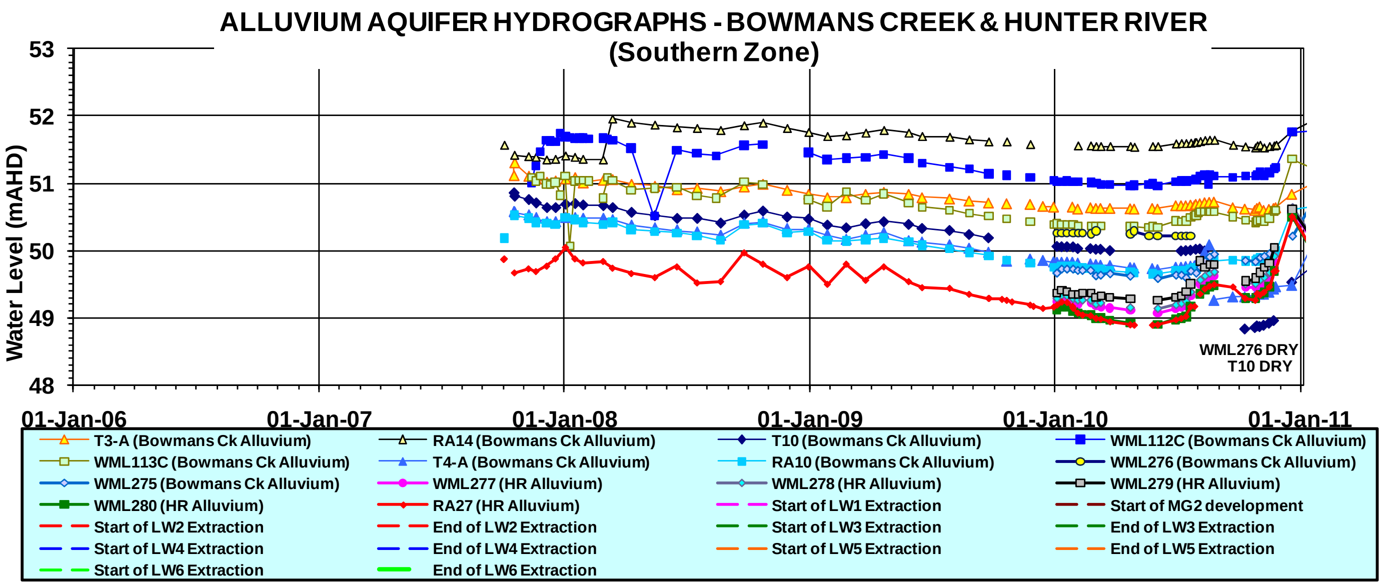


Legend
- Groundwater Flow
- Water Table
- Base of Alluvium
- Base of Colluvium
- Chain Pillars

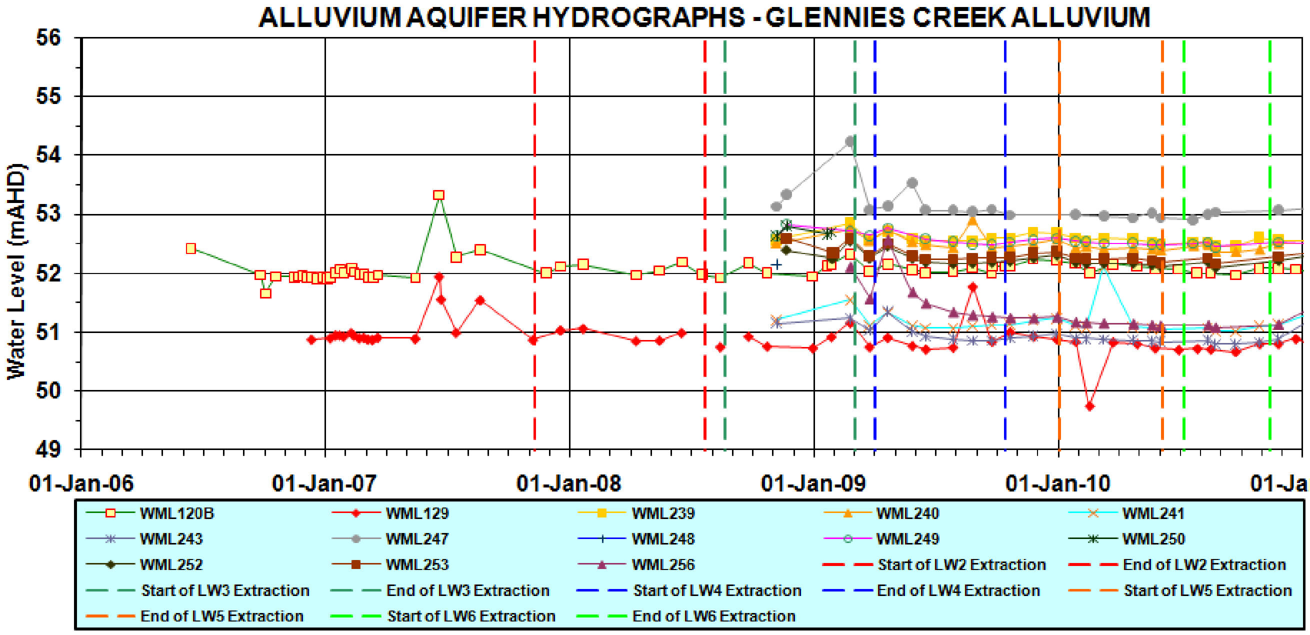
DATE: 02-12-10	SCALE: as indicated	**ASHTON COAL PTY LTD**
AUTHOR: JVDA CHECKED: PD	PROJECT NO: S55 H3	**LW6 EAST - WEST HYDROGEOLOGICAL CROSS SECTION LW6**
DRAWING NO: S55-305m	REVISION: M	
RPS Aquaterra		**Figure 16**

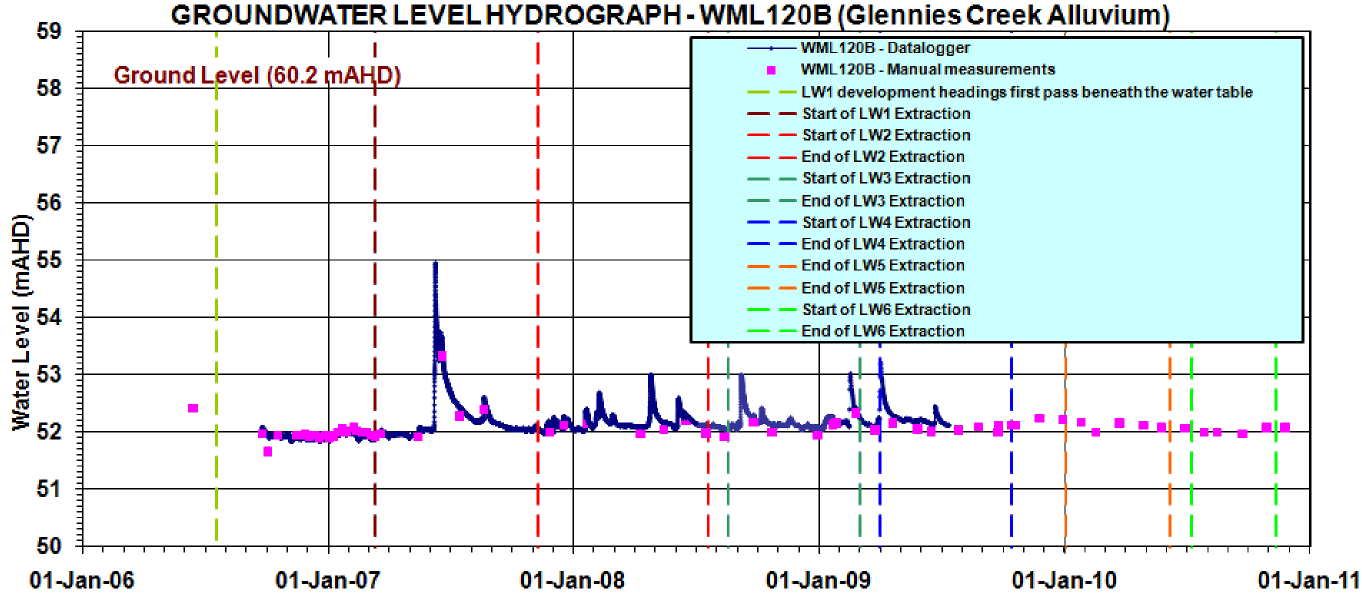


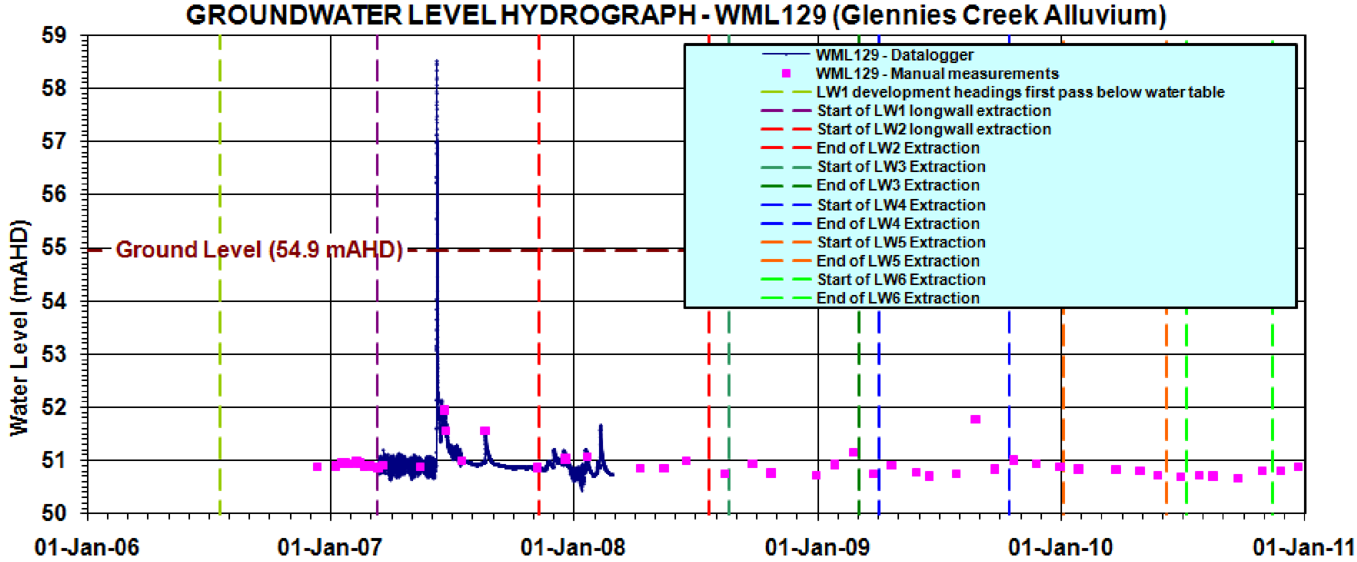




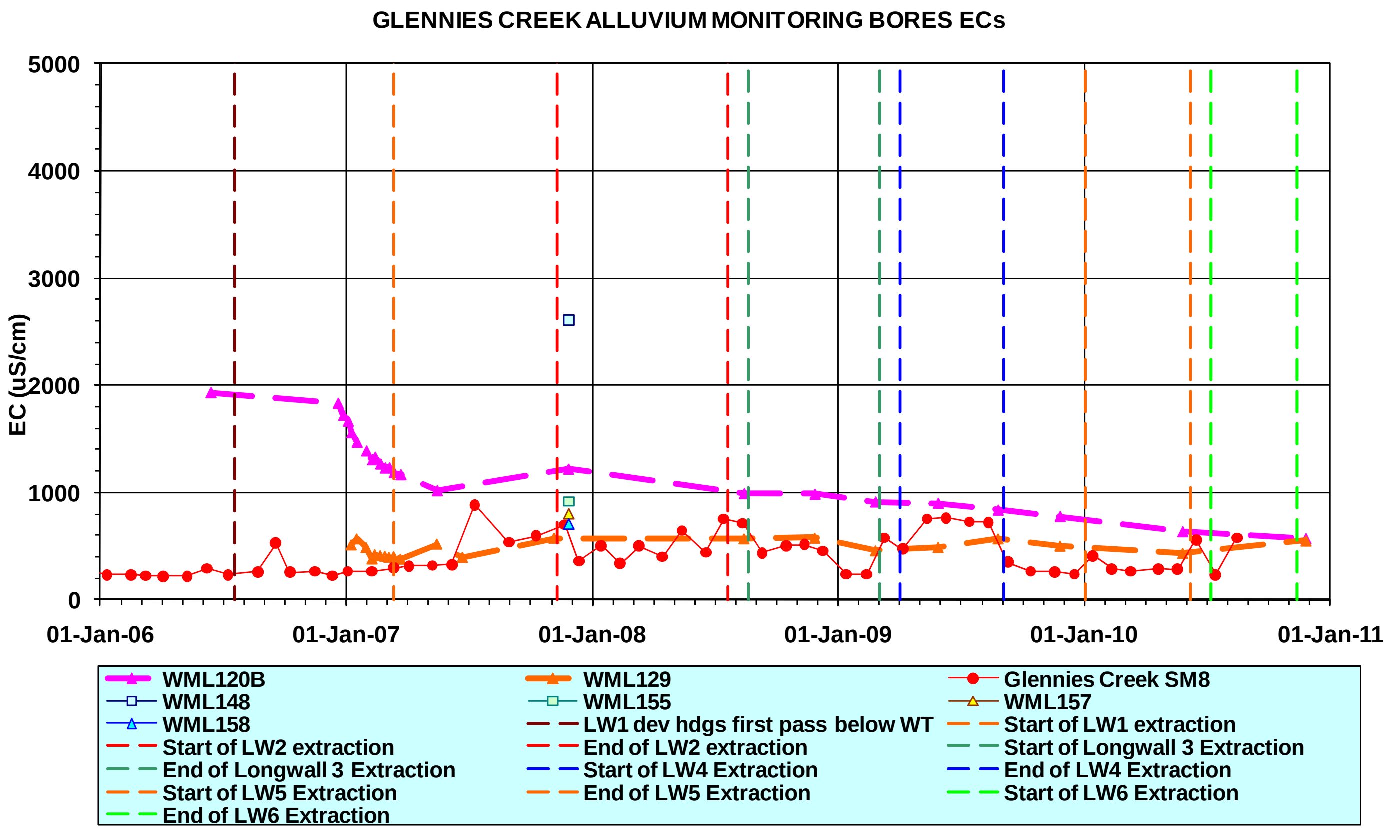
Date 13 January 2011	Scale	**Ashton Coal Operations Ltd**
Initials TL	Project S55 D5	GROUNDWATER LEVEL HYDROGRAPHS BOWMANS CREEK & HUNTER RIVER ALLUVIUM
Drawing Number srf-017	Revision C	
RPS Aquaterra		**Figure 17**

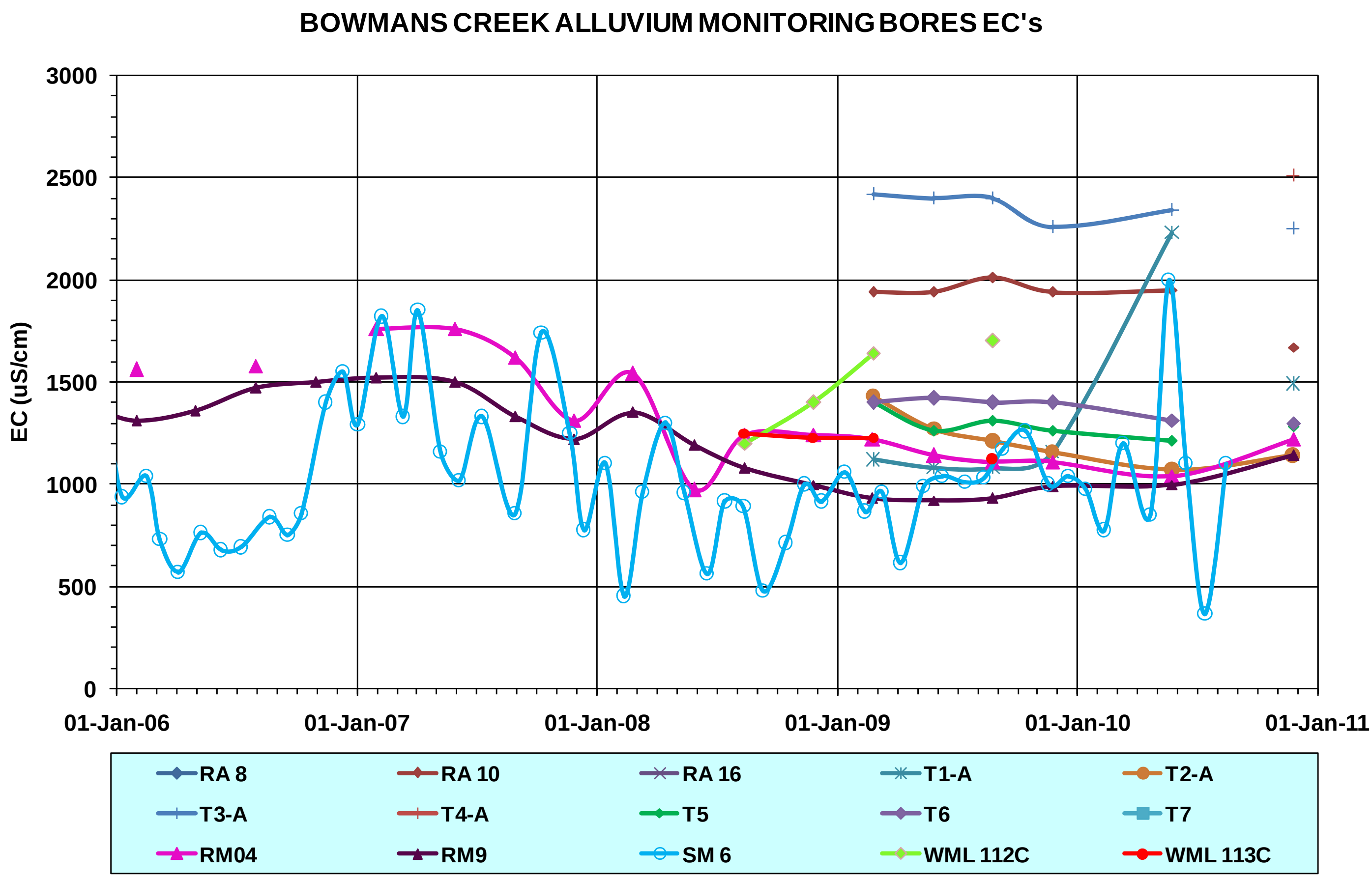




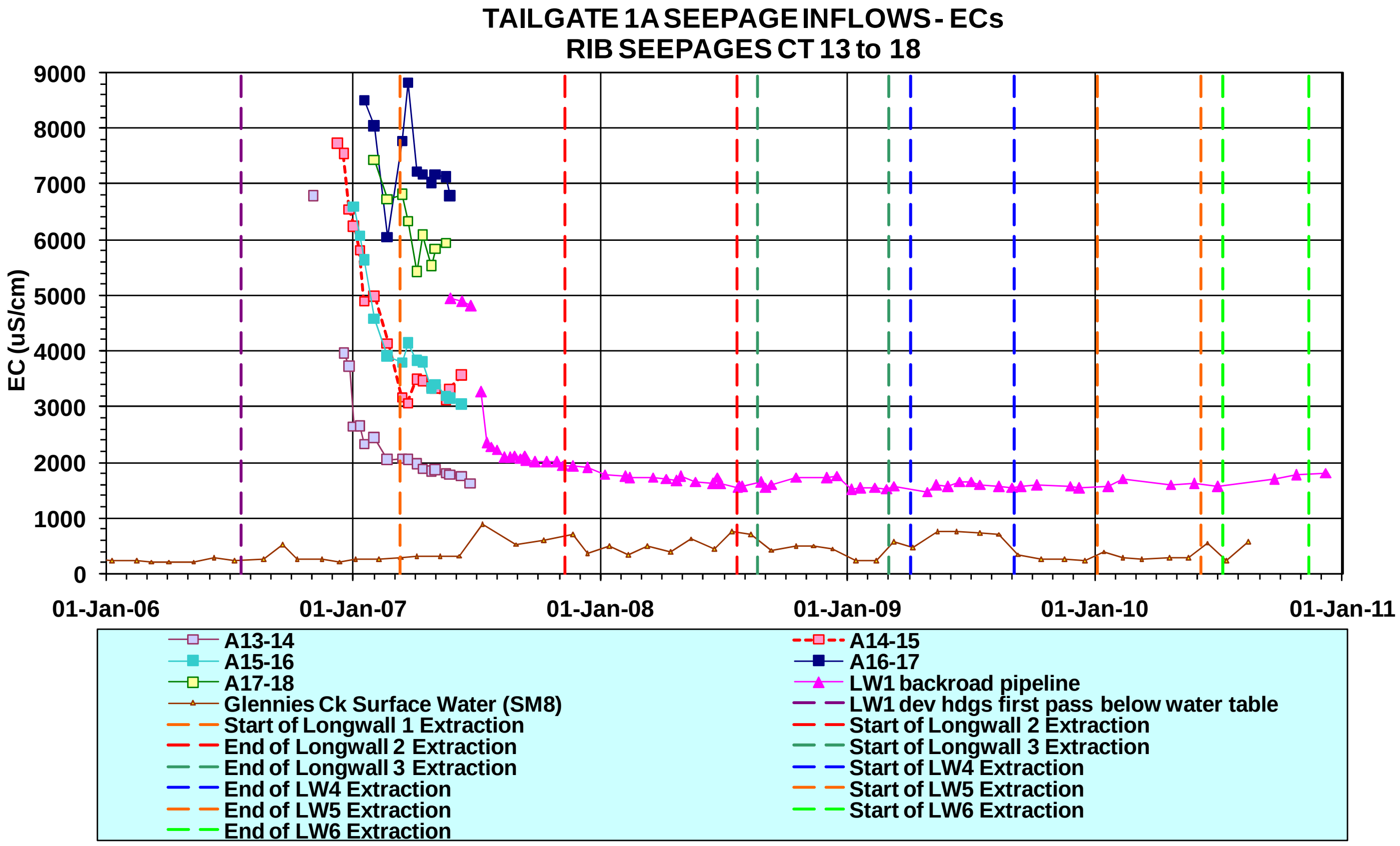


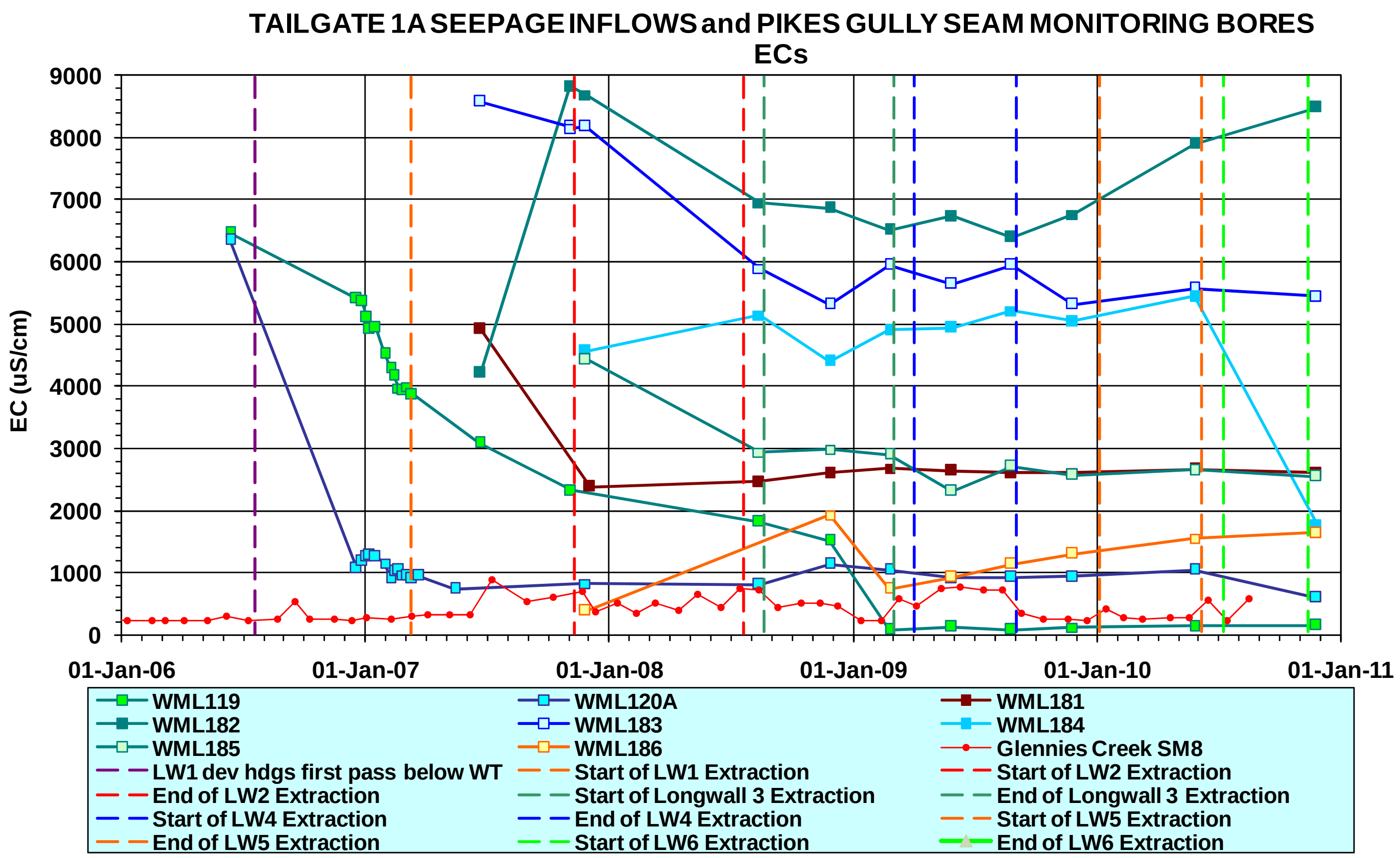
Date 13 January 2011	Scale	**Ashton Coal Operations Ltd**
Initials TL	Project S55 D5	GROUNDWATER LEVEL HYDROGRAPHS GLENNIES CREEK ALLUVIUM
Drawing Number srf-023	Revision C	
RPS Aquaterra		**Figure 18**



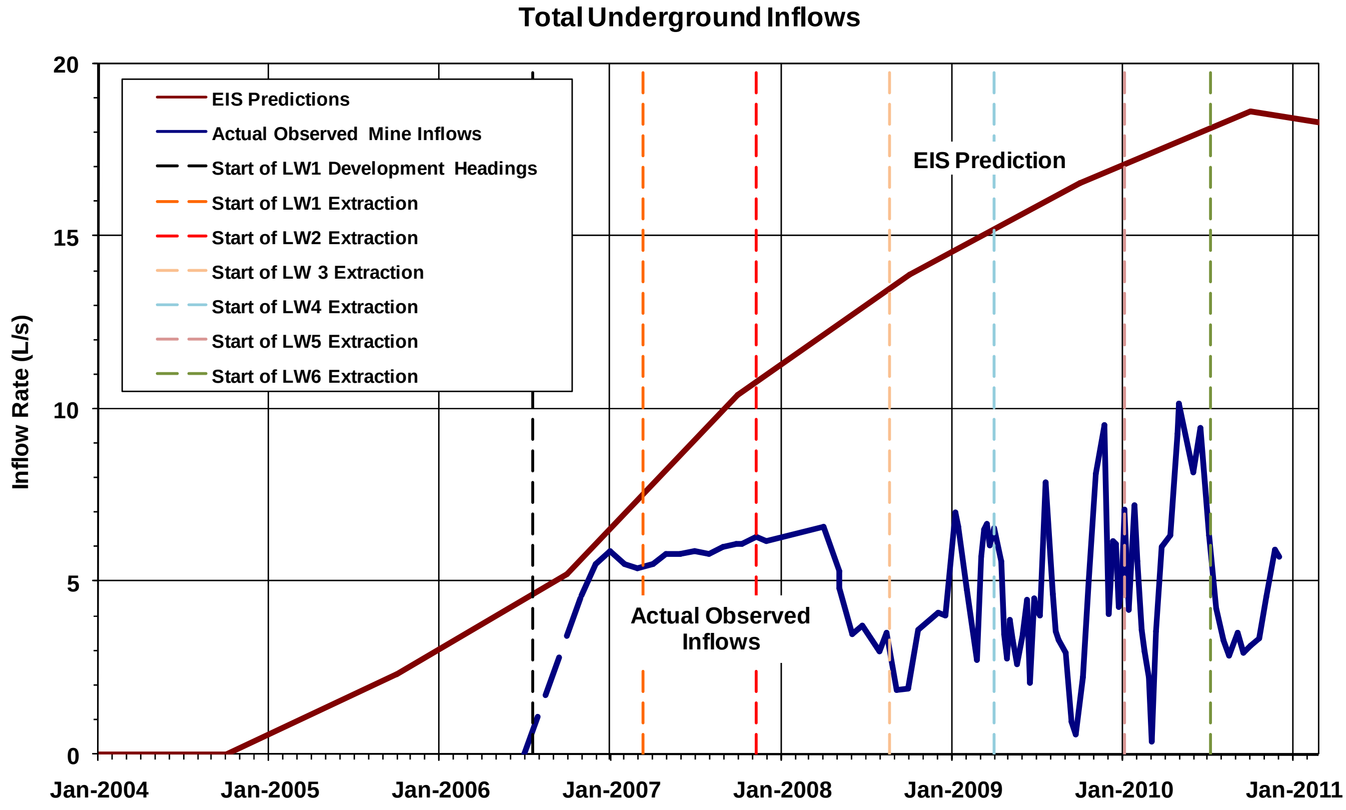


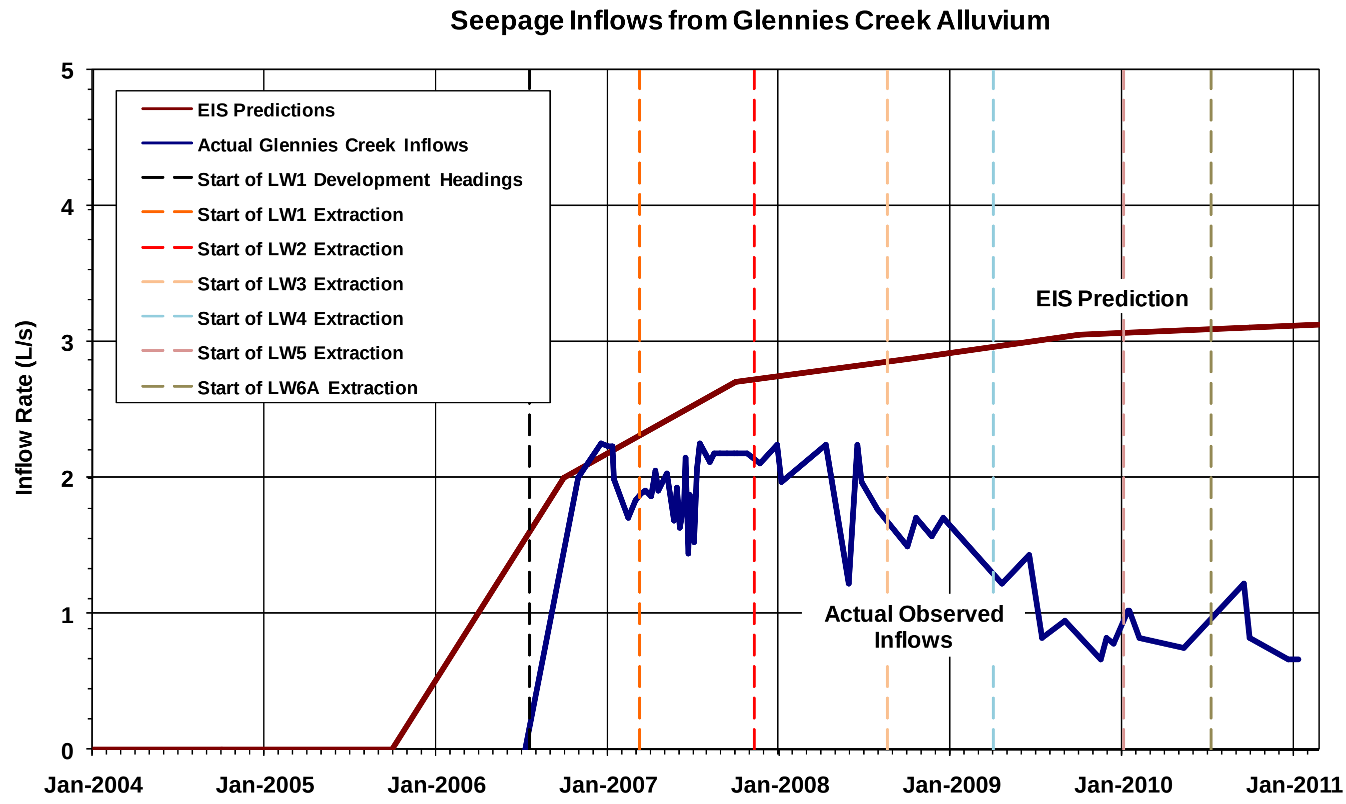
Date 17 January 2011	Scale	**Ashton Coal Operations Ltd**	
Initials TL	Project S55 D5	GROUNDWATER EC GLENNIES CREEK ALLUVIUM BOWMANS CREEK ALLUVIUM	
Drawing Number srf-013	Revision C		
RPS Aquaterra			**Figure 19**





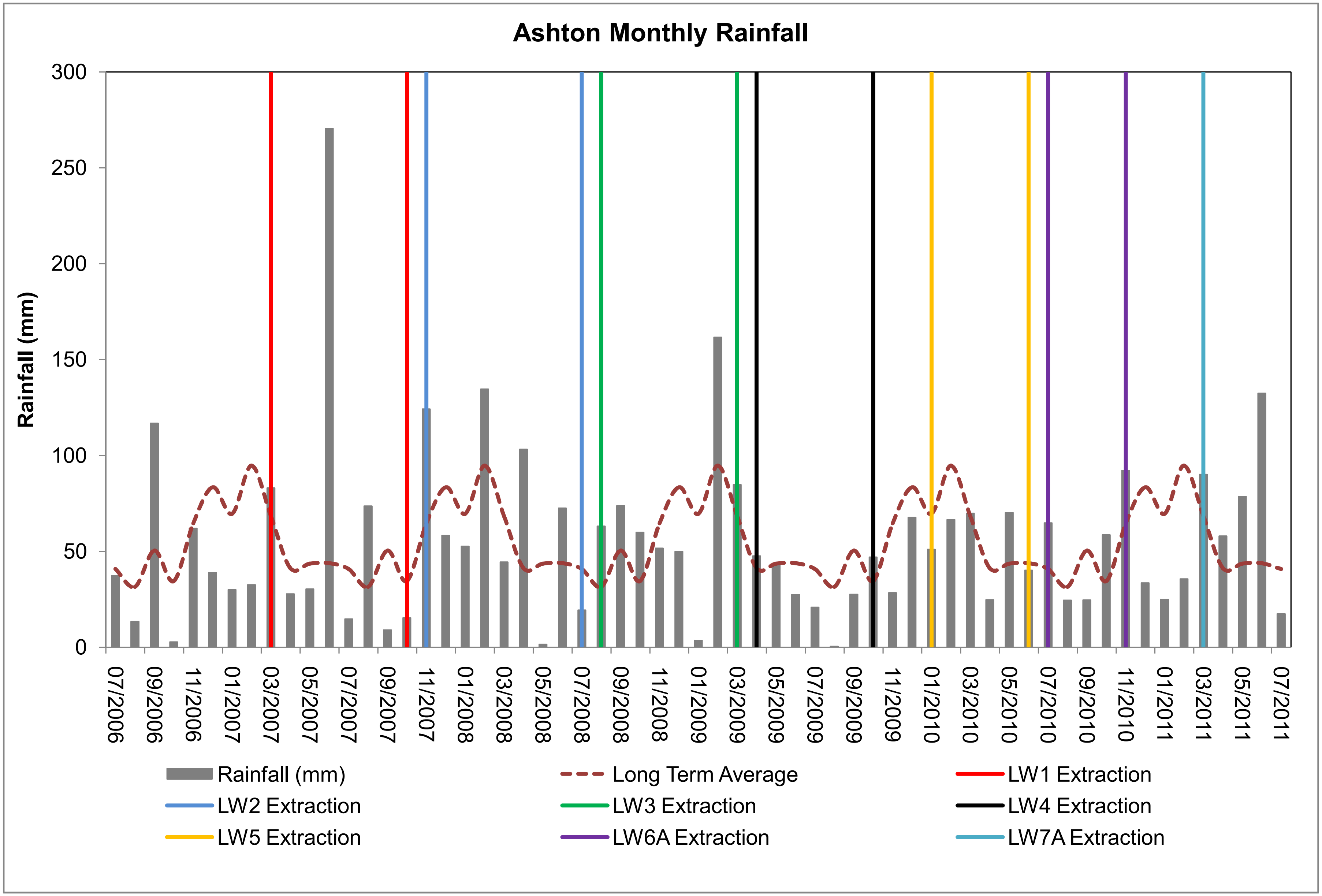
Date 17 January 2011	Scale	**Ashton Coal Operations Ltd**
Initials TL	Project S55 D5	GROUNDWATER EC TAILGATE 1A SEEPAGES PIKES GULLY
Drawing Number srf-014	Revision C	
RPS Aquaterra		Figure 20





Date	13 January 2011	Scale	**Ashton Coal Operations Ltd**
Initials	TL	Project S55 D4	GROUNDWATER INFLOW vs EIS PREDICTIONS
Drawing Number srf-015		Revision B	
RPS Aquaterra			Figure 21

Appendix A:
Monthly Rainfall


Ashton Monthly Rainfall
Rainfall (mm)
300
250
200
150
100
50
0
07/2006
09/2006
11/2006
01/2007
03/2007
05/2007
07/2007
09/2007
11/2007
01/2008
03/2008
05/2008
07/2008
09/2008
11/2008
01/2009
03/2009
05/2009
07/2009
09/2009
11/2009
01/2010
03/2010
05/2010
07/2010
09/2010
11/2010
01/2011
03/2011
05/2011
07/2011
Rainfall (mm)
Long Term Average
LW1 Extraction
LW2 Extraction
LW3 Extraction
LW4 Extraction
LW5 Extraction
LW6A Extraction
LW7A Extraction

Rainfall Data 2006 – 2007		
Month	**Rainfall (mm)**	**Long Term Median Rainfall (mm)**
Jul-06	37.40	40.8
Aug-06	13.40	31.5
Sep-06	116.8	50.4
Oct-06	2.8	34.5
Nov-06	62	64.6
Dec-06	39.0	83.4
Jan-07	30.0	69.6
Feb-07	32.6	94.7
Mar-07	83.0	68.5
Apr-07	27.8	41.3
May-07	30.4	43.6
Jun-07	270.5	43.8
Jul-07	14.8	40.8
Aug-07	73.7	31.5
Sep-07	9.0	50.4
Oct-07	15.4	34.5
Nov-07	124.2	64.6
Dec-07	58.2	83.4
Jan-08	52.6	69.6
Feb-08	134.6	94.7
Mar-08	44.4	68.5
Apr-08	103.2	41.3
May-08	1.6	43.6
Jun-08	72.6	43.8
Jul-08	19.4	40.8
Aug-08	63.2	31.5
Sep-08	73.8	50.4
Oct-08	60.0	34.5
Nov-08	51.6	64.6
Dec-08	50.0	83.4
Jan-09	3.6	69.6
Feb-09	161.6	94.7
Mar-09	84.8	68.5
Apr-09	47.6	41.3
May-09	42.8	43.6
Jun-09	27.4	43.8
Jul-09	20.9	40.8
Aug-09	0.4	31.5
Sep-09	27.6	50.4
Oct-09	47.0	34.5
Nov-09	28.4	64.6
Dec-09	67.6	83.4
Jan-10	51.0	69.6
Feb-10	66.6	94.7
Mar-10	69.8	68.5
Apr-10	24.8	41.3

Rainfall Data 2006 – 2007		
Month	**Rainfall (mm)**	**Long Term Median Rainfall (mm)**
May-10	70.2	43.6
Jun-10	40.2	43.8
Jul-10	64.8	40.8
Aug-10	24.5	31.5
Sep-10	24.6	50.4
Oct-10	58.6	34.5
Nov-10	92.2	64.6
Dec-10	33.6	83.4
Jan-11	25.0	69.6
Feb-11	35.6	94.7
Mar-11	90.2	68.5
Apr-11	58.0	41.3
May-11	78.6	43.6
Jun-11	132.4	43.8
Jul-11	17.4	40.8