RPS Aquaterra

UPPER LIDDELL SEAM EXTRACTION PLAN
GROUNDWATER IMPACT ASSESSMENT

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EXECUTIVE SUMMARY

The purpose of this report is to revise the predictions of the potential groundwater impacts attributed to the Upper Liddell (ULD) Seam longwall (LW) mining development, within the Ashton Coal Project (ACP). The revised impacts have been refined based on additional hydrogeological information that has been acquired since the original Development Consent (DC) was granted.

The findings contained in this report form part of the ACP ULD Extraction Plan and are presented in two stages, LWs 1 to 4 and LWs 5 to 8. The assessment includes a revision of cumulative impacts from the completion of mining in the Pikes Gully (PG) Seam.

The assessment meets the conditions contained within the Ashton Coal Operations Pty Ltd (ACOL) DC (309-11-2001-MOD7) for a coal Extraction Plan, which was approved by the Department of Planning & Infrastructure (DP&I) on 15 June 2011. DC condition requirements of groundwater relevance are listed in **Appendix A** with the relevant section numbers from this report that contain information applicable to address the conditions. The DC conditions and commitments made by ACOL encompass:

- The revision of predictions made in previous approved documents for subsidence and groundwater impact/environmental consequences;
- Performance measures to be in place for key environmental indicators; and
- Compliance measures to be established, including a water management plan to manage and mitigate water related impacts from the development.

A comparison has been made of the revised impacts against the predictions that were made in the groundwater impact assessment reports for the EIS (HLA, 2001) and the Bowmans Creek Diversion Environment Assessment (EA) (Evens & Peck, 2009 and Aquaterra, 2009e). The revised groundwater related impacts of ULD LW1 to 8 are consistent with, or below the performance measures contained within the EIS (HLA, 2001), EA for the Bowmans Creek Diversion (Aquaterra 2009e), and the Statement of Commitments (Schedule C of the DC), that were developed in response to EA submissions.

The revised predictions of groundwater impacts contained in this report are primarily based on the model developed for the Bowmans Creek Diversion Modification (Aquaterra, 2009e and Evens & Peck, 2009). This model, through a number of upgrades, had been modified and improved from the original EIS (HLA, 2001). Since these studies, ongoing groundwater monitoring and specific investigations have been conducted to improve the understanding of the effects of subsidence and hydraulic characteristics of the ULD seam. Further, the ULD LW1 to 8 mine plan that was simulated in this assessment is offset to the west of the overlying PG LW1 to 8 mine plan, by approximately 60m. The offset will minimise any additional baseflow losses from Glennies Creek, caused by the extraction of ULD LW1 (and subsequent LW's), by maintaining the permeability characteristics of the hard rock within the barrier between ULD LW1 and Glennies Creek.

The additional modifications that have been incorporated into to the latest model (since the DC was first granted) has resulted in an improved simulation of mine inflows and some minor reductions of predicted impacts, specifically in terms of baseflow impacts to Glennies Creek, Bowmans Creek and the Hunter River. As such, the revised groundwater impacts outlined in this report are consistent with, or below the predicted levels outlined in the BCD EA (Aquaterra, 2009) and in the original EIS (HLA, 2001). The main outcomes from this review are summarised in **Table E1**.

Table E1: Comparison of Revised Groundwater Impacts to 2001 EIS and 2009 EA Predictions

Impact Description	Modelled Impact ULD LW1-4		Modelled Impact ULD LW5-8		2009 BCD EA, LW1-8	2001 EIS LW1-6
	Total (PG+ULD)	Additional (ULD only)	Total (PG+ULD)	Additional (ULD only)	Total (PG+ULD)	Total (PG+ULD)
Groundwater drawdown to the Glennies Creek alluvium south of ULD LW1	0.11m	0.06m	0.16m	0.11m	*NR*	*NR*
Groundwater drawdown to the Glennies Creek alluvium east of PG and ULD LW1	**0.18m**	0.04m	**0.20m**	0.06m	*NR*	2.5m
Groundwater drawdown impacts to the Hunter River alluvium southwest of ULD LW1	0.0m	0.0m	0.0m	0.0m	0.0m	*NR*
Groundwater drawdown impacts to the Hunter River alluvium south of ULD LWs 5 to 7	0.01m	0.01m	0.01m	0.01m	0.01m	<0.5m
Groundwater drawdown impacts to the Bowmans Creek alluvium (in the vicinity of the oxbow)	**0.45m**	0.13m	**0.73m**	0.41 m	1.7m	*NR*
Baseflow impacts to Glennies Creek	**2.9L/s**	0.3L/s	**3.0L/s**	0.4L/s	*NR*	3.3 - 5.5L/s
Baseflow impacts to Bowman Creek	**0.59L/s**	0.14L/s	**0.86L/s**	0.41L/s	0.5 - 1.2L/s	4.3 - 4.6L/s
Baseflow impacts to Hunter River	**0.13L/s**	0.06L/s	**0.23L/s**	0.16L/s	0.3 - 0.5L/s	2.9 - 3.5L/s
Total underground inflows	16L/s	1 - 10L/s	**14 - 16L/s**	14L/s	14 - 16L/s	17.6 -19L/s

NR = Impact not reported. Values in green are less than 2009 BCD EA or 2001 EIS predictions

Summary of Potential Impacts

The impacts of mining on groundwater (largely due to dewatering, and the impacts of subsidence fracturing on aquifer properties) can affect the interaction between surface water and groundwater resources often incurring losses from the alluvium and baseflow in watercourses.

The layout of the ULD LW1 to 4 area has been configured to minimise baseflow losses by avoiding alluvial aquifers, the Rivers and creeks. At its closest point, ULD TG1 will be offset about 185m to the west of Glennies Creek, and ULD LW4B is offset by at least 40m from the high bank of Bowmans Creek. ULD LW5 to 8 mining will be offset by at least 200m from the Hunter River Alluvium, but mining will occur below the Bowmans Creek alluvium, although mining will be at a much greater depth as the strata dip towards the west.

This assessment has focused on impacts to four key areas where mining will occur closest to the alluvium including:

- Glennies Creek Alluvium to the east of ULD LW1;
- Glennies Creek and Hunter River Alluvium to the south of ULD LW1;
- Hunter River Alluvium directly south of ULD LW5 to 8; and
- Bowmans Creek Alluvium in the vicinity of the Oxbow, west of ULD LW4.

Revised baseflow impacts are also summarised for Glennies Creek, the Hunter River and Bowmans Creek. Both the drawdown and baseflow impacts are summarised at key times, which are aligned with the completion of ULD LW4 and ULD LW8.

ULD LW1 to 4 Mining Impacts summary

The revised predicted impacts caused by ULD LW 1 to 4 mining are consistent with, or below the predictions made in the groundwater impact assessment reports of the EIS (HLA, 2001) and the Bowmans Creek Diversion EA (Aquaterra, 2009e) for this stage of mining. The revised impacts indicate the following:

- Drawdown to Glennies Creek alluvium is predicted to increase to 0.11m south east of ULD LW1 at the end of ULD LW4 mining (2014). This represents an additional impact of 0.06m post PG mining cessation;
- There is very little alluvium on the western side of Glennies Creek in the area closest to the underground mine. Here, the drawdown is predicted to increase to 0.18m at the end of ULD LW4 mining (2014) and represents an additional impact of 0.04m post PG mining cessation. The revised impact is consistent with the 2009 EA prediction, but is much lower than the 2001 EIS prediction of 2.5m;
- No impact to the Hunter River alluvium to the south west of ULD LW1 and south of ULD LW5 to 7, which is consistent with both the 2001 EIS and 2009 EA predictions;
- Drawdown to the Bowmans Creek alluvium at the oxbow are mostly residual effects from the mining of the PG Seam. Drawdown is predicted to increase to 0.45m at the end of ULD LW4 mining (2014) and represents an additional impact of 0.13m post PG mining cessation. The revised impact is consistent with the 2009 EA prediction for this stage of mining;
- Baseflow impacts to Glennies Creek are predicted to increase to 2.9L/s (0.25ML/d), from 2.6L/s (0.22ML/d) at the cessation of ULD LW4 mining. This represents an additional baseflow impact of 0.3L/s (0.026ML/d) post PG mining cessation. The revised impact is consistent with the 2009 EA predictions and lower than the 2001 EIS prediction of 3.3L/s (0.28ML/d);
- Bowmans Creek baseflow is predicted to change from a slightly gaining creek 0.011L/s to a creek that loses about 0.15L/s (0.012ML/d) at the cessation of ULD LW4 mining. This represents an additional baseflow impact of 0.12L/s (0.011ML/d) post PG mining cessation. The revised impact is lower than the impacts predicted in the 2009 EA (0.5L/s / 0.04ML/d) and 2001 EIS (4.3L/s / 0.37ML/d) for this stage of mining;
- A small reduction in baseflow contribution to the Hunter River of 0.13L/s (0.011ML/d) at the cessation of ULD LW4 mining. This represents an additional baseflow impact of only 0.06L/s (0.004ML/d) post PG mining cessation. The revised impact is lower than the impacts predicted in the 2009 EA (0.3L/s / 0.026ML/d) and 2001 EIS (2.9L/s / 0.25ML/d) for this stage of mining; and
- No Groundwater Dependant Ecosystems (GDE's) or existing users were identified in areas where groundwater impacts may occur. There are small stands of River Red Gums on the eastern side of Glennies Creek, which will not be impacted by the extraction of ULD LW1 to 4.

ULD LW5 to 8 Mining Impacts summary

The revised predicted impacts caused by ULD LW 5 to 8 mining are consistent with, or below the predictions made in the groundwater impact assessment reports of the EIS (HLA, 2001) and the Bowmans Creek Diversion EA (Aquaterra, 2009e) for this stage of mining. The revised impacts indicate the following:

- Drawdown to Glennies Creek alluvium is predicted to increase slightly to 0.16m to the south east of ULD LW1, and to 0.2m, to the east of ULD LW1 at the end of ULD LW8 mining (2016). The revised drawdown to the east of ULD LW1 is consistent with the 2009 EA prediction, but is much lower than 2001 EA prediction of 2.5m for this stage of mining;
- No impact to the Hunter River alluvium to the south west of ULD LW1 and south of ULD

LW5 to 7, which is consistent with both the 2001 EIS and 2009 EA predictions;

- Drawdown to Bowmans Creek alluvium is mostly residual effects from the mining of the PG Seam. Drawdown to Bowmans Creek alluvium at the oxbow is predicted to increase to 0.73m at the end of ULD LW8 mining (2014), and represents an additional impact of 0.41m post PG mining cessation. The revised impact is lower than the 2009 EA prediction of 1.7m for this stage of mining;
- Baseflow impacts to Glennies Creek are predicted to increase to 3.0L/s (0.26ML/d) at the cessation of ULD LW8 mining. This represents an additional baseflow impact of 0.4L/s (0.034ML/d) post PG mining cessation, however the additional impacts are minor since completing ULD LW4 mining. The revised impact is consistent with EA predictions, and is lower than EIS predictions of 5.5L/s (0.47ML/d) for this stage of mining;
- Baseflow impacts to Bowmans Creek are predicted to increase to 0.86L/s (0.074ML/d) at the cessation of ULD LW8 mining. This represents an additional baseflow loss of 0.41L/s (0.035ML/d) post PG mining cessation and 0.27L/s (0.023ML/d) since the completion of ULD LW4. The revised impact is lower than the impacts predicted in the 2009 EA (1.2L/s / 0.1ML/d) and 2001 EIS (4.62L/s / 0.4ML/d) for this stage of mining;
- A small reduction in the baseflow contribution to the Hunter River by 0.23L/s (0.02ML/d) at the cessation of ULD LW8 mining. This represents an additional baseflow reduction of 0.16L/s (0.014ML/d) post PG mining cessation and 0.1L/s (0.008ML/d) since the completion of ULD LW4. The revised impact is lower than the impacts predicted in the 2009 EA (0.5L/s / 0.04ML/d) and 2001 EIS (3.47L/s / 0.3ML/d) for this stage of mining; and
- No GDE's or existing users were identified in areas where groundwater impacts may occur. There are small stands of River Red Gums near the Hunter River, but these are located outside the zone of predicted drawdown, and therefore they will not be impacted by the extraction of ULD LW5 to 8.

The potential for surface water inflow to the underground mine as a result of mining beneath the Bowmans Creek floodplain during ULD LWs 6 to 8 have also been assessed. The presence of large subsidence troughs within the Bowmans Creek floodplain has the potential to cause large volumes of water to 'pond' in the subsidence troughs and drain into the mine workings via connective cracking if flooding occurs within the floodplain. In order to prevent this, the project includes proposals to first rehabilitate surface cracking and where practical reshape subsidence troughs to create a 'free draining' landscape to promote surface water flows to the downstream creek channel or floodplain.

Inflows to the underground from inundation of the troughs have been assessed to be minimal, in the range of 0.3 to 4.3L/s (0.03 to 0.37ML/d). The currently installed pump capacity is sufficient to handle the predicted peak inflow rates that might arise from a sudden flood event.

Compliance Measures

Compliance measures are currently in place to ensure the key performance indicators are met and to trigger an investigation if a situation arises where an exceedance is observed or anticipated.

Ongoing groundwater and surface water monitoring programs, which were implemented prior to the start of mining at the ACP, are detailed in the Site water management plans. These plans also include detailed contingency/response plans and address licensing, reporting and review requirements.

Recommendations

RPS Aquaterra recommends:

- The continuation of the current groundwater monitoring program and Trigger Action

Response Plans, and extending them to include:

- monitoring of water extracted from the Mine at lower seams as they are mined;
- when possible, monitoring of mine inflows related to the Glennies Creek barrier; and
- measures to monitor and mitigate the risk of flooding and inundation of subsidence troughs.

- Where possible, the installation of additional monitoring points around the southern portion ULD LW1 to detect any unforeseen impacts to the Glennies Creek and Hunter River alluvium. Ideally this should comprise:
  - two multilevel vibrating wire piezometers to target Permian coal measures at the southern end of ULD LW1.
  - one standpipe piezometer to target the Glennies Creek Alluvium, located directly west of WML129 (east of ULD LW1).
  - two standpipe piezometers to target the Hunter River Alluvium, located to the south and south west of ULD LW1.
- Increasing the monitoring frequency to fortnightly for standpipes/piezometers located in the barrier and south of ULD LW1 during critical stages of ULD LW1 extraction (i.e. at start of ULD LW1 extraction and as the LW face passes the closest point to Glennies Creek);
- Repeat hydraulic testing of standpipes in the barrier to determine whether permeability characteristics within the PG seam and overburden along the alignment of PG TG1 have been maintained following the advancement of ULD LW1;
- The re-surveying of subsidence impact monitoring lines across LW1 and subsequent periodic re-surveying of Lines during LW2 to 4 extraction to monitor lateral movement;
- Increasing the monitoring frequency to fortnightly of key standpipes to monitor any unforeseen impacts to the Bowmans Creek and Hunter River alluvium, during the early and/or final stages of ULD LW4B, LW6 and LW7 extraction; and
- A modelling post-audit or review to be carried out every five years throughout mine life to indicate any significant variance from Model predictions on groundwater quality or levels.

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FIGURES

Figures (continued)

APPENDICES

KEY TO ABBREVIATIONS

ACOL	Ashton Coal Operations Pty Limited
ACP	Ashton Coal Project
AEMR	Annual Environmental Management Report
BCD	Bowmans Creek Diversion
CCC	Community Consultative Committee
CHPP	Coal Handling and Preparation Plant
DC	Development Consent
DP&I	Department of Planning and Infrastructure
DPI	NSW Department of Primary Industries (division of DTIRIS)
DRE	Division of Resources and Energy (within DTIRIS)
DTIRIS	Department of Trade and Investment, Regional Infrastructure and Services (Trade & Investment)
EA	Environmental Assessment
EIS	Environmental Impact Statement
EL	Exploration Licence
EMP	Environmental Management Plan
EMS	Environmental Management System
EP	Extraction Plan
EP&A Act 1979	Environmental Planning Assessment Act 1979 (NSW)
EPA	Environment Protection Authority (part of OEH)
EPL	Environment Protection Licence
GDE	Groundwater Dependent Ecosystem
GWMP	Groundwater Management Plan
LB	Lower Barrett
Lem	Lemington
LW	Longwall
ML	Mining Lease
NEOC	North East Open Cut
NOW	NSW Office of Water
OEH	Office of Environment and Heritage, Division of NSW Department of Premier and Cabinet
PG	Pikes Gully
RUM	Ravensworth Underground Mine
SEOC	Proposed South East Open Cut Project
SMP	Subsidence Management Plan
SOC	Statement of Commitments
SSC	Singleton Shire Council

TARP	Trigger Action Response Plan
TG	Tailgate
UG	Underground
ULD	Upper Liddell
ULLD	Upper Lower Liddell
VWP	Vibrating Wire Piezometer
WMP	Water Management Plan
WSP	Water Sharing Plan

UNITS OF MEASUREMENT

µS/cm	Micro Siemens per centimetre (units of measurement for electrical conductivity)
AHD	Australian Height Datum
ARI	Average Recurrence Interval (measured in years, to determine flood size and likelihood)
EC	Electrical Conductivity
ha	Hectares
K	Hydraulic Conductivity
Kh	Horizontal Hydraulic Conductivity
kL	Kilolitres
km	Kilometres
Kv	Vertical Conductivity
L/s	Litres per second
m	Metres
m/s	Metres per second
mg/l	Milligrams per litre
ML	Megalitres
mm	Millimetres
Mt	Million tonnes
Mtpa	Million tonnes per annum
pH	Measure of acidity (<7) or alkalinity (>7) of a (water) sample
RL	Reduced Level (relative height (m) compared to Australian Height Datum (AHD))
TSS	Total Suspended Solids

1. INTRODUCTION

1.1 The Ashton Coal Project

Ashton Coal Operations Pty Limited (ACOL) operates the Ashton Coal Project (ACP) approximately 14km west of Singleton in the Hunter Valley, NSW. ACOL is a wholly owned subsidiary of Yancoal Australia Limited (Yancoal), which is the majority (90%) joint venture owner of the mine.

The ACP comprises an open cut mine, an underground mine, a coal handling and preparation plant (CHPP), rail loading facilities, run-of-mine (ROM) and product coals stockpiles, and various surface support infrastructure and facilities. Development consent (DA 309-11-2001) for the ACP was granted by the Minister for Planning in October 2002. The ACP is approved to produce up to 5.45Mtpa of ROM coal up to February 2024.

Construction of the open cut mine (the North East Open Cut – NEOC) commenced in 2002, and ceased coal production in September 2011. The mine void will be used for rejects and tailings emplacement for the remaining life of the underground mine.

The underground mine is a longwall operation which is approved to mine coal from the Pikes Gully (PG), Upper Liddell (ULD), Upper Lower Liddell (ULLD) and Lower Barrett (LB) coal seams (in descending order). The underground mine is located south of the New England Highway and is situated between the highway and the Hunter River. It is accessed from the highwall of the open cut pit, on the north side of the highway.

Development of the underground mine commenced in the PG seam in 2005 with longwall coal extraction commencing in 2007. The general longwall layout comprises eight longwall panels (LW1, LW2, LW3, LW4, LW5, LW6A & 6B, LW7A &7B and LW8). In 2012, longwall extraction in the PG seam will be completed and the longwall will be relocated to the ULD seam.

Installation of the drift from the PG Mains to access the ULD Seam commenced in 2010, and initial work on the ULD LW1 development headings in early 2011. ULD extraction is planned to commence during 2012. Longwall mining of the ULD Seam will commence following the completion of mining in the overlying PG Seam. Mining and the potential impacts of ULD Seam longwall extraction on the groundwater environment are considered in two stages – ULD LW1 to 4 and ULD LW5 to 8.

This report quantifies the individual impacts from the proposed extraction of the ULD seam. Cumulative impacts from the ACP and adjacent mining operations are also addressed.

1.2 Relevant Policies and Guidelines

This report has been prepared with reference to the following policies and guidelines:

- NSW Groundwater Policy Framework Document – General (DLWC, 1997);
- NSW Groundwater Quality Protection Policy (DLWC, 1998);
- NSW Groundwater Dependant Ecosystem Policy (DLWC, 2002);
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000);
- NSW Water Sharing Plan for the Hunter Regulated River Water (WSP), 2003; and
- NSW Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources (WSP), 2009.

1.3 Water Licensing

Water licensing at the ACP is administered under the *Water Management Act 2000* (WM Act) and *Water Act 1912* (W Act). Access to and share in entitlements for surface water and alluvial groundwater sources at the ACP is governed by the rules of the *Water Sharing Plan* *for the Hunter Regulated River Water Source 2003* and *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009.* Non-alluvial groundwater licences are governed by the W Act.

A complete list of ACOL's water access entitlements and licences is provided in **Appendix A.**

1.4 Scope of the Report

This report provides a review of the potential impacts from approved longwall extraction in the ULD Seam on groundwater levels, groundwater quality, mine inflows, groundwater dependent ecosystems (GDEs), stream baseflows, and other groundwater users.

The information contained within this report is based on data gathered from previous studies, ongoing monitoring and the results from calibrated groundwater models.

The report is structured as follows:

- Section 2 describes the pre mining hydrogeological environment;
- Section 3 outlines the ULD mining proposal and schedule;
- Section 4 outlines a summary of previous groundwater investigations, including those undertaken specifically in support of the ULD Extraction Plan;
- Section 5 describes the potential impacts of the proposed project in two separate stages (Stage 1 – LW 1 to 4 and Stage 2 – LW 5 to 8) on groundwater levels, groundwater quality, stream baseflow, GDEs and other groundwater users;
- Section 6 details proposed monitoring, mitigation and management strategies in relation to any identified potential impacts;
- Section 7 describes recommendations resulting from the impact assessment;
- Section 8 provides a list of references; and
- Appendices supporting this report contain:
  - Appendix A - Relevant Development Consent conditions which are addressed in this report.
  - Appendix B - A description of the existing hydrogeological environment to provide context.
  - Appendix C - A summary of the groundwater modelling processes utilised to determine potential impacts including model calibration.
  - Appendix D - Details of groundwater monitoring bores.
  - Appendix E - Results of hydraulic testing.
  - Appendix F - Results of water quality monitoring.

2. HYDROGEOLOGICAL ENVIRONMENT

2.1 Pre-Mining Groundwater Conditions

The pre-mining hydrogeological environment is described in detail in **Appendix B**. The key features are:

- The general groundwater flow direction within the Permian was to the south and the west. Groundwater flow is controlled by elevation with elevated areas of the subcrop on the eastern side of the underground mine, through to the deeper Permian associated with the Bayswater syncline to the west.
- Potentiometric head in the Permian was generally higher than the Bowmans Creek alluvium groundwater levels in the lower valley areas, particularly in the south near the Hunter River confluence. A similar situation occurs to the east within the Glennies Creek alluvium, where a potential for upwards flow from the Permian to the alluvium occurs in the baseline condition.
- Bowmans Creek, Glennies Creek and the Hunter River were all generally gaining watercourses in the pre-mining hydrogeological environment (i.e. alluvial groundwater contributed baseflow into the creeks and River).

2.2 Alluvium Hydraulic Connectivity

The alluvial sediments associated with Glennies Creek and Bowmans Creek comprise clay and silt-bound sands and gravel, with occasional coarser lenses or horizons where sands and gravel have been concentrated.

There is limited alluvium associated with Glennies Creek to the east of ULD LW1. The Glennies Creek alluvium has generally been found to be moderately or poorly permeable, with hydraulic conductivity values less than 1m/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.

The hydraulic connection between alluvial deposits and shallow weathered Permian sediments is limited to small localised variations, which is of particular relevance to water management. The limited hydraulic connection is evidenced by differences in groundwater levels, differences in groundwater quality and differing responses to recharge or mining activity.

The groundwater monitoring that was undertaken during PG LW5 to 7A extraction provided the first opportunity to observe the poor hydraulic connection between the alluvium and the underlying Permian coal measures. In all cases where there was a marked decline in head or pressure in the upper part of the coal measures, there has been no decline in head in the alluvium. This demonstrated that there is an effective aquiclude at the base of the alluvium, protecting the alluvium from drainage into subsidence affected strata beneath.

3. ULD SEAM MINE PLAN

3.1 ULD Seam Mine Schedule

The PG Seam mine workings and the approved panel layout for the underlying ULD Seam are shown in **Figure 1**. The proposed ULD mine extraction schedule is shown in **Figure 2**.

The layout of ULD Seam panels has been offset to the west of PG LW1 to 8 by approximately 60m. This offset will minimise the potential for increased interaction between ULD LW1 and Glennies Creek. It will also minimise the effect of cumulative subsidence from multi-seam mining.

The ULD mine plan also provides for an offset of at least 40m between the high bank of Bowmans Creek (in its diverted form) and ULD LW4B, 6B and 7A, and an offset of at least 200m between the Hunter River Alluvium and the southern extents of ULD LW5, 6A and 7A.

3.2 Interaction with Other Mines

ULD Seam secondary extraction will occur, at least in part, simultaneously with the progressive backfilling of the NEOC void (with rejects and tailings), ongoing operations at the Ravensworth Underground Mine (RUM) and Narama Open Cut Mine to the west. These activities will affect groundwater levels at the same time as ULD Seam mining. Accordingly, the cumulative impacts of these operations are addressed within this report.

The estimated mining schedule (up to 2016) for the ACP underground is shown in **Figure 2**. The ACP and the RUM schedules that have been included in the groundwater model are detailed in **Appendix C**.

4. GROUNDWATER INVESTIGATIONS

4.1 Summary of Previous Groundwater Investigations

As part of the approval process for the ACP, extensive groundwater investigations have been conducted and a detailed network of monitoring bores has been installed across the Site (see **Figure A5** and **Appendix D**).

Initial groundwater studies were undertaken during the period 2000 to 2003 as part of the development application process for the ACP and Environmental Impact Statement (EIS) (HLA, 2001).

Subsequent groundwater investigations were undertaken during 2006, in support of the SMP for PG Seam LW1 to 4 (Peter Dundon & Associates, 2006). This was followed by a focused drilling and hydraulic testing program in and around the Bowmans Creek floodplain in 2007 (Aquaterra, 2008b). The objective of the program was to delineate the extent of the saturated alluvium and to further define the nature and properties of the alluvial aquifer system. These investigations were completed in 2008 and used to support the SMP for the PG Seam LW/MW5 to 9 (Aquaterra, 2008c).

Further groundwater investigations (Aquaterra, 2009a, 2009e) were undertaken in 2008 and early 2009 to support the Bowmans Creek Diversion Environmental Assessment (EA) (Evans & Peck, 2009) and the Environmental Assessment for the South East Open Cut (SEOC) project proposal (Wells Environmental, 2009). The Bowmans Creek Diversion investigations, followed on from the extensive investigation into the alluvial aquifer properties and its relationship with the deeper Permian aquifers. The SEOC investigations focused on defining and understanding the hydrogeological environment on the eastern side of Glennies Creek.

Detailed information on previous groundwater investigations can be found in **Appendix C**.

4.2 Groundwater Investigations Undertaken for ULD Seam Extraction

4.2.1 Overview and Purpose

Previous groundwater investigations have been focussed on the PG Seam, its overburden and the shallow alluvium/colluvium/regolith layer. As part of the current assessment, specific investigations have been conducted to provide further information on the hydraulic characteristics of the ULD Seam in the zone between the eastern side of the underground mine and the subcrop of the seam beneath the Glennies Creek floodplain, and to provide additional monitoring points below the PG Seam. This involved the installation of one test/monitoring bore, one standpipe piezometer and one grouted multi-level vibrating wire piezometer (VWP).These were added to the existing groundwater monitoring network in order to obtain pre-ULD LW extraction baseline data and to enable the effect of ULD LW1 to 8 extraction on this water source to be monitored and quantified.

Piezometer Drilling and Construction

The locations of the three new bores (WML261, WML262, and WMLC248) are shown in **Figure 3**. All three are located east of the underground mining area, between the mine and Glennies Creek. The ULD sub-crop is located further to the east. The monitoring bore/standpipe piezometer was constructed in accordance with the minimum standards for construction requirements for water bores in Australia. Details on the construction methods and materials used are included in **Appendix D**.

Monitoring/test bore WML261 was drilled at a site on the western edge of the Glennies Creek floodplain, as close as practicable to ULD LW1 (near its northern end), and north of the section of Glennies Creek closest to the underground mine. The site is approximately 370m west of the ULD Seam subcrop. The ULD Seam is relatively shallow in this locality at around 30m below surface. WML261 was completed with 150mm diameter casing and a screen in order to allow for extended high rate test pumping if required.

Piezometer WML262 was drilled adjacent to existing PG Seam piezometers WML119 and WML186, located between LW1 and Glennies Creek. At this site, the ULD Seam is about 57m below surface, and approximately 640m to the west of the ULD Seam subcrop line. WML262 was completed to 60m with 50mm casing and screen.

Both WML261 and WML262 were screened across the ULD Seam, with the annulus gravel-packed through the screen interval and sealed above with a bentonite seal.

Borehole WMLC248 is located near WML261 and was completed with VWPs set at the ULD, ULLD, LB and Hebden seams, and encased in a fully grouted hole.

Hydraulic Testing

Constant Rates Tests (CRT) were performed on WML261 and WML262 using a low capacity pump. WML261 was subjected to a 45 minute constant rate (and recovery) test at a rate of $16m^3/d$. WML262 was subjected to a seven minute constant rate (and recovery) test at a rate of $14m^3/d$. The short duration of the pumping tests on both piezometers was due to rapid drawdowns to the pump inlet in both bores as a result of the low hydraulic conductivity of the ULD coal seam (screened unit).

The following analytical methods were used to analyse the pumping test results from the piezometers:

- Jacob's Straight-line Method for unsteady flow in a confined aquifer (Cooper and Jacob, 1946); and
- Theis Recovery Method (Cooper and Jacob, 1946), for unsteady state flow in a confined aquifer.

The recovery data measured in WML262 after the CRT were also analysed using the Hvorslev method (Hvorslev, 1951) for slug tests (Rising Head Test). This analysis is considered appropriate for obtaining an indicative estimate of hydraulic conductivity within the constraints of the short duration test and the very slow subsequent recovery of groundwater levels.

The analyses indicate that the horizontal hydraulic conductivities (Kh) in the ULD Seam are in the order of 0.002 to 0.03m/d. The higher hydraulic conductivity of 0.03m/d was measured in WML261 which is closer to the ULD subcrop and has shallower depth of cover than WML262, with permeability enhanced by the greater degree of unloading. This same trend is seen in the Pikes Gully seam, with bores WML120A and WML184 revealing permeabilities that are one to two magnitudes higher (0.2 to 7m/d) than the permeability of ULD seam, at the same location. The enhanced hydraulic permeability between Glennies Creek and the Permian subcrop has been allowed for in the modelling assessment.

These results are included in the summary of derived hydraulic conductivities in **Appendix E**. Hydraulic test results of WML261 and WML262 are presented in **Figure 4** and **Figure 5** respectively.

4.2.2 Groundwater Quality

Groundwater salinities of the ULD Seam were measured during the CRT as 2,510µS/cm EC (indicating approximately 1,400mg/L TDS) in WML261 and 6,270µS/cm EC (approximately 3,500mg/L TDS) in WML262. The lower EC encountered in WML261 may reflect some hydraulic connection with the less saline groundwater of the overlying alluvium, as indicated by the elevated hydraulic conductivity. Details of water quality testing are provided in **Appendix F**.

4.2.3 Impact of Mining Operations to Date

Groundwater Levels

Mining of the NEOC and PG LWs 1 to 7 have reduced groundwater levels within the deeper Permian to the extent that the PG Seam is now largely dewatered over the longwall panel area

(Aquaterra, 2009b and 2009c). Groundwater contours (in mAHD) of the measured potentiometric heads at the end of the mining of LW6A are shown in **Figure 6**. Although drawdown impacts on the PG Seam are significant, the groundwater contours show that the effects are localised, with steep gradients around the mining perimeter, indicating low hydraulic connectivity with the strata outside the mined area.

Figure 7 shows the hydrostatic head profiles for multi-level VWPs WML189 and WML191, which are located above chain pillars between PG LW2 and LW3, and WML115A and WML213, which are located outside the area affected by the first workings in ULD LW1 to 3. The plots represent a snapshot of groundwater pressures in relation to the elevation of each piezometer, following the extractions of PG LW1 to 7A.

Generally, under pre-mining conditions, pressures plot close to the 45° ‘hydrostatic line’, although there is a slight shift from the line due to the upward head gradient. During mining, WML189 and WML191 show that there is significant, rapid depressurisation of overlying Permian layers (Lemington 15 seam) for up to 50m above the PG Seam. However, outside of the mined area, large impacts are limited to the PG Seam, and overlying seams show a muted, slow response. This demonstrates a lack of vertical hydraulic connectivity between Permian layers, except where direct fracturing due to mining has occurred.

Several piezometers have shown partial recovery of groundwater levels after an initial drawdown impact from mining. The best example of this is WML107-98m set at the Lemington 19 Seam (**Figure 8**), 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 relative to the drawdown.

Similar effects were noted during the mining of PG LW4 to 6A at nearby piezometers WML110-65m (Lem8-9), WML110-90m (Lem10-12), WML110-110m (Lem15), WML111-118m (Lem15), WML112-130m and WML269-130m (Lem15). These hydrograph responses are not shown in this report, although are discussed in more detail in the PG LW6A End of Panel Report (RPS Aquaterra, 2011).

It is thought that this ‘drawdown/recovery’ response relates to two separate processes – changes in storage and decreases in bulk hydraulic condicivity. The two processes are summarised below, and are discussed in more detail in Booth, 2009 and in the PG LW4 End of Panel Report, Aquaterra, 2010.

Process 1: Changes in storage

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

In areas above the longwall panel where there is no direct connection to the underground workings, fissure and bedding plane dilation causes relatively large increases in storage and hence a significant decline in pressure. This causes pressure heads outside the longwall panel to drop in response. Although hydraulic conductivity is very low in these strata layers, storativity is also very low, hence the pressure effect can propagate relatively quickly beyond the longwall panel. It should be noted that:

- This effect does not require any bulk movement of groundwater (or dewatering) and it can occur in areas where there is little effective change in hydraulic conductivity (fissures do not have to be inter-connected for the change in storage to occur). It simply requires a small change in effective void storage within the rock mass itself; and

- Over time the bedding plane separation tends to decrease as the rock mass 'settles' and re-compresses after the initial change in stress regime. This can happen quickly or over a longer term, particularly where changes in stress have been transferred along strata layers some distance away from the main subsidence area. The subsequent compression reduces storage and increases pressure, leading to the rises in groundwater pressure head as seen in the observation boreholes.

This type of pressure-storage response is thought to have caused the responses in boreholes in mid and upper layers to the west and south of the longwall panels during extraction in the PG Seam.

Process 2: Decreases in bulk hydraulic conductivity

In some cases the bulk hydraulic conductivity of a layer/unit is initially increased due to subsidence cracking and the strata are being de-watered by mining (primarily in lower layers connected to the caved and heavily fractured zones immediately above the panel). This initial increase in hydraulic conductivity can start to reduce or be reversed as the strata layers re-compact and/or become filled by fines that have been mobilised by the caving and groundwater movements. This begins to steepen the hydraulic gradient, leading to rises in groundwater level in observation boreholes.

Standpipe piezometers WML119, WML120A and WML183 to WML186, located within the PG Seam between PG LW1 and Glennies Creek have also shown steady recovery post PG LW1 extraction (**Figure 9**). These bore responses are particularly significant, as the water levels in these bores are controlled by the head difference between Glennies Creek alluvium to the east, PG TG1A (the eastern heading alongside PG LW1) to the west, and the hydraulic conductivity of the PG Seam between the two. The head difference between Glennies Creek alluvium and PG TG1A has remained essentially unchanged during the period of ongoing mining (see borehole WML120B in **Figure 10**). The steady bore recovery responses are not thought to be associated with the pressure-storage response referred to earlier. It is considered that they are caused primarily by a progressive reduction in the hydraulic conductivity of the PG Seam between the creek alluvium and the underground mine. This may be due to clogging as silty, near surface waters pass through the coal seam, and/or a delayed benefit from the PG TG1A rib-grouting measures that were implemented to reduce inflows during PG LW1 extraction. This progressive reduction in hydraulic conductivity will have resulted in a gradual, parabolic mounding of the hydraulic gradient within the coal seam in the barrier between the Mine and the Glennies Creek alluvium, resulting in a rise in observed pressure heads in that area.

A small drawdown of 0.4m was observed in alluvium monitoring bore WML120B (near Glennies Creek and adjacent to WML120A), between June 2006 and December 2006, coinciding with the advance of PG TG1A past the bore location (**Figure 10**). No further drawdown occurred in the alluvium bores during subsequent extractions of PG LWs 1 to 5, 6A and 7A. All drawdown impacts occurred during the development heading stage of PG LW1.

Mine Inflows and Baseflow Impacts to Date

Figure 11 compares the total underground inflows and estimated seepage from Glennies Creek alluvium against the model predictions. These plots show that the original EIS (HLA, 2001) tended to over-estimate impacts, and that a significantly improved calibration has been achieved with the current groundwater model.

The recorded total groundwater inflow rate to the underground mine at the completion of PG LW1 was 5.5L/s (0.48ML/d) and during the extraction of PG LW2 to 6A, has varied from approximately 1L/s to 10L/s (0.086ML/d to 0.86ML/d),with an average of around 5L/s (0.43ML/d).

The flow rate of total seepage into PG TG1A (easternmost heading of PG LW1) is monitored separately from other inflows to allow the assessment of inflows from the Glennies Creek area. The PG TG1A seepage inflow rate, as measured from the PG LW1 Backroad Pipe, reached a peak rate of 3.4L/s (0.3ML/d) in July 2007 (during extraction of PG LW1), but declined to an average rate of 2.4L/s (0.2ML/d) over the period of PG LW3 extraction (August 2008 to March 2009). The PG TG1A seepage inflow rate has continued to decline with an average rate of less than 1L/s (0.086ML/d) during PG LW6A extraction (January 2011).

Water quality of mine water seepages varies (**Figure 12**). Initial EC ranged between approximately 1,000 and 9,000µS/cm. Seepages from PG TG1A have since remained stable throughout PG Seam mining with a much smaller range between 1,700 and 2,100µS/cm. Measured water quality from PG MG03, in June 2009, was 8,500µS/cm and has steadily declined to approximately 4,500µS/cm in June 2011.

Based on EC comparisons with the in-situ salinities of both the PG Seam and Glennies Creek alluvium it has been estimated that approximately 70% of the total seepage monitored in PG TG1 for the later period (August 2008 to March 2009) is derived from the Glennies Creek alluvium, i.e. an average of 1.7L/s (0.14ML/d). Estimated flow rates from the Glennies Creek alluvium through to the mine, based on recorded inflows and this 70% adjustment, are also shown in **Figure 11**. This factor may over-estimate the input from the Glennies Creek alluvium at the start of the inflow record, as more of the initial inflow may have been associated with storage release from the Permian strata. EC values, as indicated in **Figure 12**, which were higher near the start of the inflow record, suggest that this was the case. However, the higher initial values generally just reflect the fact that fresher, near-surface groundwaters will have had to ‘push’ the in-situ deeper groundwaters into the mine before the fresher waters could migrate into the tailgate. It is therefore impossible to quantify how much of the initial higher inflow related to the release of storage around the development heading.

The extractions of PG LW5A and 6A have caused part of the Bowmans Creek alluvium to subside, however no reduction in alluvium storage has occurred. It should be noted that there is not expected to be any, nor is there any evidence of significant seepage of groundwater from the Bowmans Creek alluvium to the PG longwall panels to date.

5. REVISED GROUNDWATER IMPACT PREDICTIONS

5.1 Background

This section of the report details the revised groundwater impacts that may arise from the extraction of ULD LW1 to 4 and ULD LW5 to 8. Where possible, the revised impacts have been compared against the predictions that were made in the groundwater impact assessment reports for the EIS (HLA, 2001) and the Bowmans Creek Diversion EA (Aquaterra, 2009e).

The ACP Underground Mine Model (Model) developed for this ULD Extraction Plan groundwater impact assessment is primarily based on the model used for the Bowmans Creek Diversion Groundwater Impact Assessment (Aquaterra, 2009e). The model domain is shown on **Figure 13**. This Model, through a number of upgrades, had been modified/improved from the original EIS model (HLA Envirosciences, 2001). The ongoing investigations and monitoring described in **Section 4** have been used to improve the current Model both in terms of conceptual behaviour and calibration. Some improvements to model geometry, recharge and boundary conditions were also made during the Bowmans Creek Diversion assessment (Aquaterra, 2009e). Further, additional modifications to the 2009 model used in the Bowmans Creek Diversion assessment (Aquaterra, 2009e) described in **Appendix C** have resulted in an improved simulation of mine inflows and some minor changes to predicted impacts, specifically in terms of pre-mining and post-mining baseflow impacts. Improvements in the understanding of Glennies Creek and its alluvium gained during the SEOC EA investigations (Aquaterra, 2009a) have also been included within the current Model.

Information relating to the ACP Model design, modelling approach, calibration and uncertainty analysis are provided in **Appendix C**.

The impacts described in this section are primarily focused on assessing and quantifying the impacts from mining the ULD Seam post PG Seam extraction, by assessing the changes to key hydrogeological indicators defined above.

5.2 Changes to Previous Modelling Simulations

The Model results presented in this report vary slightly with that of previous model studies conducted for the ACP. Primarily this relates to predictive impacts on mine inflows and baseflows. This is due to model simulations involving the variably-saturated flow conditions using the van Genuchten function as an unsaturated flow modelling option provided by the MODFLOW SURFACT BCF4 package as opposed to the Pseudo Soil Function which was previously used. Although these changes are subtle, they are not significant and therefore provide a more accurate representation of recharge processes and the groundwater flow regime in the unsaturated zone.

5.3 Upper Liddell Impact Assessment Methodology

The primary effect of underground mining on the groundwater regime comes from changes in bulk rock-mass hydraulic conductivity caused by fracturing associated with longwall subsidence (caving). This is followed by the pumping out of groundwater that enters the mine as a consequence (mine inflow). Further details of these mechanisms and the quantification of the effects on rock mass hydraulic conductivity, are given in **Section 4.2.3**.

The fracturing associated with longwall subsidence (caving) and associated extraction of groundwater have a number of effects on the hydrogeological system during mining operations that need to be evaluated as part of the impact assessment, which include:

- Impacts on groundwater levels during longwall mining within the Permian hard rock strata and the alluvium associated with Bowmans Creek, Glennies Creek and the Hunter River;
- Impacts on baseflow to Bowmans Creek, Glennies Creek and the Hunter River during longwall mining; and

- Inflow of water to the underground mine and the management of that mine water.

These primary impacts could lead to secondary impacts on groundwater dependant receptors including GDEs, other groundwater and surface water users, and in-stream aquatic ecology.

To assess the impacts of ULD Seam mining, groundwater level elevations and drawdowns have been predicted for key hydrogeological units and periods including the:

- Alluvium/regolith (Layer 1) shown in **Figures 14** to **19** at January 2012 (notional cessation of PG Seam mining), March 2014 (completion of ULD LW4) and June 2016 (completion of ULD LW8);
- PG Seam (Layer 8) shown in **Figures 20** to **25** at the years 2012, 2014 and 2016; and
- ULD Seam (Layer 10) shown in **Figure 26** to **31** at the years 2012, 2014 and 2016.

Baseflow modelled impacts for Bowmans Creek, Glennies Creek and the Hunter River have also been assessed (**Figure 32**). Impacts on baseflow have been determined as the best model representation of the total losses that occur from the surface water sources to the underlying Permian strata as a result of mine induced dewatering. The assessment of baseflow impacts are discussed below, concentrating on the key periods at 2014 (end of ULD LW4) and 2016 (end of ULD LW8). Note that, a positive value indicates net gaining conditions and thus is referred to as baseflow from here-on-in; a negative baseflow indicates net losing conditions and is thus representing river leakage from the surface water source to the aquifer, and is referred to as aquifer recharge.

Hydrographs of model-predicted groundwater levels within the alluvium, PG Seam and the ULD Seam are shown in **Figures 33** and **35**. The locations of the model targets are shown on **Figure 13**.

Please note that although this report concentrates on the modelled impacts predicted from dewatering the ULD Seam, figures showing the predicted groundwater levels and drawdown impacts associated with PG Seam mining have also been included for completeness and are referred to only where required when assessing impacts caused by the ULD Seam extraction.

5.4 Comparison of Revised Groundwater Impacts to 2001 EIS and 2009 EA Predictions

A summary of impacts observed to date as a result of PG Seam mining and predicted impacts from mining each stage of the ULD Seam are presented in **Table 5.1.** The modelled predictions of the 2001 EIS and 2009 EA are also shown for comparison. Note that predicted drawdown impacts in the Permian coal measures were only presented in the 2001 EIS for the completion of mining, and not for intermediate stages of the mine life, and it is therefore not possible to directly compare impacts to the Bowmans Creek and Hunter River alluvium. However, revised groundwater impacts which are lower than the 2001 EIS or 2009 EA predictions are highlighted in green, whilst impacts that are consistent with the 2001 EIS or 2009 EA predictions are shown in black.

There were no revised impacts which exceeded the EIS or EA predictions.

The summary assessment has been based on four key locations as shown in **Figure 13,** where mining occurs closest to the alluvium, including:

- Glennies Creek Alluvium to the east of ULD LW1;
- Glennies Creek and Hunter River Alluvium to the south of ULD LW1;
- Hunter River Alluvium directly south of ULD LW5 to 8; and
- Bowmans Creek Alluvium in the vicinity of the Oxbow, west of ULD LW4.

Baseflow impacts are also summarised for Glennies Creek, the Hunter River and Bowmans Creek. Both the drawdown and baseflow impacts are summaries at key times, which are aligned with the completion of PG LW 8 (notionally January 2012), ULD LW4 (notionally March 2014) and ULD LW8 (notionally June 2016).

Table 5.1: Comparison of Revised Groundwater Impacts to 2001 EIS and 2009 EA Predictions

Impact Description	Impacts observed to date (PG LW 1-7B)	Modelled Impact PG LW1-8	Modelled Impact ULD LW1-4		Modelled Impact ULD LW1-8		2009 BCD EA, LW1-8	2001 EIS LW1-6*
		Total (PG LW1-8 only)	Total (PGLW1-8 +ULD LW1-4)	Additional (ULD LW1-4 only)	Total (PG LW1-8 + ULD LW1-8)	Additional (ULD LW1-8 only)	Total (PG+ULD LW1-8)	Total (PG LW1-6+ULD LW1-6)
Groundwater drawdown to the Glennies Creek alluvium South of ULD LW1	N/A	0.05m	0.11m	0.06m	0.16m	0.11m	*NR*	*NR*
Groundwater drawdown to the Glennies Creek alluvium east of PG and ULD LW1	**up to 0.4m, followed by full recovery**	0.14m	**0.18m**	0.04m	**0.2m**	0.06m	*NR*	1.3 - 2.5m
Groundwater drawdown impacts to the Hunter River alluvium southwest of ULD LW1	no impact observed	0.0m	0.0m	0.0m	0.0m	0.0m	0.0m	*NR*
Groundwater drawdown impacts to the Hunter River alluvium south of ULD LWs 5 to 7	no impact observed	0.0m	0.01m	0.01m	0.01m	0.01m	0.01m	<0.5m
Groundwater drawdown impacts to the Bowmans Creek alluvium in the vicinity of the oxbow	**no impact observed**	0.32 m	**0.45m**	0.13m	**0.73m**	0.41m	1.70m	*NR*
Baseflow impacts to Glennies Creek	**2L/s during LW1-LW2, decreasing to 0.66L/s at LW7B**	2.6L/s	**2.9L/s**	0.3L/s	**3.0L/s**	0.4L/s	*NR*	3.3 - 5.5L/s
Baseflow impacts to Bowmans Creek	**no impact observed**	0.45L/s	**0.59L/s**	0.14L/s	**0.86L/s**	0.41L/s	0.5 - 1.2L/s	4.3 - 4.6L/s
Baseflow impacts to Hunter River	**no impact observed**	0.07L/s	**0.13L/s**	0.06L/s	**0.23L/s**	0.16L/s	0.3 - 0.5L/s	2.9 - 3.5L/s
Total underground inflows	**0.6 - 10L/s**	4 -15L/s	16L/s	1 - 10L/s	**14 - 16L/s**	14L/s	14 - 16L/s	17.6 -19L/s

NR = Impact not reported. Values in green are less than 2009 BCD EA or 2001 EIS predictions. * Note 2001 EIS LW panel layout included wider longer panels.

5.5 Impact Summary from PG LW1 to 8

The revised modelled impacts caused by PG Seam mining indicate the following:

- Drawdown to Glennies Creek alluvium is predicted to be 0.05m south of ULD LW 1 at the end of PG LW8 mining (2012);
- Drawdown impacts to Glennies Creek alluvium are slightly greater east of ULD LW1, with an impact of 0.14m being predicted at the cessation of PG LW8 mining. The revised impact is lower than the impact of 1.3m predicted in the 2001 EIS;
- No drawdown impacts due to PG Seam mining are predicted on the Hunter River alluvium at the cessation of PG LW8 mining. This is consistent with current observations to date;
- Predicted drawdown located in the Bowmans Creek alluvium in the vicinity of the oxbow is 0.32m at the end of PG LW8 mining. This is a conservative impact compared to the current observations which show no drawdown impact on Bowmans Creek alluvium in other areas (i.e. parts of PG LW6A and LW7A) where mining has occurred beneath saturated alluvium (RPS Aquaterra 2011);
- Glennies Creek is predicted to change gaining creek 1.22L/s (0.1ML/d) prior to PG LW1, to a creek that recharges the aquifer at a rate of 1.5L/s (-0.13ML/d), by the end of PG LW8. This represents a total baseflow impact of 2.7L/s (0.23ML/d) at the cessation of PG LW8 mining. This is a conservative prediction compared to current baseflow impacts estimated at approximately 0.60 to 1.5L/s (0.052 to 0.13ML/d), **Figure 11**;
- A reduction in baseflow contribution to Bowmans Creek by 0.45L/s (0.039ML/d) at the cessation of PG LW8 mining. Although mining of PG LW6A and 7A occurred beneath parts of the Bowmans Creek alluvium, there has been no reduction in alluvium storage, and hence no baseflow impacts on Bowmans Creek have been observed to date (RPS Aquaterra 2011); and
- A reduction in baseflow contribution to the Hunter River by only 0.07L/s (0.006ML/d) at the cessation of PG LW8 mining. No baseflow impacts on the Hunter River have been observed to date.

5.6 Impacts from ULD LW1 to 4

5.6.1 Groundwater Level Impacts

Alluvium

Figure 15 shows the predicted water table elevations within the alluvium/regolith (Layer1) at the end of ULD LW4 mining (2014); and includes four zoomed-in insert boxes to allow for a more detailed assessment at key locations. The corresponding drawdown is shown in **Figure 18** and this represents the additional drawdown that is predicted to impact the alluvium/regolith as a result of ULD Seam mining only by 2014. It does not include the previous drawdown impacts predicted by PG Seam mining prior to 2012 (which are shown in **Figure 17**).

Figure 18 shows that:

- There is relatively little alluvium on the western side of Glennies Creek in the area closest to ULD LW1 (insert 2 and 4) and drawdown to the alluvial groundwater levels from ULD LW1 are predicted to increase to 0.18m or less. This represents an additional impact of 0.04m post PG Seam mining. The revised impact is therefore much lower than the drawdown of 2.5m predicted in the 2001 EIS for this stage of mining. Additional impacts in this area are minimised due to the offset of the ULD Seam and PG Seam mine plans, which maintains the permeability characteristics of the hard rock within the PG Seam and overburden along the alignment of PG TG1;

- Drawdown to the Glennies Creek alluvium is predicted to increase to 0.11m at the south east of ULD LW1 at the end of ULD LW4 mining (2014). This represents an additional impact of 0.06m post PG Seam mining;
- Drawdowns to Bowmans Creek alluvium in the vicinity of the oxbow next to ULD LW4B is predicted to increase to 0.45m at the end of ULD LW4 mining (2014). This represents a minor additional drawdown of groundwater levels of up to 0.13m (insert 1). Greater drawdowns of up to 1m are predicted further away, to the east of ULD LW4, however since mining of the ULD has not progressed into this area by 2014, the drawdowns modelled here are drawdown residuals caused by the extraction of the PG Seam. This prediction is consistent with both the 2001 EIS and 2009 EA predictions, but should be treated as conservative, as groundwater monitoring during the extractions of PG LW6A and 7A has showed no impact in the alluvium to date. Also there is the potential for some of this modeled drawdown to be attributed to the underground mining operations at the RUM; and
- No significant impacts to the Hunter River Alluvium to the south west of ULD LW1 and ULD LW4 (insert 3) at the end of ULD LW 4 mining. The revised impact is consistent with both the 2001 EIS and 2009 EA predictions.

PG Seam

Figures 20 and **21** show the predicted groundwater elevations of the PG Seam (Layer 8) at the end of PG Seam mining (2012) and at the end of ULD LW4 mining (2014). **Figures 23** and **24** show the corresponding predicted groundwater drawdown at these times respectively.

Figure 23 and **24** show:

- The PG Seam will be completely dewatered across the entire underground mine footprint by 2012 as drawdown occurs to the base of the PG Seam;
- By 2014, additional drawdown of up to 10m outside of the ACP mine plan extent is predicted to occur to the west and north-west as a result of mining at RUM (which shows local drawdown of up to 190m);
- No additional drawdown is predicted to occur by 2014 within the ACP mine plan extent as a result of ULD mining due to the PG Seam being fully depressurised by the end of PG Seam mining (2012);
- A localised drawdown of up to 50m within the PG Seam is predicted in the southern section of ULD LW1 (**Figure 24**);
- Drawdown to the north-east and east is also affected by the NEOC; and
- The modelled impacts from extracting the ULD seam from the Ashton underground mine primarily affect the south and southwest by 2014 (**Figure 24**), where drawdowns of 5m or more in the PG Seam are predicted up to 1.5km from the southern end of the mine. Some of this impact however may be also attributed to the RUM.

ULD Seam

Figures 26 and **27** show the predicted groundwater elevations of the ULD Seam (Layer 10) at the end of PG mining (2012) and at the end of ULD LW4 mining (2014). **Figures 29** and **30** show the corresponding predicted groundwater drawdown at these times respectively.

Figures 29 and **30** show that:

- By 2012, mining of the PG Seam has already started to impact the groundwater pressures within the ULD Seam (due to upward leakage) with the 30m drawdown contour being extensive over the majority of the mine plan. Development headings associated with ULD LW1 and LW2 at 2012 have also resulted in large predicted drawdowns which are maximised at approximately 100m at the southern section of ULD LW1 (**Figure 29**);

- Drawdowns of up to 10m with a maximum extent of approximately 500m are predicted to occur at the completion of PG Seam mining (**Figure 29**);
- Additional drawdown of up to 120m is predicted to occur post mining cessation of the PG Seam, with the maximum drawdown occurring as a result of development heading works on ULD LW4, LW5 and LW6 and the northern head works associated with ULD LW8 by 2014 (**Figure 30**); and
- An additional drawdown (post PG mining) of 10m extending up to 500m from the south and east of the underground mine are predicted to occur at the completion of ULD LW4 mining (**Figure 29**).

5.6.2 Baseflow Impacts

Modelled baseflows in Bowmans Creek, Glennies Creek and the Hunter River up to the end of ULD LW8 are shown in **Figure 32**. The revised baseflow impacts are consistent with or below the 2001 EIS or 2009 EA predictions for this stage of mining (**Table 5.1**).

The following baseflow impacts are predicted to occur by the completion of ULD LW4 (2014):

Glennies Creek

- The net impacts on baseflow from ULD Seam extraction alone are lower in comparison to the PG Seam extraction. This is due to the offset of the ULD Seam and PG Seam mine plans;
- Recharge to groundwater from Glennies Creek is predicted to increase from -1.48L/s (-0.13ML/d) at the commencement of ULD LW1 to -1.66L/s (-0.14ML/d) by the completion of LW4 extraction at March 2014. This represents an increase loss of only 0.026ML/d which is caused by ULD Seam mining only at the end of ULD LW4 (March 2014); and
- The total cumulative baseflow impact to Glennies Creek is predicted to increase to 2.9L/s (0.25ML/d) at the cessation of ULD LW4 mining (March 2014). The revised baseflow impact is consistent with the 2009 EA prediction and is lower than the 2001 EIS prediction of 3.3L/s (0.29ML/d), for this stage of mining.

Bowmans Creek

- Most of the total baseflow reduction is due to the ongoing affects from PG Seam mining and mining being carried out at neighboring mines, rather than ULD Seam extraction; and
- Bowmans Creek baseflow is predicted to change from a slightly gaining creek (0.001ML/d / 0.11L/s) to a creek that recharges the aquifer system at a rate of -0.12L/s (-0.01ML/d) at the cessation of ULD LW4 mining. This represents an additional baseflow impact of 0.14L/s (0.012ML/d) post PG Seam mining cessation.
- The total cumulative baseflow impact to Bowmans Creek is predicted to increase to 0.59L/s (0.05ML/d) at the cessation of ULD LW4 mining (March 2014). The revised impact is consistent with the impact predicted in the 2009 EA (0.5L/s / 0.04ML/d) and lower than the impact predicted in the 2001 EIS (4.3L/s / 0.37ML/d) for this stage of mining.

Hunter River

- A slight reduction in the baseflow contribution to the Hunter River is predicted, reducing from 1.2L/s (0.1ML/d) at the commencement of ULD LW1 to 1.14L/s (0.1ML/d) by the completion ULD LW4 extraction at March 2014. This represents a total reduction in predicted baseflow contributions of 0.13L/s (0.011ML/d), which is lower than the impacted predicted in the 2009 EA (0.3L/s / 0.02ML/d) and 2001 EIS (2.9L/s / 0.25ML/d) for this stage of mining. Again, most of this is believed to be a residual effect of completion of mining in the PG Seam. Mining at the Ravensworth open cut and underground mines have had little impact on the Hunter River during this period.

5.6.3 Predicted Mine Inflows

Model predictions of mine inflow rates to the PG Seam and ULD Seam underground workings are shown in **Figure 36**. This figure shows the predicted mine inflow rates over the calibration and prediction periods, as well as a comparison to both the Bowmans Creek Diversion modelling predictions and measured underground inflow rates observed to date. These results are reasonably consistent with previous assessments, although both observed and currently predicted inflow rates are generally lower than the original EIS (HLA, 2001) predictions. Note **Figure 36** assumes ULD longwall extraction commencing January 2012.

It should be noted that measured net groundwater inflow rates to the total underground mining operation (6L/s or 0.5ML/d in mid August 2008) are consistent with the current model predictions until mid 2008. After this time, measured rates have remained stable whereas the model predicted rates increase significantly from that time. That is, the model predictions are conservative in the longer term and will tend to over-predict inflows.

5.6.4 Groundwater and Surface Water Quality Impacts

The monitoring results from the groundwater investigation program to date have shown that the only significant risk to alluvium groundwater quality is from the high in-situ salinity of the underlying Permian groundwater. No evidence of significant acid forming potential, or potential for iron precipitation or heavy metal contamination, has been identified in the Permian rocks or Permian groundwater.

Contamination of alluvial groundwater from saline water within the mine workings will not occur during the mining of ULD LW1 to 4 due to the strong downward gradients as a result of mine inflows and mine dewatering.

As there are significant in-situ low permeability barriers between the mine workings and the Hunter River and Glennies Creek alluvium, the risk to these groundwater and surface water resources is considered to be negligible, even during the post mining recovery period. The large vertical separation between the ULD Seam mine workings and Bowmans Creek alluvium and the strong downward gradients prevents impact on the water quality in the alluvium.

5.6.5 Potential Impacts on Groundwater Dependent Ecosystems

Because predicted impacts on flows in Bowmans Creek, the Hunter River and Glennies Creek, and on groundwater levels within their associated alluvium from mining of the ULD Seam are negligible, it is considered unlikely that there will be an impact on GDEs associated with those water courses and their floodplain areas. For Glennies Creek, there will be a slight decrease in baseflow, but these are limited to 2.9L/s (0.25ML/d) or less at the end of ULD LW1 to 4.

The ecological investigations conducted by ERM, 2009 show that there are no GDEs within those parts of the alluvium that are predicted to be impacted during mining activities within the ULD. A small isolated and narrow stand of River Red Gums have been recorded along the eastern side of the Glennies Creek, and one individual River Red Gum was recorded along the northern portion of Glennies Creek (**Figure 18**). These are expected to be largely dependent on surface water flows, and to an extent, on groundwater baseflows through extending their roots into the water table. There are no impacts predicted on alluvial groundwater levels in this area.

5.6.6 Potential Impacts on Existing Groundwater Users

No impacts are predicted from the mining operation on surrounding registered groundwater licence holders.

5.7 Impacts from ULD LW5 to 8

5.7.1 Groundwater Level Impacts

Alluvium

Figures 16 shows the predicted water table elevations within the alluvium / regolith (Layer 1) at the end of ULD LW 8 mining (2016); and includes four zoomed-in insert boxes to allow for a more detailed assessment at key locations. The corresponding drawdowns are shown in **Figure 19** and this represents the additional drawdown (post PG Seam mining cessation at 2012) that is predicted to impact the alluvium/regolith at the cessation of ULD mining by 2016. It does not include the previous drawdown impacts predicted by PG Seam mining prior to 2012 (which are shown in **Figure 17**).

Figure 19 shows:

- Small drawdown of up to 0.2m in the Glennies Creek alluvium to the east of ULD LW1 at the end of ULD LW8 mining (2016). This represents an additional impact of up to 0.11m post PG Seam mining cessation (insert 2 and 4). The revised impact is lower than the 2001 EIS prediction of 2.5m for this stage of mining;
- Small impacts of up to 0.73m in the vicinity of the Bowmans Creek oxbow (insert 1) at the end of ULD LW8 mining (2016). This represents an additional impact of 0.41m post PG Seam mining cessation. The revised impact is lower than the 2009 EA prediction of 1.7m for this stage of mining;
- Additional localised impacts on groundwater levels of 2 to 3m in the Bowmans Creek alluvium above the mined ULD LW6 panel (insert 1); and
- At its closest point, the southern extents of ULD LW5 to 7 will be at least 200m from the Hunter River Alluvium, and therefore no increase in drawdown is predicted in the alluvium near the Hunter River (insert 3). This is consistent with both the 2001 EIS and 2009 EA predictions.

PG Seam

Figure 22 shows the predicted groundwater elevations of the PG Seam (Layer 8) at the End of ULD mining (2016) with the corresponding drawdown shown in **Figure 25**. These figures show the following:

- The PG Seam will be fully dewatered across the entire underground mine footprint by this time with depressurisation continuing to extend to the west and northwest as a result of continual mining within the PG Seam at the RUM; and
- Regional drawdown impacts from the Ashton underground mine continue to affect the south and south west areas, with the 5m drawdown contour increasing from approximately 1.5km from the southern end of the mine at 2014 to approximately 2km by 2016 (**Figure 25**).

ULD Seam

Figure 28 show the predicted groundwater elevations of the ULD Seam (Layer 10) at the End of ULD mining (2016) with the corresponding drawdown shown in **Figure 31**. These figures show the following:

- The 10m drawdown contour south of the Ashton underground mine extends from approximately 500m (at the completion of ULD LW4 at 2012) to approximately 1.5km at the completion of ULD LW8.

Due to model software constraints, the model drains are set slightly above the base of the layer in the model, resulting in the ULD seam not quite being fully dewatered, although in fact it will be fully dewatered across the ULD LW1 to 8 footprint by this time.

Figure 35 shows modelled hydrographs for five ACP groundwater monitoring locations within the ULD Seam. Aside from targets WML261 and WML262, actual monitoring at the other specific points does not extend to the ULD Seam. These hydrographs show the expected impact within the ULD Seam which will essentially be dewatered at the end of ULD mining (2016).

5.7.2 Baseflow Impacts

The revised baseflow impacts are consistent with, or below the 2001 EIS or 2009 EA predictions for this stage of mining (**Table 5.1**). Referring to **Figure 32**, the following revised baseflow impacts are predicted to occur by the completion of ULD LW8 (2016):

Glennies Creek

- Recharge to groundwater from Glennies Creek (seepage loss) is predicted to increase from - 1.6L/s (-0.14ML/d) at the completion of ULD LW4 extraction (March 2014) to -1.74L/s (-0.15ML/d) by the completion ULD LW8 extraction by June 2016. This represents a reduction of recharge of only 0.1L/s (0.007ML/d) post ULD LW4 mining and 0.4L/s (0.034ML/d) post PG Seam mining; and
- The total cumulative baseflow impacts to Glennies Creek are predicted to increase to 3.0L/s (0.26ML/d) at the cessation of ULD LW8 mining. The revised baseflow impact is consistent with the 2009 EA prediction and is lower than the 2001 EIS prediction of 5.5L/s (0.47ML/d), for this stage of mining.

Bowmans Creek

- Bowmans Creek is predicted to continue to recharge the aquifer at a rate of -0.3L/s (-0.03ML/d) by the completion of ULD LW8 (June 2016), representing an additional loss of 0.16L/s (0.014ML/d) post ULD LW4 mining and 0.41L/s (0.035ML/d) post PG Seam mining; and
- The total cumulative baseflow impact to Bowmans Creek is predicted to increase to 0.86L/s (0.07ML/d) at the cessation of ULD LW8 mining. The revised baseflow impact is lower than the impacts predicted in the 2009 EA (1.2L/s / 0.1ML/d) and the 2001 EIS (4.62L/s / 0.4ML/d), for this stage of mining.

Hunter River

- By the completion of ULD LW8 mining, the predicted baseflow contribution from groundwater to the Hunter River is predicted to decrease from 1.14L/s (0.1ML/d) at the completion of ULD LW4, to 1.1L/s (0.092ML/d) by the completion ULD LW8 extraction at June 2016. This represents an additional loss in predicted baseflow of 0.008ML/d; and
- The contribution of baseflow to the Hunter River is predicted to decrease by 0.23L/s (0.02ML/d) at the cessation of ULD LW8 mining. The revised baseflow impact is lower than the impacts predicted in the 2009 EA (0.5L/s / 0.04ML/d) and the 2001 EIS (3.4L/s / 0.3ML/d), for this stage of mining.

5.7.3 Predicted Mine Inflows

Total mine inflows into the ULD Seam workings are expected to peak at about 14L/s (1.2ML/d) during the extraction of ULD LW6B, which is consistent with the 2009 EA predictions (**Figure 36**).

5.7.4 Groundwater and Surface Water Quality Impacts

The monitoring results from the groundwater investigation programme to date have shown that the only significant risk to alluvium groundwater quality is from the high in-situ salinity of the underlying Permian groundwater. No evidence of significant acid forming potential, or potential for iron precipitation or heavy metal contamination, has been identified in the Permian rocks or Permian groundwater.

As there are significant in-situ low permeability barriers between the mine workings and the Hunter River and Glennies Creek alluvium, the risk to these groundwater and surface water bodies is considered to be negligible, even during the post mining recovery period. The large vertical separation between the ULD mine workings and Bowmans Creek alluvium and the strong downward gradients also prevents impact on the water quality of the alluvium.

5.7.5 Potential Impacts on Groundwater Dependent Ecosystems

Because predicted impacts on flows in Bowmans Creek, the Hunter River and Glennies Creek, and on groundwater levels within their associated alluvium from mining of the ULD seam are negligible, it is very unlikely that there would be any impact on GDEs associated with those water courses and their floodplain areas. For Bowmans Creek, there will be a slight decrease in baseflow due to losses from the non-diverted sections of the creek, but these are limited to 0.13ML/d or less. The ecological investigations show that there are no GDEs within those parts of the alluvium that are predicted to be dewatered during mining activities within the ULD. Two stands of River Red Gum have been recorded, but these are further south, next to the creek between the southern end of the western diversion and the Hunter River (**Figure 19**). Impacts on alluvial groundwater levels in this area are predicted to be less than 0.5m, which is not considered sufficient to detrimentally affect the river red gums (Marine Pollution Research, 2009).

5.7.6 Potential Impacts on Existing Groundwater Users

No impacts are predicted from the mining operation on registered groundwater licence holders.

5.8 Potential Mine Inflow Risk Associated with Bowmans Creek Diversion

During the extraction of ULD LW6 to 8, the potential for water inflow to the underground mine arises as a result of mining critical width longwall panels beneath the Bowmans Creek alluvium. During the mining of the ULD and subsequent seams, there is the potential for connected cracking to extend from the underground mine to the base of the Bowmans Creek alluvium.

The proposed diversion of Bowmans Creek from areas directly above the panels will ensure that any subsidence fracturing that extends up to the base of the abandoned creek channel will not expose the normal streamflows to inflow to the mine.

However, flows greater than a 5 year recurrence interval flow will overflow into the former channels, as well as flowing down the diversions. There is also the possibility of local runoff to accumulate in the old channel following local rain storms.

Subsidence troughs will be reshaped and fill will be used where practicable to create a free draining landform. This approach is expected to reduce the potential for surface pooling and inflow into the mine.

5.8.1 Estimated Inflow before Repair of Surface Cracks

The hypothetical increased inflow rate due to the inundation of a subsidence trough containing un-repaired surface cracks has been assessed by assuming a much higher vertical conductivity for the area of open cracks. A very conservative effective conductivity of 500m/d was assumed to apply to an area of 0.2ha, comprising a strip 10m wide for 100m along the eastern and western sides of the longwall panel. The peak inflow rate would be 4.6ML/d higher, although as water would infiltrate more quickly, the pond would drain more quickly, and the total inflow volume would not change materially. Thus, for the ‘high inflow’ case considered above, the peak inflow rate is predicted to increase from 1.1ML/d to 5.7ML/d during mining of the ULD seam.

However, this is an extreme assumption reflective of possible worst case conditions, and is not expected to occur. It would occur only if a full 100m of panel length remained un-repaired, and the surface cracks remained open rather than self-healed, either partly or fully. Experience with open cracks above PG LW1 during the June 2007 flood event, and farm dams above PG LW1, LW2 and LW4 that partly filled with water while surface cracks remained open, both of which saw no noticeable increase in mine water inflow, suggests that this extreme hypothetical inflow response has a very low likelihood of occurrence.

5.8.2 Estimated Inflow after Repair of Surface Cracks

Three scenarios for infiltration through the subsidence troughs were examined by Aquaterra in June 2009, representing high, mid and low inflow cases, during the mining of the ULD seam. The results of these calculations are shown in **Table 5.2**. These calculations assumed that all surface cracks had been repaired, and were based on assumed effective vertical permeability rates for the subsidence troughs, on the assumption that there would be some increase in vertical hydraulic conductivity across the full subsidence area, but that the permeability increase would be greatest around the margins where the greatest intensity of tensile stress cracking would have occurred.

Subsidence troughs which are not proposed to be reshaped with fill (mainly the part of the trough above LW6B which is occupied by the former creek channel, and shorter sections also above LW7A and 7B) will be able to fill with water following flooding, and retain water for some time after the flood event. The maximum volume of the un-backfilled subsidence troughs has been calculated at 46ML after mining of the ULD.

Table 5.2: Predicted Inflow Rates and Volumes from non-remediated Subsidence Troughs

During ULD Mining	High	Mid	Low
Effective Kv (m/d)	0.024	0.0072	0.0015
Total Inflow (ML)	33.7	23.2	9.2
Peak Inflow Rate (ML/d)	1.09	0.3	0.07
Average Inflow Rate (ML/d)	0.37	0.13	0.03
Duration of inflow (days)	95	181	290

The maximum inflows would occur during mining of LW6B, as this contains the main area of subsidence trough proposed to not be backfilled. The currently installed pumping capacity (3.8ML/d at the southern end of LW6A) is sufficient to handle the predicted peak inflow rates under all scenarios (i.e. low, medium and high) during mining of the ULD seam.

The potential storage available in the mine in the event that the LW6 BH pump became unavailable for any reason has also been considered. Water would drain naturally to the low points in the mine, in particular to the SW (down dip) corner of the mine, i.e. the SW corner of PG LW7A. The seam elevation at the SE corner of the PG LW7A goaf is approximately 164mAHD. Water would be able to accumulate in the SW corner of the mine up to approximately this elevation without over-spilling into other currently active parts of the mine.

The volume of void space below the 164mAHD level within the LW7 main gateroads has been calculated at 35ML. This is more than sufficient to accommodate the maximum potential inflow volume from a flood event inundating the LW6B subsidence trough, whether surface cracks have been repaired or not.

5.8.3 Mitigation and Contingency Measures

A number of controls are recommended to mitigate the operational risk and environmental impact that could be caused by increased surface water entering the mine workings, including:

- Prompt repair of surface cracks within subsidence troughs;
- Where possible, maintaining a free-draining surface above LW6B;

- Diverting larger flows away from the former Bowmans Creek channel (if feasible); and
- Pumping out ponded water as soon as practicable, to shorten the duration of inundation.

Contingency measures include:

- Installing pumping capacity underground to deal with predicted inflow volumes/rates;
- Mobilising additional surface pumping capacity to expedite pumping out of surface subsidence troughs;
- Developing and implementing mine evacuation plans; and
- Providing equipment protection measures.

6. MONITORING, MANAGEMENT AND MITIGATION

6.1 Overview

Condition 3.9 to Schedule 2 of DA 309-11-2001-i describes the subsidence impact performance measures for the underground mine on surrounding water sources. This includes ensuring no greater subsidence impact or environmental consequences to water sources then that predicted and approved in the various environmental assessment documents prepared in support of development applications for the ACP.

ACOL has developed a Site water management plan to monitor mine impacts and ensure compliance with these performance measures.

Any flow of water to the underground mine workings will be through the Permian hard rock aquifers. The water draining out of the Permian into the mine workings is replaced in limited amounts from a combination of the natural rainfall recharge to groundwater in the areas affected by the regional groundwater drawdown and to a much lesser extent by vertical drainage out of the alluvium.

ACOL holds water entitlements sufficient to account for the reduction in water levels that may be attributed to the impact of ULD Seam extraction.

6.2 Water Management Plan

An integrated site Water Management Plan (WMP) has been prepared for the ACP. The WMP includes a detailed monitoring program; erosion, surface water and groundwater management and control measures; and response and contingency plans for mine related surface water and groundwater impacts.

Components of the WMP that relate to this assessment are briefly summarised below.

6.2.1 Impact Assessment Criteria

Water level indicators (triggers levels) have been developed for key areas and bores in the Bowmans Creek, Glennies Creek and Hunter River alluvium. The indicators are designed to facilitate impact identification and where appropriate trigger a management response. The trigger levels are based on the predicted drawdown from baseline groundwater levels, and are presented for key monitoring bores in the site WMP.

Water quality indicators based on baseline monitoring data have also been developed. An investigation into mine related impacts on groundwater quality would be initiated in the case of any sudden variation or trend from baseline salinity (EC) or pH levels.

6.2.2 Groundwater Monitoring

The ACP groundwater monitoring network is extensive and provides comprehensive coverage across the Site (see **Appendix D**). The groundwater regime in the area is monitored as part of the ongoing underground mining activities. The current monitoring network will be maintained and enhanced to enable:

- Regular assessment of groundwater levels in all vibrating wire and standpipe piezometers;
- Continued monitoring of mine inflows and water quality, including monitoring of inflows into PG TG1, where possible;
- Monitoring of mine inflows into ULD TG1 and monitoring of changes in the hydraulic conductivity of the rock barrier between the underground mine and Glennies Creek, where possible. This will enable any further impacts on Glennies Creek from the underground mine due to ULD Seam extraction to be detected and determined;
- Monitoring and repeat hydraulic testing of all piezometers located in the barrier east of ULD LW1 to monitor any unforeseen impacts to Glennies Creek alluvium;

- Where possible, the installation of an additional monitoring bore in the Glennies Creek alluvium to the east of ULD LW1. The monitoring bore should be located close to the alluvium boundary, directly west of existing alluvium bore WML129. The monitoring of these bores, along with other alluvium bores (such as AP243 on the eastern side of Glennies Creek) will enable a comparison of water level trends to be made between the bores, so that any unforeseen impacts to the Glennies Creek alluvium as a result of ULD LW1 extraction can be easily identified;
- Where possible, expansion of the monitoring network to the south and south west of ULD LW1 to monitor any unforeseen mine related drawdown to the Hunter River alluvium near the southern portion of ULD LW1;
- Monitoring of all piezometers in the Bowmans Creek alluvium, including the paired sites that were installed above the LW6B to monitor mine related drawdown to the Bowmans Creek alluvium, particularly around the oxbow; and
- Monitoring of piezometers to the south of ULD LW4 to LW7 to monitor any unforeseen mine related drawdown to the Hunter River alluvium.

6.2.3 Groundwater Management

Groundwater flow and management for the ACP underground mine is conceptualised in **Figure 37**, which also shows the relative contributions from each water source (Glennies Creek, Bowmans Creek, Hunter River, alluvial and non-alluvial aquifers):

- Baseflow impacts to Glennies Creek alluvium are predicted to reach a maximum of 3L/s (0.26ML/d) during ULD extraction. The potential for further impacts has been minimised by offsetting the ULD mine plan by 60m to the west of the PG mine plan;
- Baseflow impacts to the Bowmans Creek alluvium are predicted to reach a maximum of 0.86L/s (0.07ML/d) by the end of ULD LW8. ULD LW4B is close to and just east of an incised oxbow-shaped meander along the Bowmans Creek. The width of this longwall panel has been reduced to ensure at least a 40m setback (in a horizontal direction) between the longwall void and the high bank of Bowmans Creek. ULD LW6B and 7A are also setback by at least 40m from the high bank of Bowmans Creek;
- Baseflow impacts to Hunter River are predicted to total 0.23L/s (0.02ML/d) at the end of ULD LW8. Impacts to the Hunter River will be managed by offsetting ULD LW5 to 7 by at least 200m from the Hunter River Alluvium; and
- Total inflows into the underground mine workings (PG and ULD) are predicted to reach a maximum of 15L/s (1.3ML/d), and will be mostly comprised of water sourced from the Permian coal measures and interburden.

ACOL is committed to account for the impact of the ULD Seam extraction on surrounding water sources. This will be achieved by:

- Maintaining a register of mine inflows;
- Holding sufficient and appropriate water entitlements to account for mine inflows (or other mine related impact), generally in accordance with the rules of the relevant water sharing plan, where these apply; and
- Accounting and reporting of water inflows against these entitlements.

6.3 Reporting and Review

ACOL undertakes environmental performance reviews and reporting in accordance with the Site Environmental Management Strategy (EMS).

6.3.1 Fortnightly Monitoring and Reporting

To confirm whether the impacts to Glennies Creek, Bowmans Creek and the Hunter River (and connected alluvium) are within the EA or EIS predictions, the groundwater monitoring frequency will be intensified to fortnightly during LW extraction within or near saturated alluvium. This includes monitoring of the Glennies Creek alluvium during the extraction of ULD LW1 and the Bowmans creek alluvium during the extractions of ULD LW6 to 8. If required, fortnightly groundwater monitoring reports will be prepared by a hydrogeologist and submitted to ACOL.

6.3.2 End of Panel Reports

Post-mining longwall panel subsidence monitoring reports are produced to detail and assess subsidence, groundwater levels, water quality and mine inflows, which are then compared to the EIS/EA and the SMP/EP for the mined panel and seam. These reports are provided to NSW Office of Water (NOW).

Should any review or post-audit indicate a significant variance from the model predictions with respect to water quality or groundwater levels, then the implications of such variance will be assessed and appropriate response actions implemented in accordance with the protocols described in the WMP to plan appropriately for future extractions.

6.3.3 Annual Environmental Management Report

Monitoring data is subjected to an annual review by an appropriately qualified and suitably experienced hydrogeologist. This review forms part of the Annual Environmental Management Report (AEMR) process. The review is conducted to assess the impacts of the ACP on the groundwater environment and to compare observed and approved predicted impacts, and includes:

i. an interpretation and statistical analysis of water quality results and changes in time for water quality and water levels at surface and ground water monitoring points (supported with graphs and contour plots showing changes in aquifer pressure levels);
ii. the outcome of the mine water balance for the year;
iii. the effectiveness of established water management structures, sediment control devices and the particulars of any remedial measures undertaken in instances where uncontrolled erosion or heavy sediment deposition has occurred;
iv. a discussion of any exceedences in relation to trigger levels (specified in the WMP) and predictions made in the EIS and the EA; and responses taken to ameliorate those exceedences;
v. reporting on the differentiation between shallow and deep aquifers, with interpretation of results; and
vi. an interpretation of the water balance identifying the volume and make-up of mine pit inflows as compared to Part 5 licence entitlements (required under Part 5 of the *Water Act* 1912), and predictions made in the EIS, EA or previous AEMR;

An electronic copy of the data will be provided to the NOW.

In addition, the AEMR will incorporate a Groundwater Management Report prepared by an independent expert to the satisfaction of the NOW. It will identify trends in groundwater monitoring data and provide a comparison to predictions.

Copies of the AEMR will be submitted at the same time to the Director-General of the DP&I, DRE, OEH, NOW, SSC and the CCC, and made available for public information at SSC within fourteen days of submission to these authorities.

7. RECOMMENDATIONS

7.1 Groundwater Monitoring Program

It is recommended that the current network and monitoring regime is maintained, including:

- Monitoring of water extracted from the underground mine, which should extend to the lower seams as these are mined, and inflows from the area closest to Glennies Creek should continue to be monitored separately, where possible;
- Where possible, the installation of additional monitoring points around the southern portion ULD LW1 to detect any unforeseen impacts to the Glennies Creek and Hunter River alluvium. Ideally this should comprise
  - two multilevel vibrating wire piezometers to target Permian coal measures at the southern end of ULD LW1,
  - one standpipe piezometer to target the Glennies Creek Alluvium, located directly west of WML129 (east of ULD LW1); and
  - two standpipe piezometers to target the Hunter River Alluvium, located to the south and south west of ULD LW1.
- Increasing the monitoring frequency to fortnightly of all standpipes/piezometers that are located in the barrier between ULD LW1 and Glennies Creek and south of ULD LW1 during critical stages of ULD LW1 extraction (i.e. during the start of ULD extraction and as the LW face passes the closest point to Glennies Creek);
- Repeat hydraulic testing of standpipes in the barrier to determine whether the permeability characteristics within the PG seam and overburden along the alignment of PG TG1 have been maintained following advancement of ULD LW1; and
- Increasing the monitoring frequency to fortnightly of key standpipes to monitor any unforeseen impacts to the Bowmans Creek and Hunter River alluvium, during the early and/or final stages of ULD LW4B, LW6 and LW7 extraction.

7.2 Response Plans

The existing trigger action response plan (TARP) has been revised to include:

- Where possible, the monitoring of the lower seam inflows as they are mined, which are related to the Glennies Creek barrier;
- Monitoring triggers for the proposed boreholes drilled to monitor for impacts from the ULD extraction; and
- Measures to monitor and mitigate the risk of mine flooding.

7.3 Subsidence Impact Monitoring

It is recommended that the subsided monitoring lines across LW1 be re-surveyed during secondary extraction of ULD LW1. Any observed lateral movements may indicate a possible increase in hydraulic conductivity of the barrier between LW1 and Glennies Creek. This should be correlated with any changes of aquifer permeability detected through the repeat hydraulic testing of standpipe piezometers in the barrier. Periodic re-surveying is also recommended during subsequent extraction of ULD LW2 to 4, which allows for more accurate subsidence predictions before progressing to ULD LW5 to 8.

7.4 Review

A review of the numerical groundwater model should be carried out at least every five years for the duration of the mine, in accordance with industry best practice (MDBC, 2001).

Should any review or post-audit indicate a significant variance from the model predictions with respect to water quality or groundwater levels, then the implications of such variance should be assessed. Appropriate response actions should then be developed and implemented in consultation with the DRE and NOW as appropriate.

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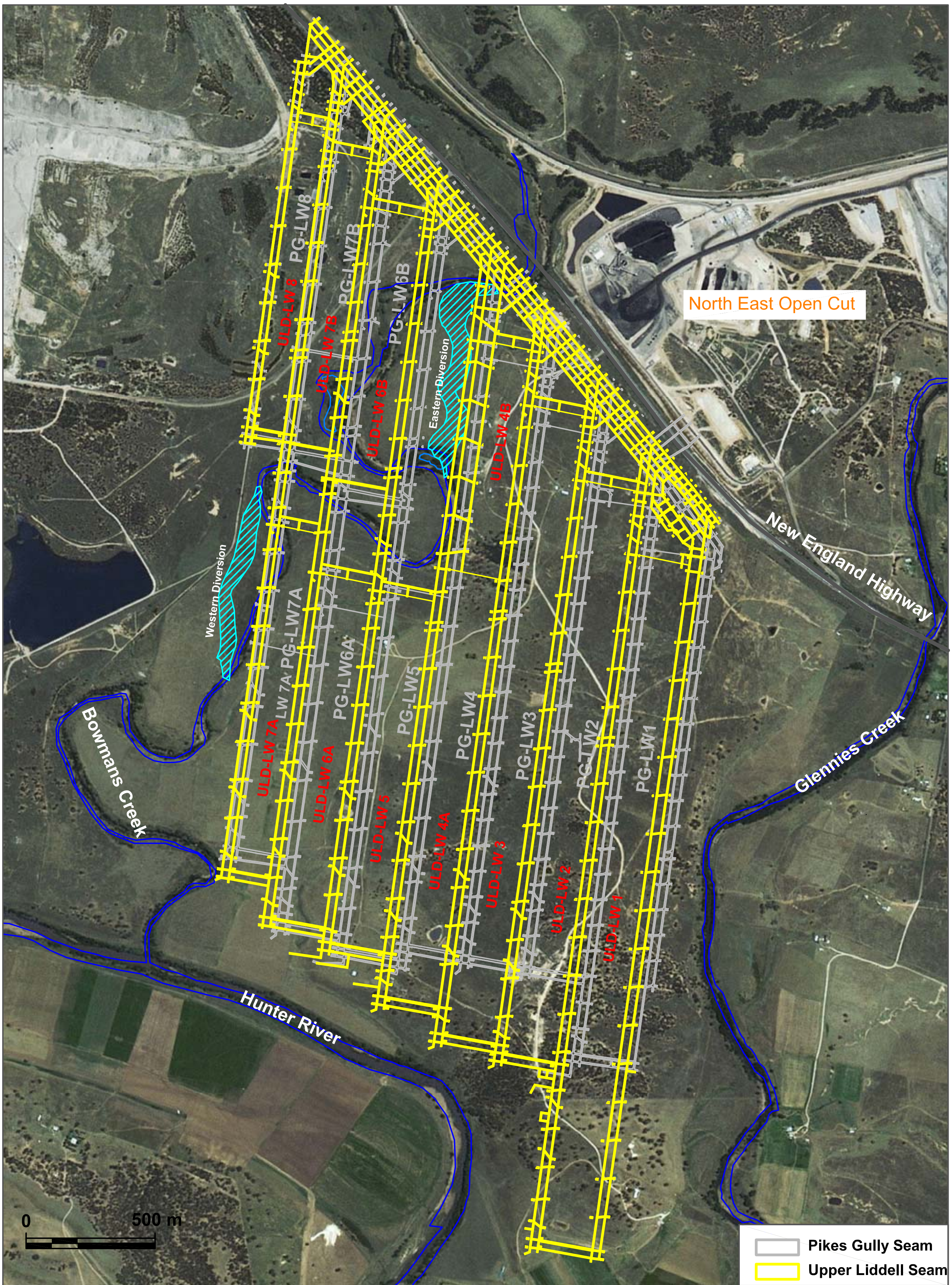
FIGURES



Date:	14 June 2011	Scale:	as shown
Initials:	HZ	Job No:	S55J
Drawing No:	S55J-001a	Rev:	A

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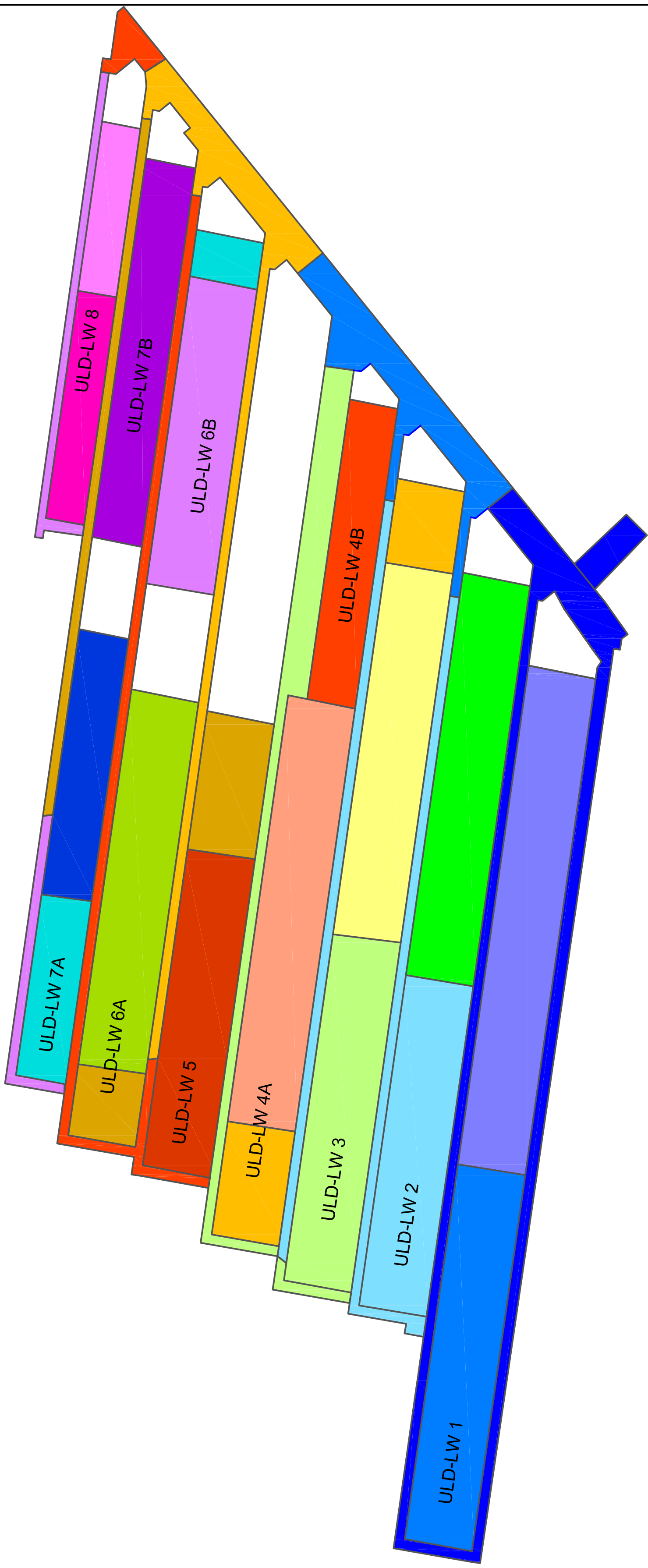
Ashton Coal Operations Ltd

Mine Layout in the Pikes Gully and Upper Liddell Seam

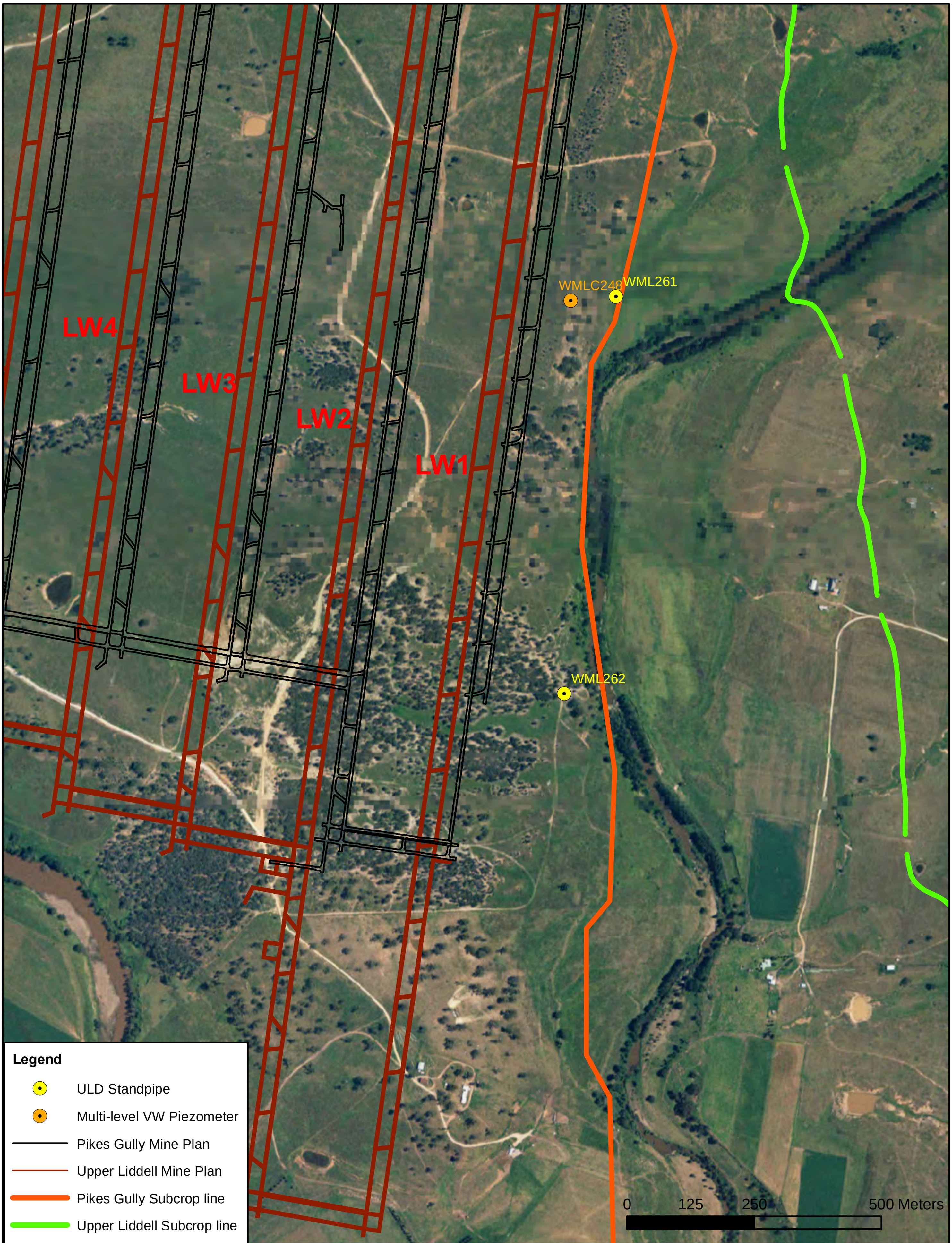
Figure 1



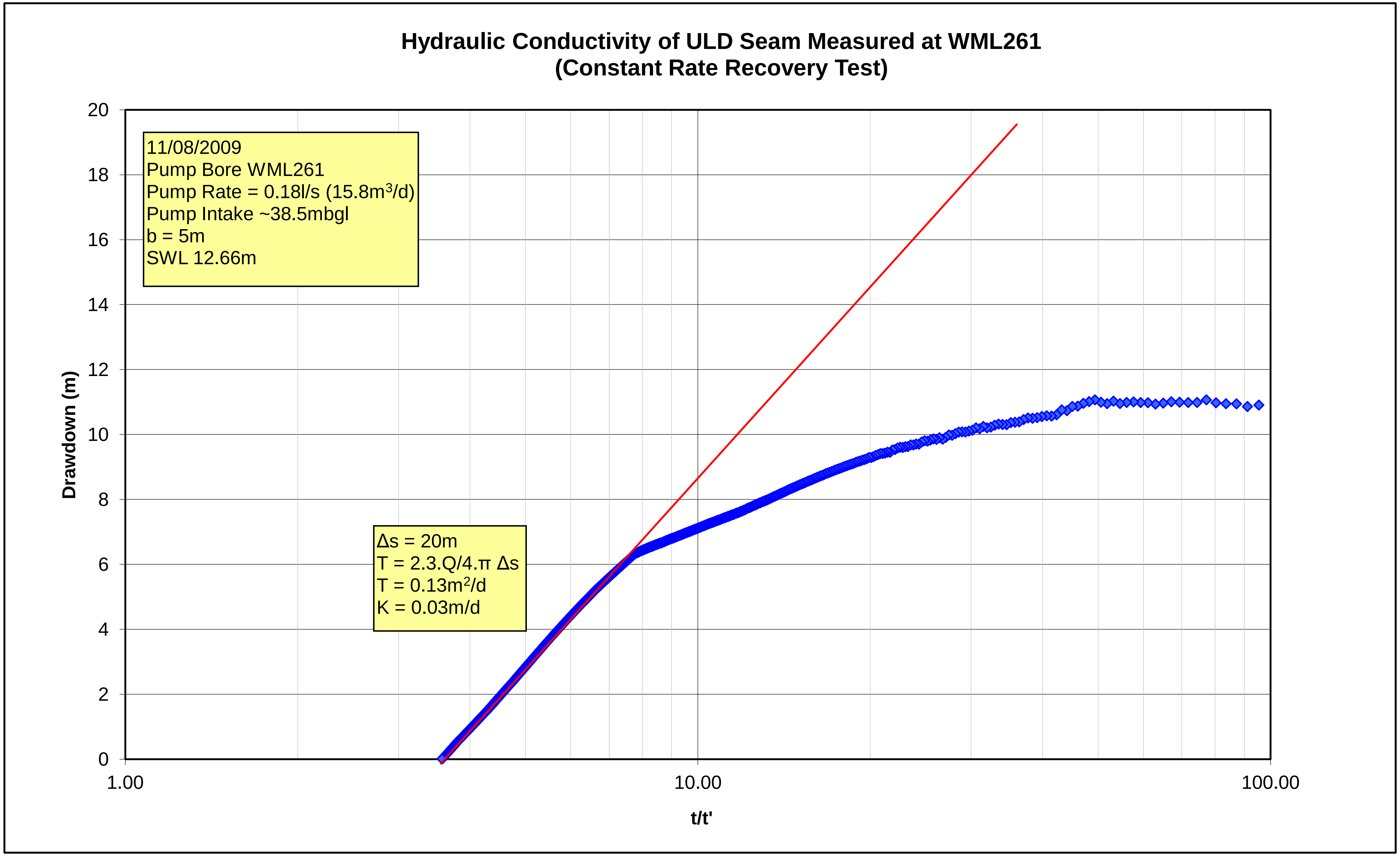
LW Extraction Date

Commencement	Completion
01/01/2011	31/12/2011
01/01/2012	31/03/2012
01/04/2012	30/06/2012
01/07/2012	30/09/2012
01/10/2012	31/12/2012
01/01/2013	31/03/2013
01/04/2013	30/06/2013
01/07/2013	30/09/2013
01/10/2013	31/12/2013
01/01/2014	31/03/2014
01/04/2014	30/06/2014
01/07/2014	30/09/2014
01/10/2014	31/12/2014
01/01/2015	31/03/2015
01/04/2015	30/06/2015
01/07/2015	30/09/2015
01/10/2015	31/12/2015
01/01/2016	31/03/2016
01/04/2016	30/06/2016

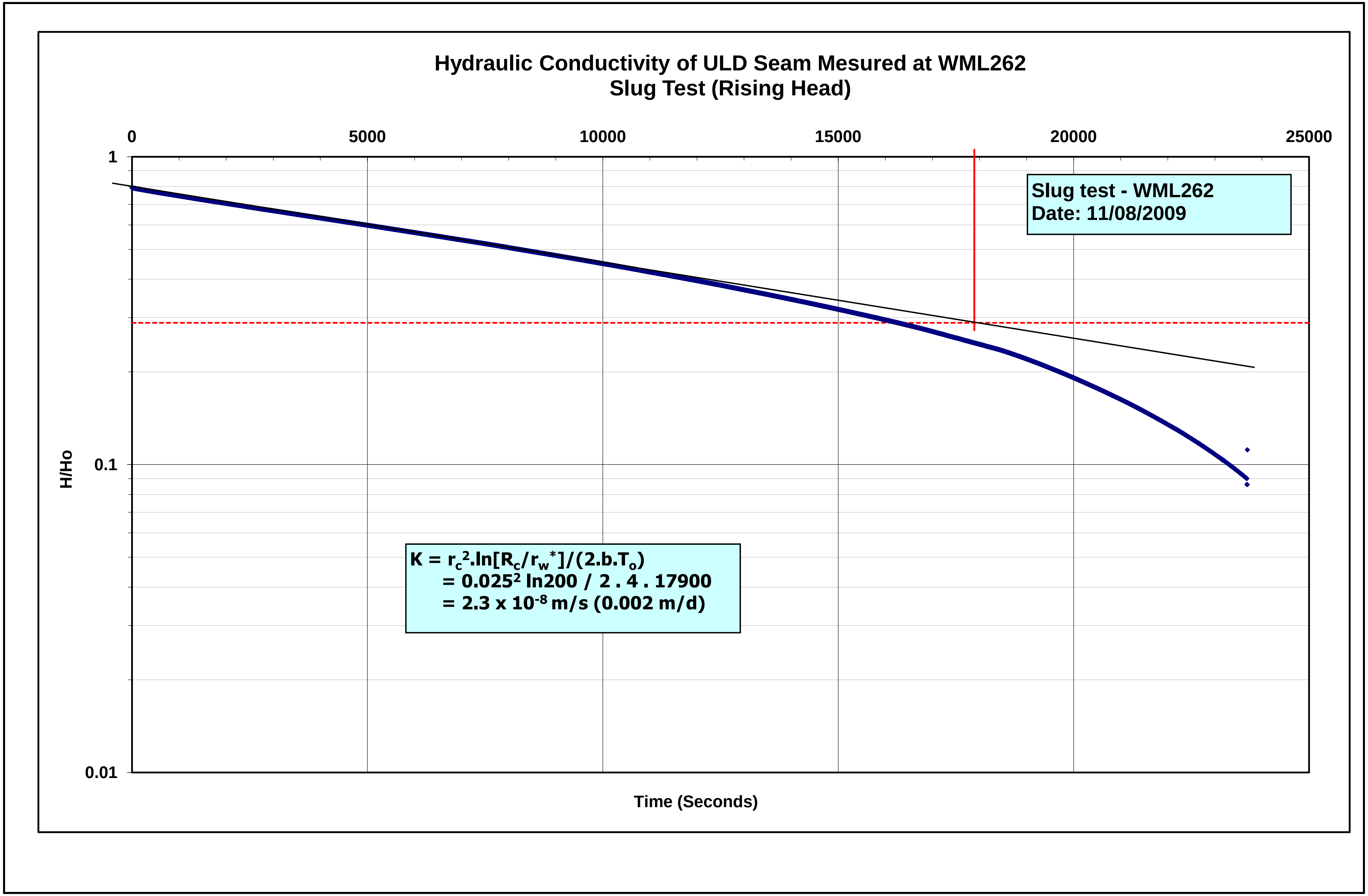
Date: 19 May 2011	Scale: N/A	**Ashton Coal Operations Ltd**
Initials: HZ	Job No: S55J	**Proposed Upper Liddell Annual Production Schedule**
Drawing No: S55J-004	Rev: A	
		Figure 2

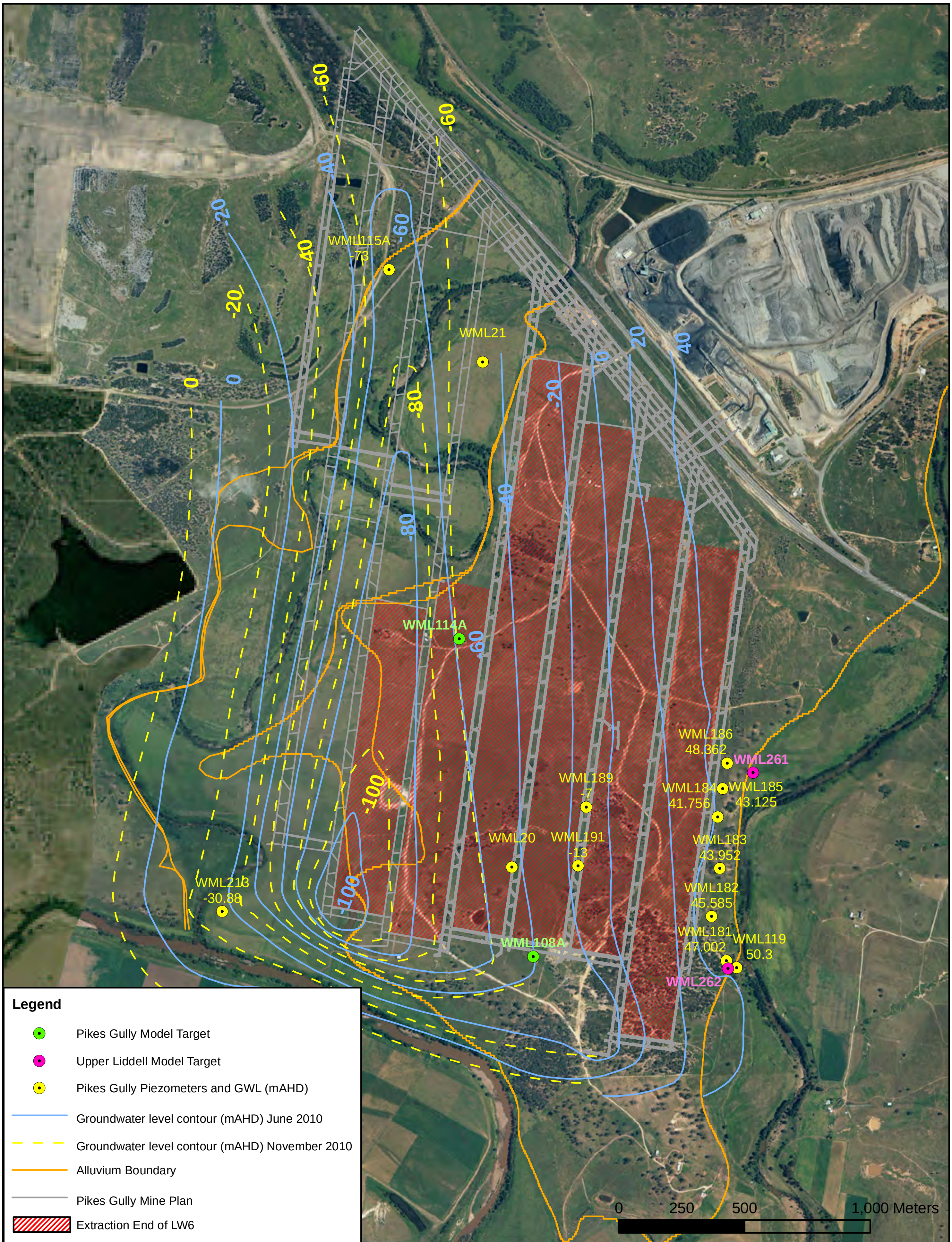


Date:	11 July 2011	Scale:	As Shown	**Ashton Coal Operations Ltd**
Initials:	HZ	Job No.:	S55J	**Location of Piezometers Installed in the Upper Liddell Seam**
Drawing No.:	S55J-406	Rev:	A	
RPS Aquaterra				**Figure 3**

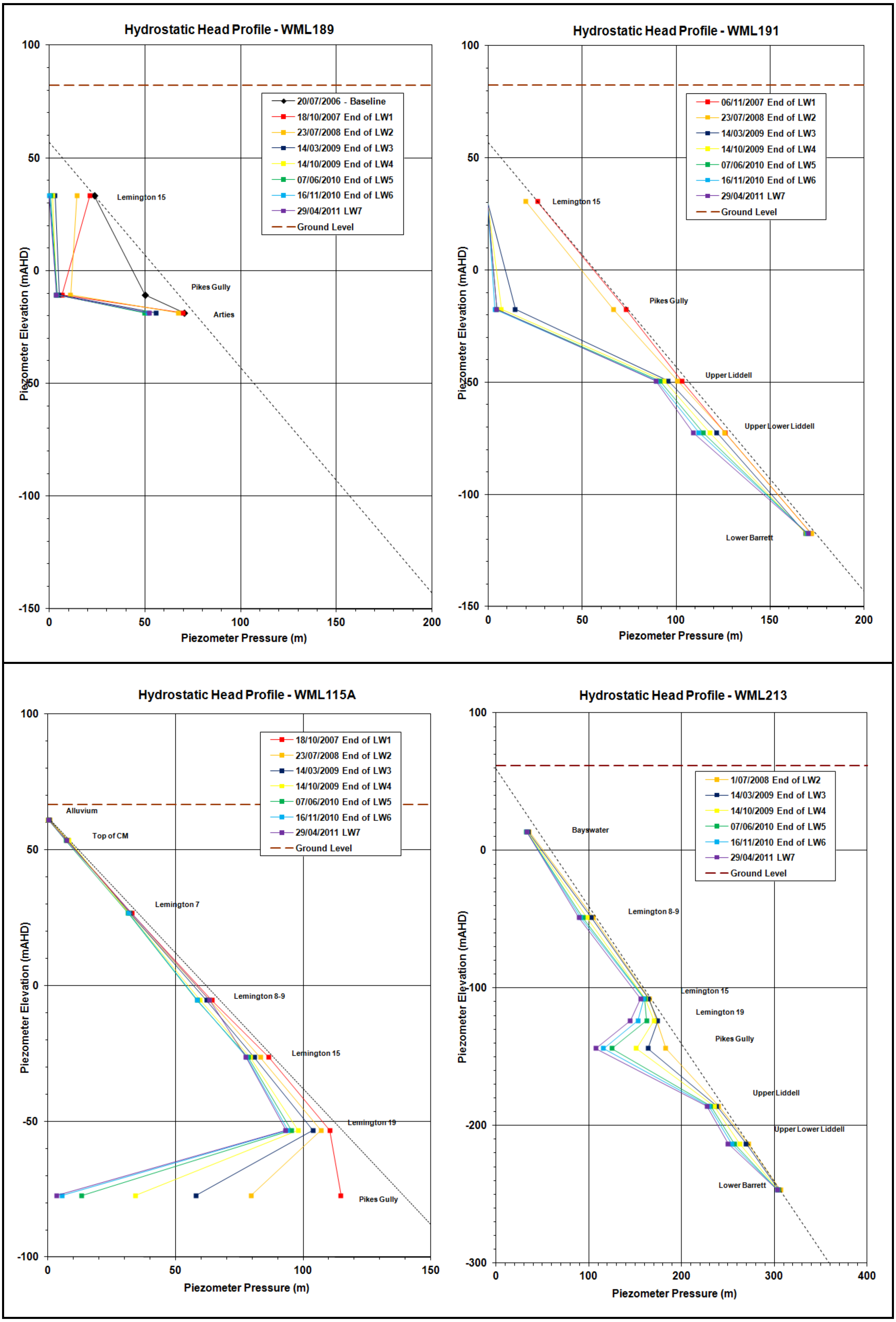


RPS Aquaterra


Hydraulic Conductivity of ULD Seam Mesured at WML262
Slug Test (Rising Head)
0
5000
10000
15000
20000
25000
1
0.1
0.01
H/Ho
Time (Seconds)
Slug test - WML262
Date: 11/08/2009
K = r_c^2.ln[R_c/r_w^*]/(2.b.T_o)
= 0.025^2 ln200 / 2 . 4 . 17900
= 2.3 x 10^-8 m/s (0.002 m/d)



Date:	13 October 2011	Scale:	As Shown	**Ashton Coal Operations Ltd**
Initials:	HZ	Job No.:	S55J	**Groundwater Elevation - Pikes Gully End of LW6A**
Drawing No.:	S55J-403	Rev:	C	
RPS Aquaterra				**Figure 6**



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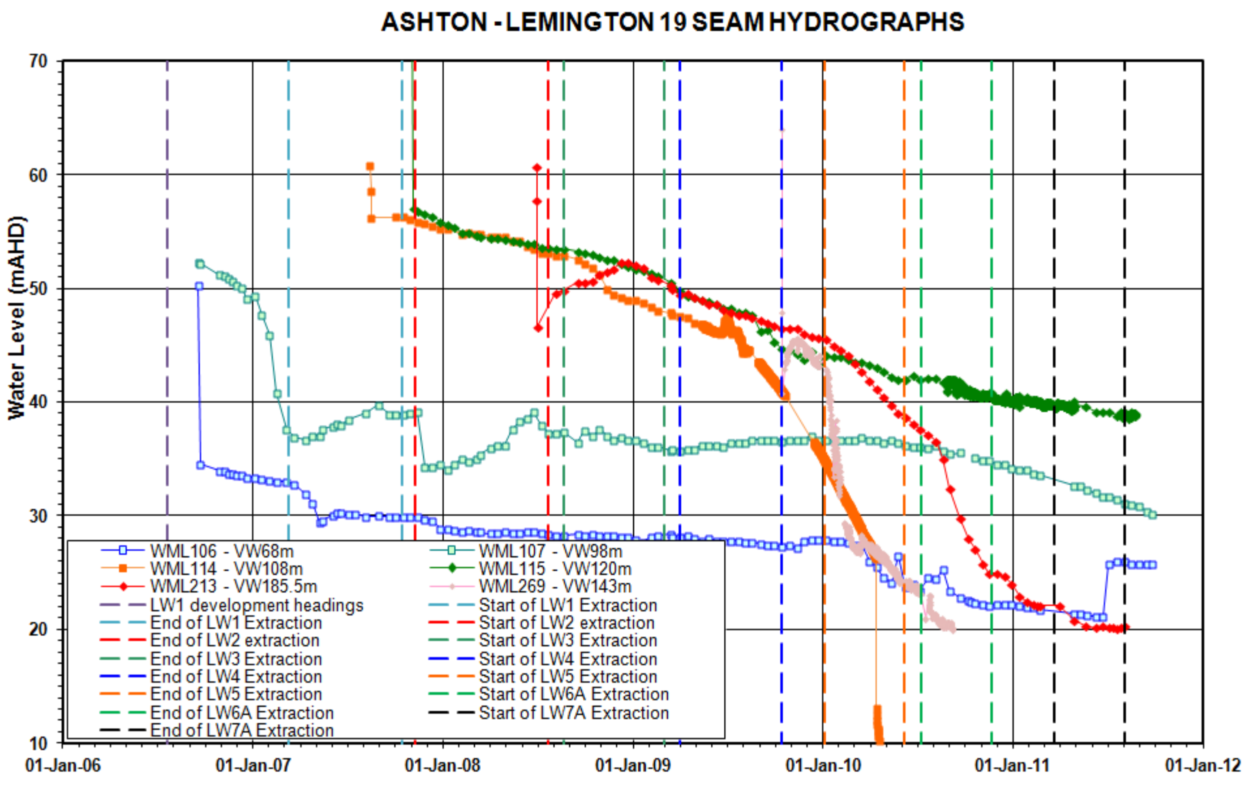
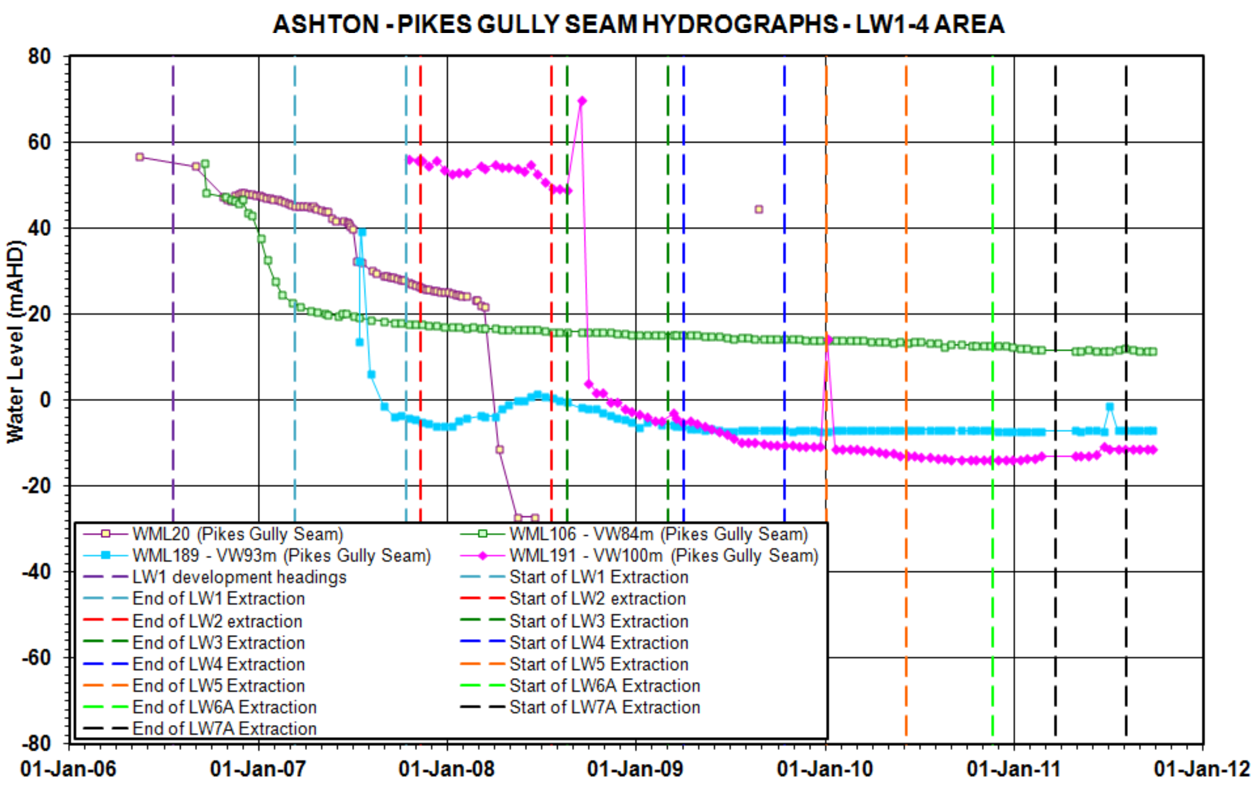
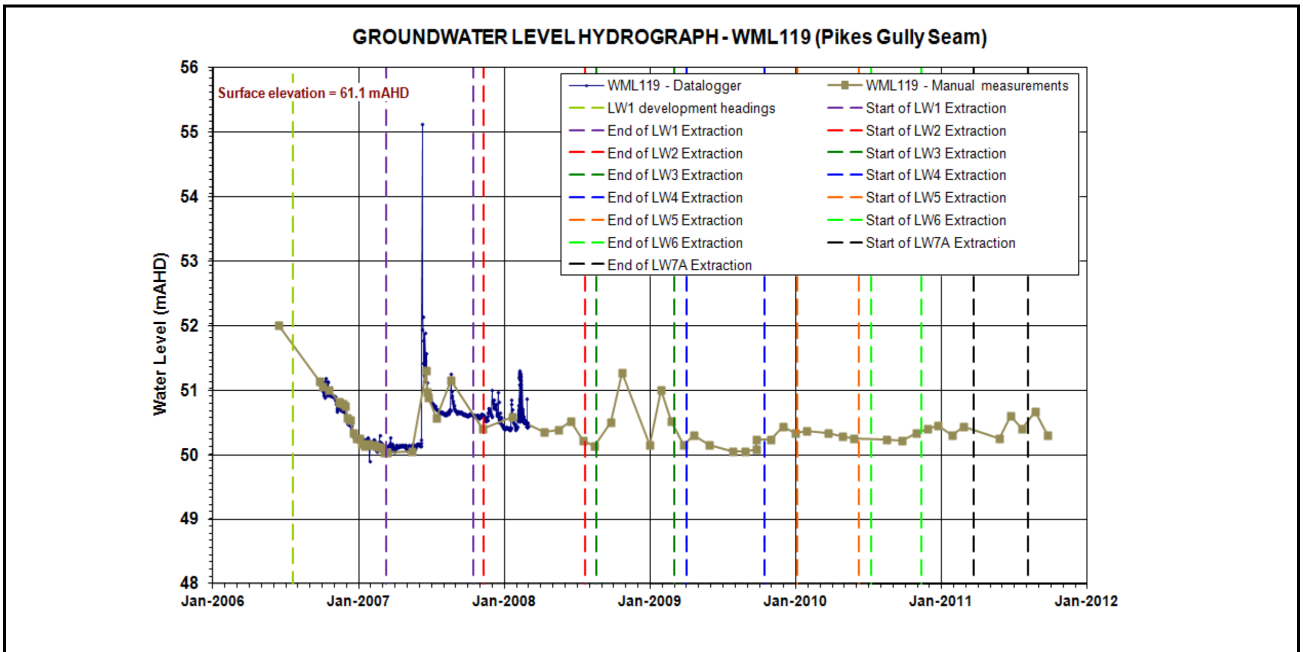
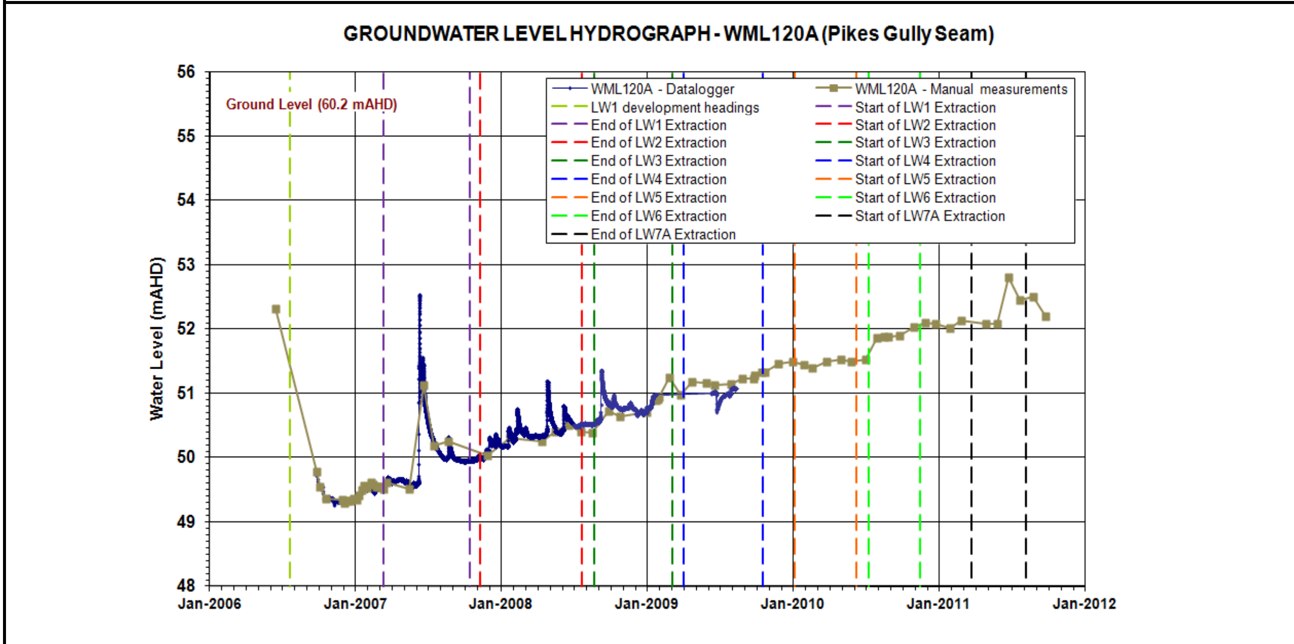
Hydrostatic Head Profiles WML189, WML191, WML115, WML213 FIGURE 7

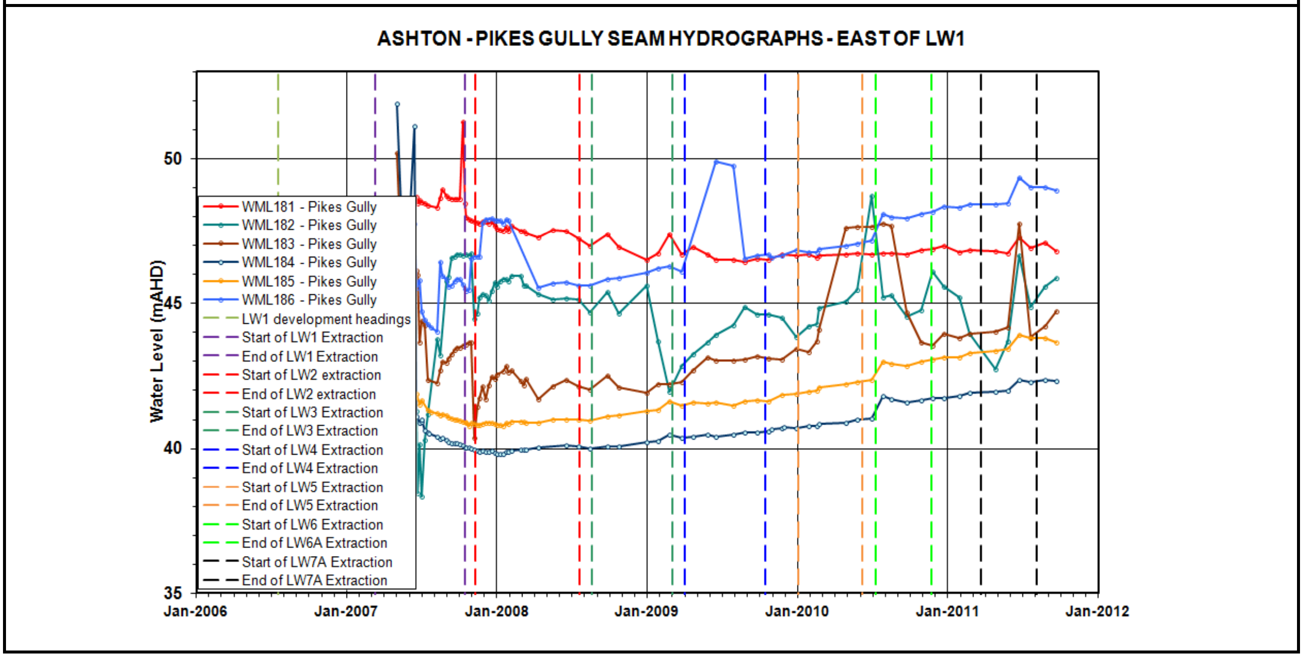




Groundwater Levels Hydrographs-Lemington19 Seam and Pikes Gully Seam FIGURE 8







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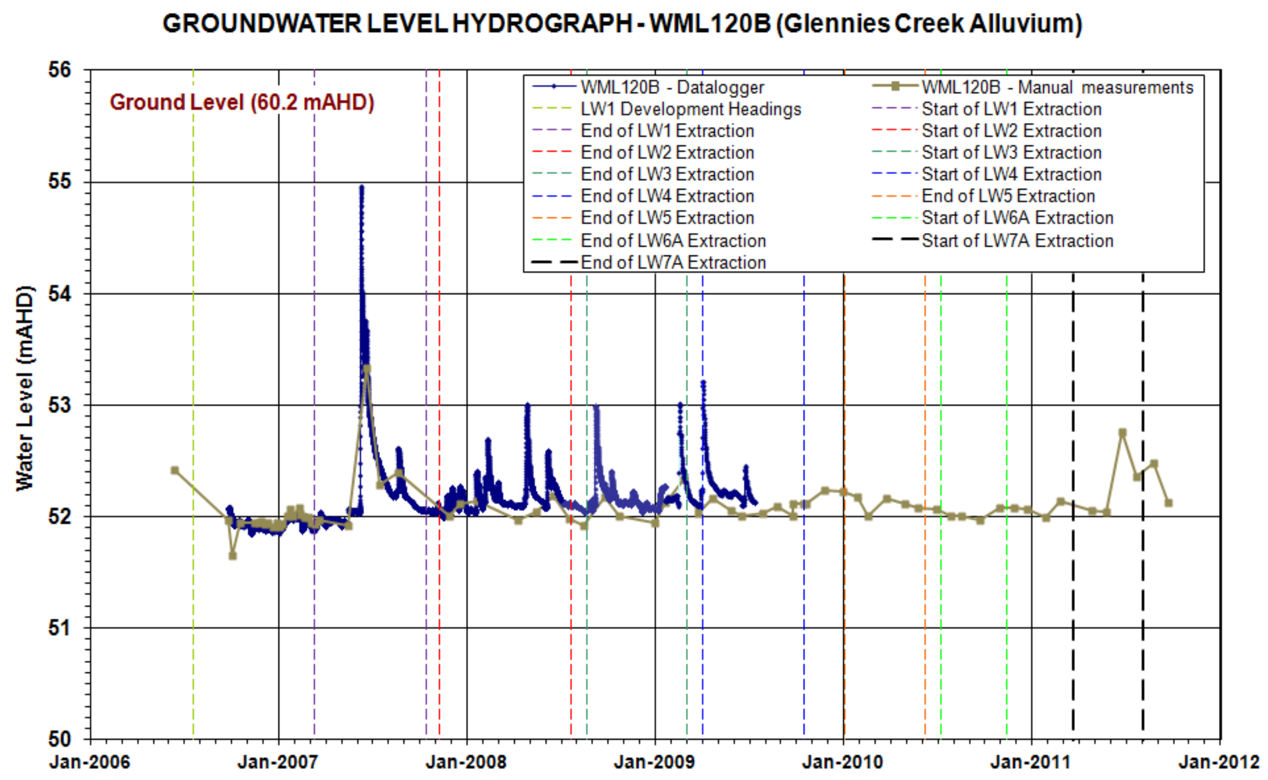
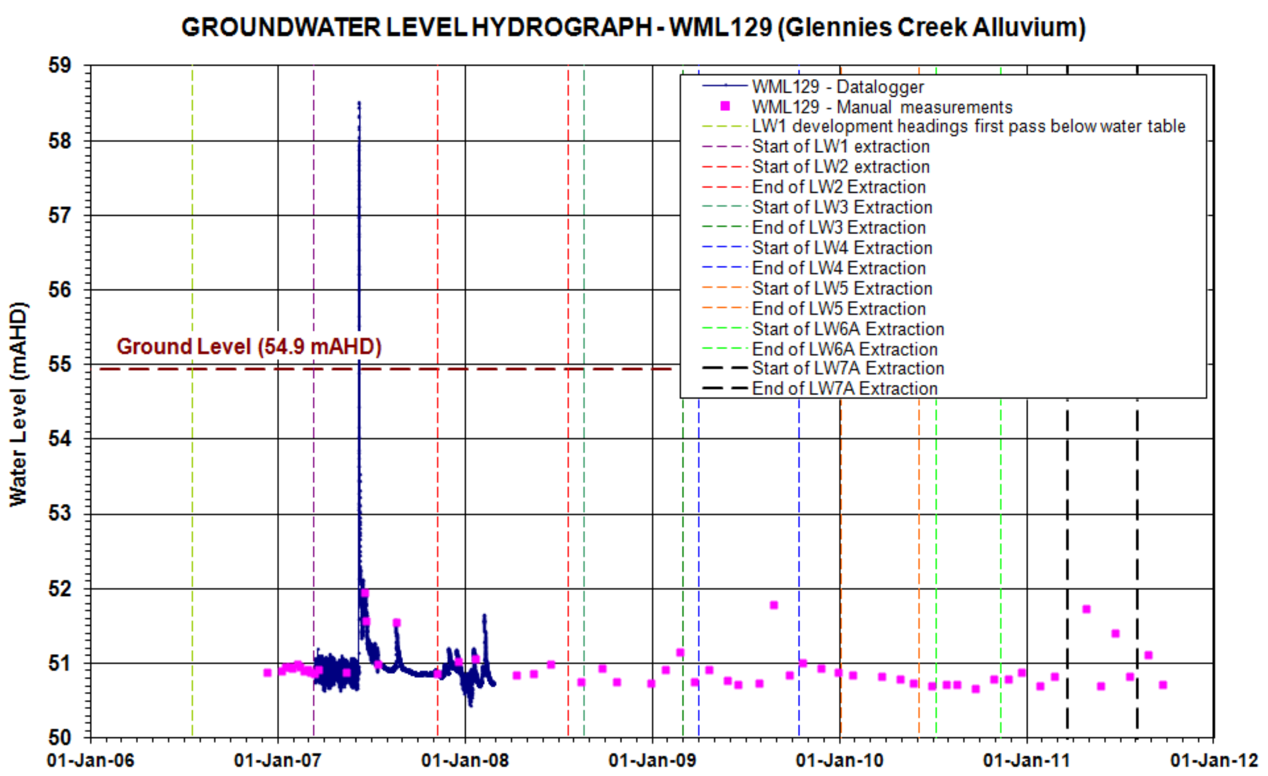
Groundwater Level Hydrographs - Pikes Gully Seam, East LW1 FIGURE 9





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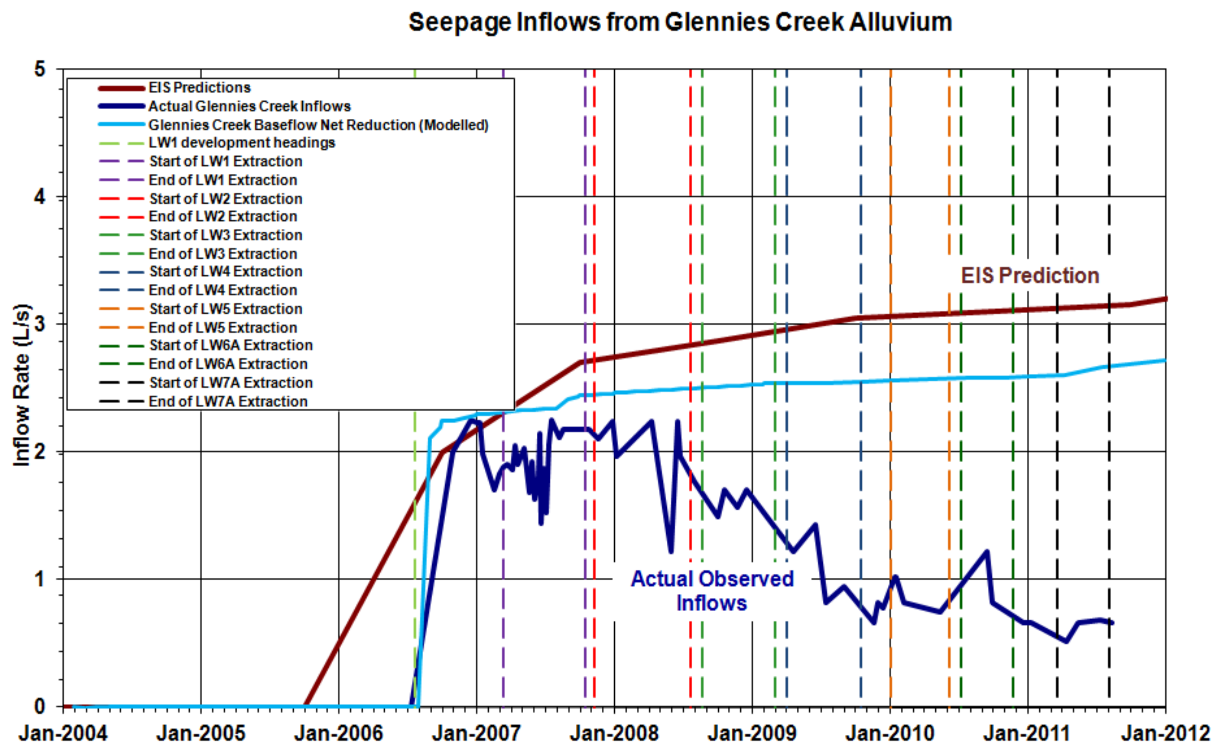
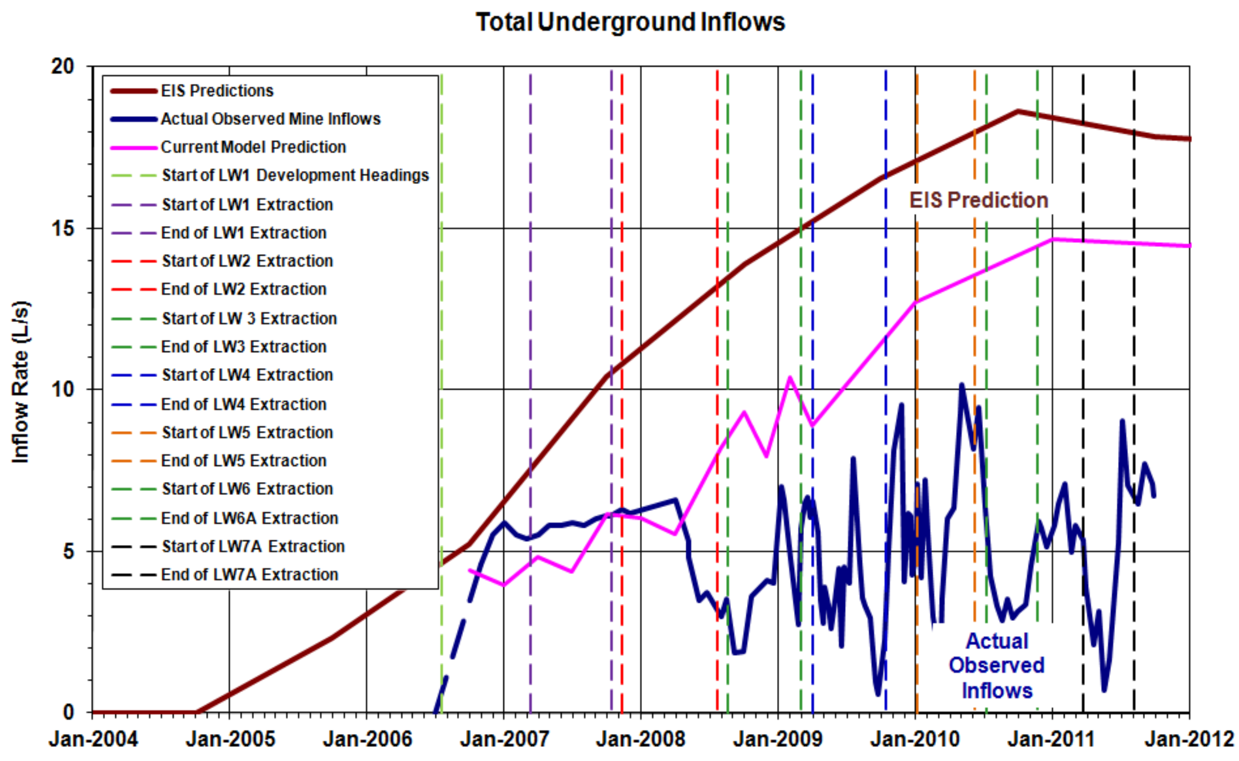
Groundwater Level Hydrographs-Glennies Creek Alluvium FIGURE 10





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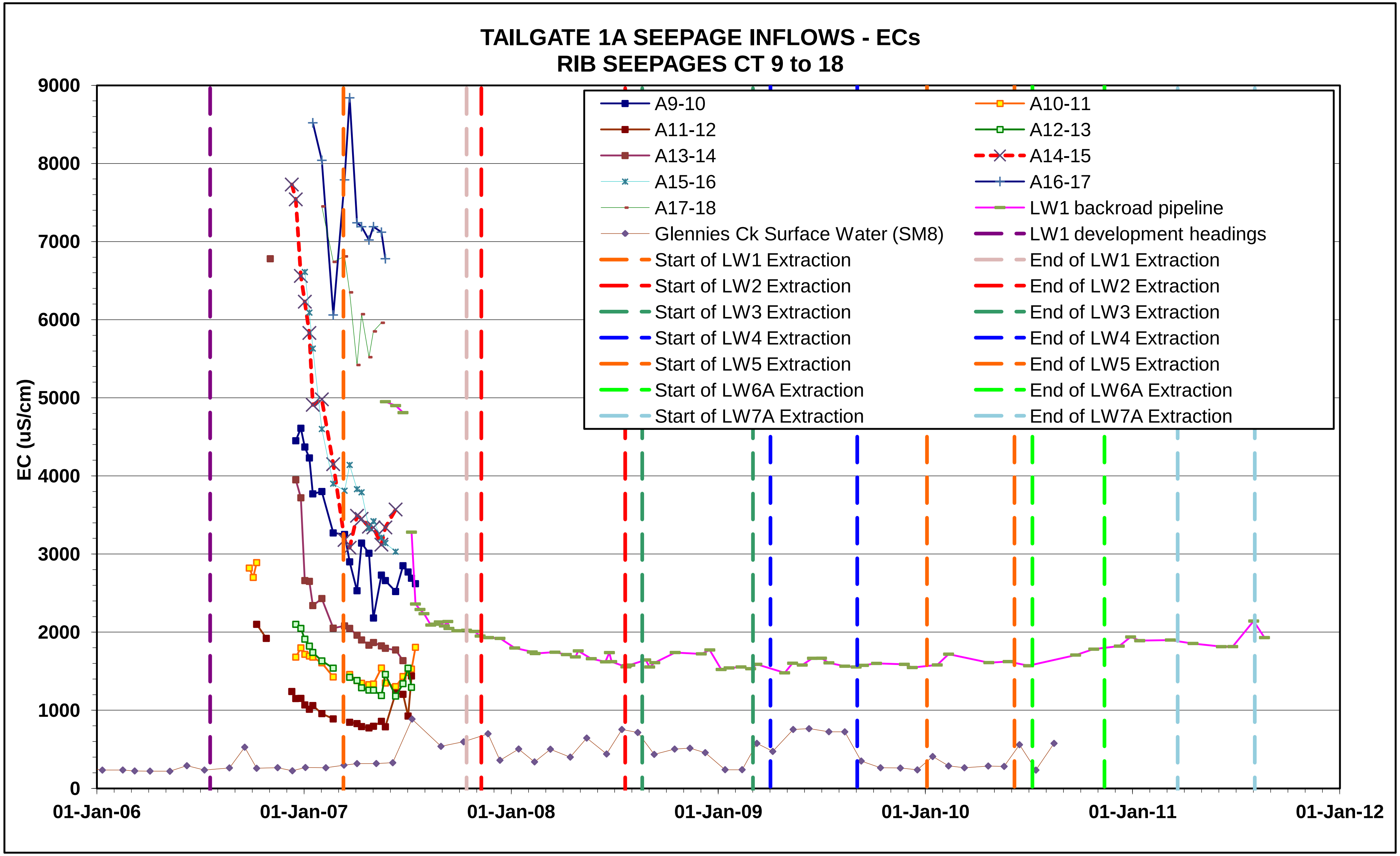
Underground Mine Groundwater Inflows vs EIS Predictions FIGURE 11



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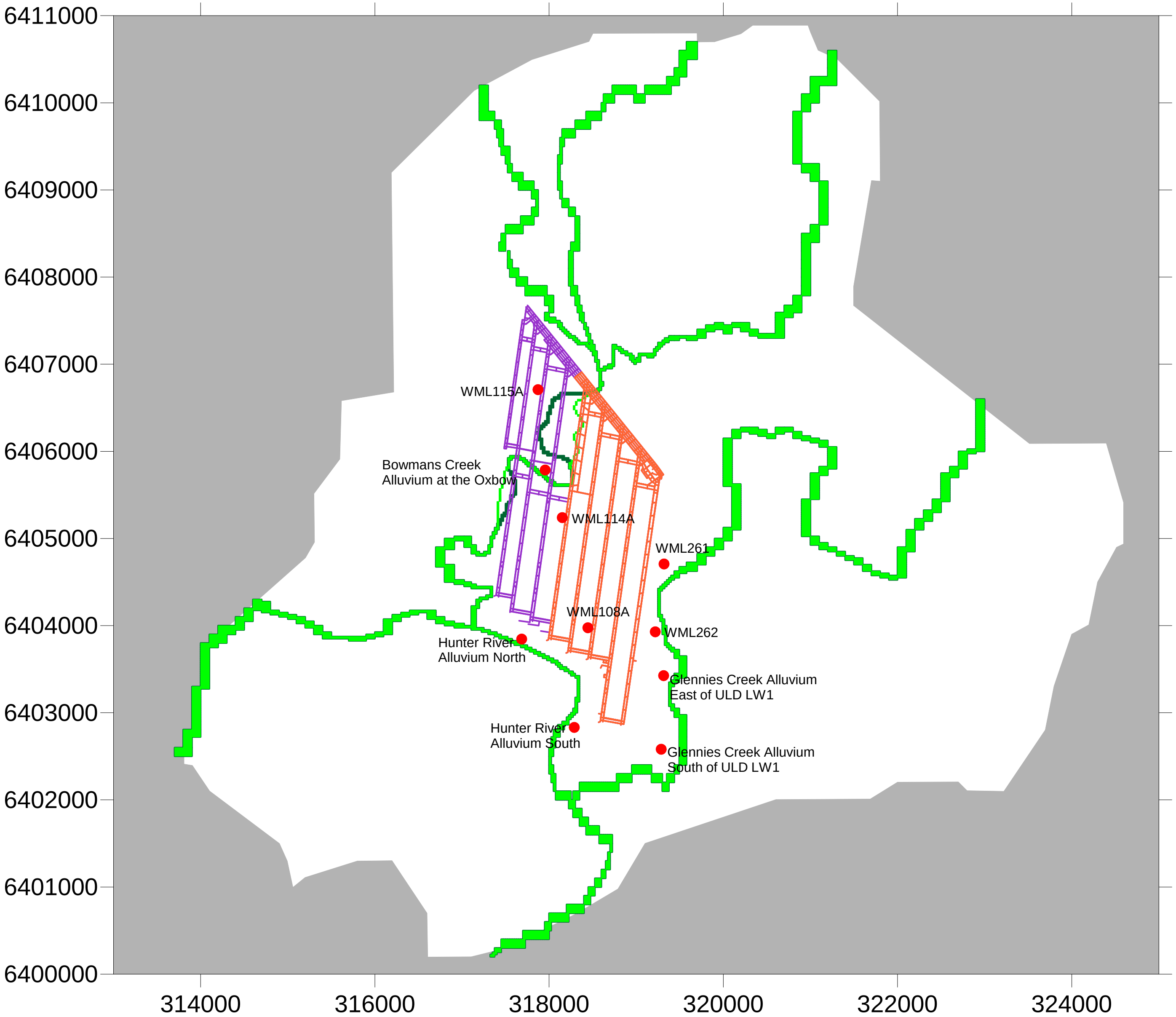
Longwall 1 TG1-A Seepages ECs FIGURE 12



Groundwater Impacts Observations
Noflow Area
Rivers or Creeks
Former Bowmans Creek Channel
Upper Liddell Mine Plan (LW1-4)
Upper Liddell Mine Plan (LW5-8)

Date	14 November 2011	Scale	As Shown
Initials	HZ	Project	S55J
Drawing Number	S55J-240	Revision	A

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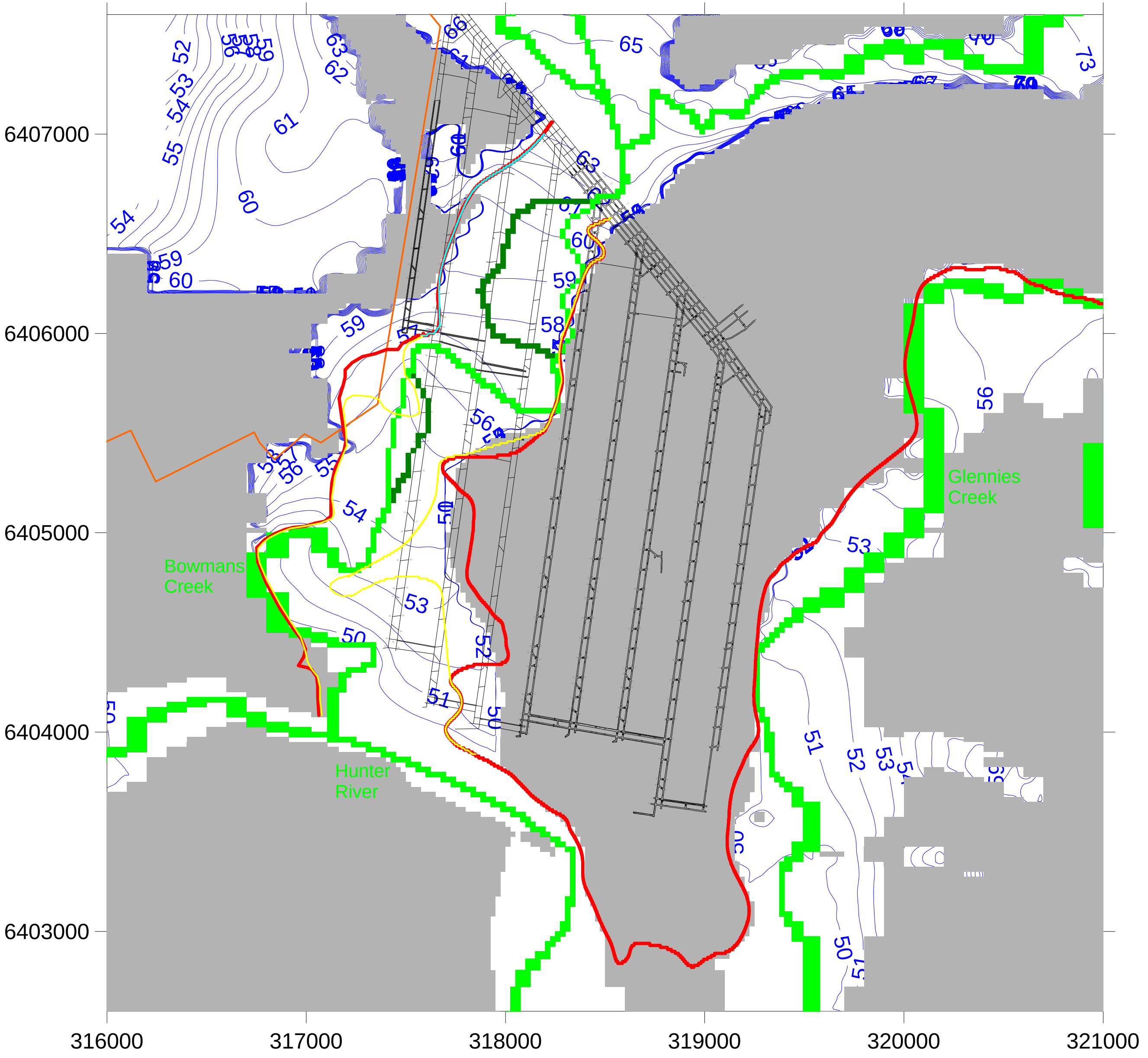
Model Domain and
Locations of Modelled Drawdown Observations

Figure 13



Predicted Groundwater Levels (mAHD)
Dry Cells
Alluvium Boundary
Extent of Saturated Alluvium
Pikes Gully Mine Plan LW1-8
Ravensworth Mine Plan
Rivers or Creeks
Former Bowmans Creek Channel

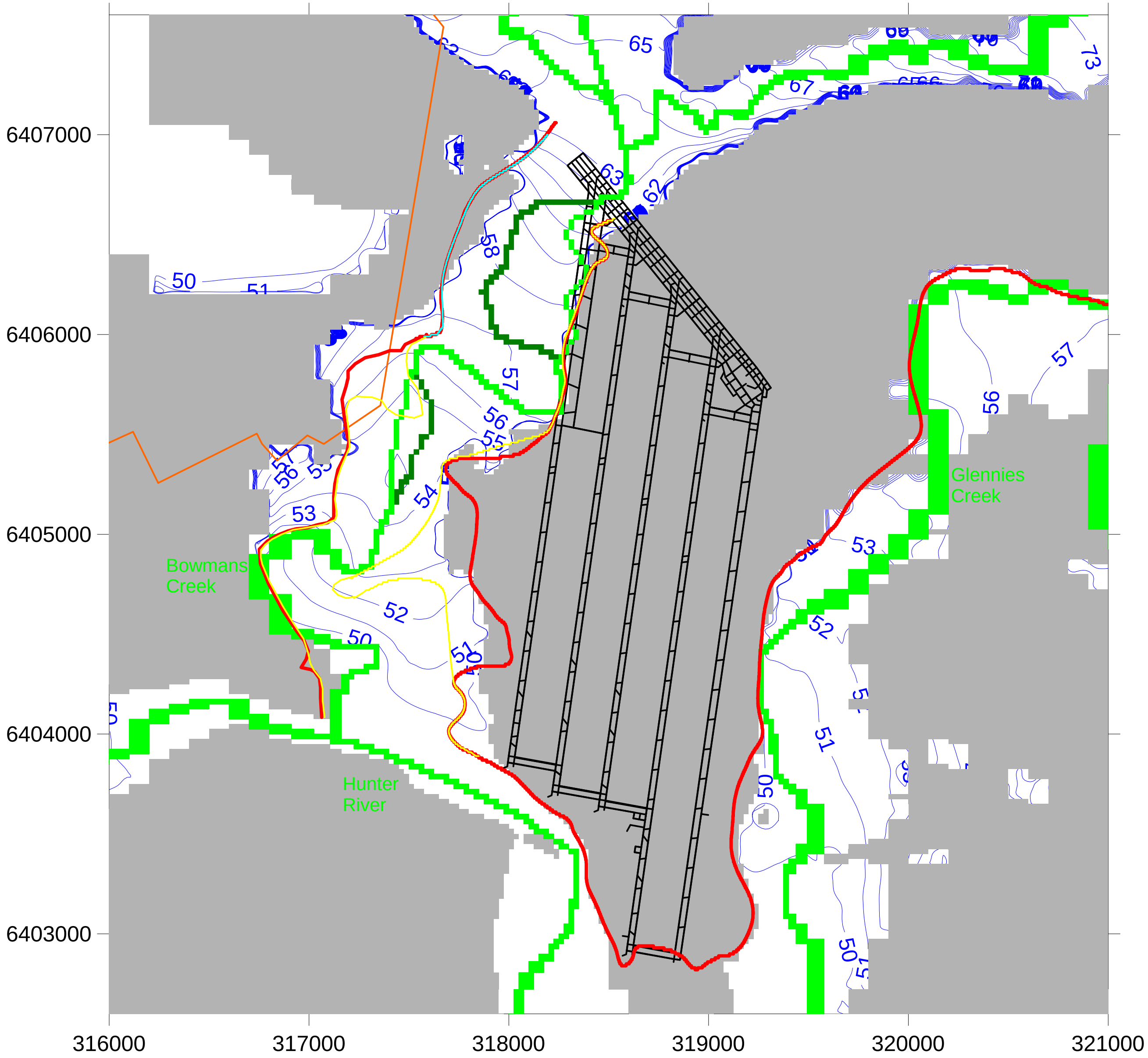
Date	12/02/2012	Scale	As Shown
Initials	HZ	Project	S55J
Drawing Number	S55J-212a	Revision	G

RPS Aquaterra

Ashton Coal Operations Ltd

Predicted Groundwater Level at the End of PG Mining (2012) in the Alluvium and Regolith (Layer1)

Figure 14



Predicted Groundwater Levels (mAHD)	Upper Liddell Mine Plan LW1-4
Dry Cells	Ravensworth Mine Plan
Alluvium Boundary	Rivers or Creeks
Extent of Saturated Alluvium	Former Bowmans Creek Channel

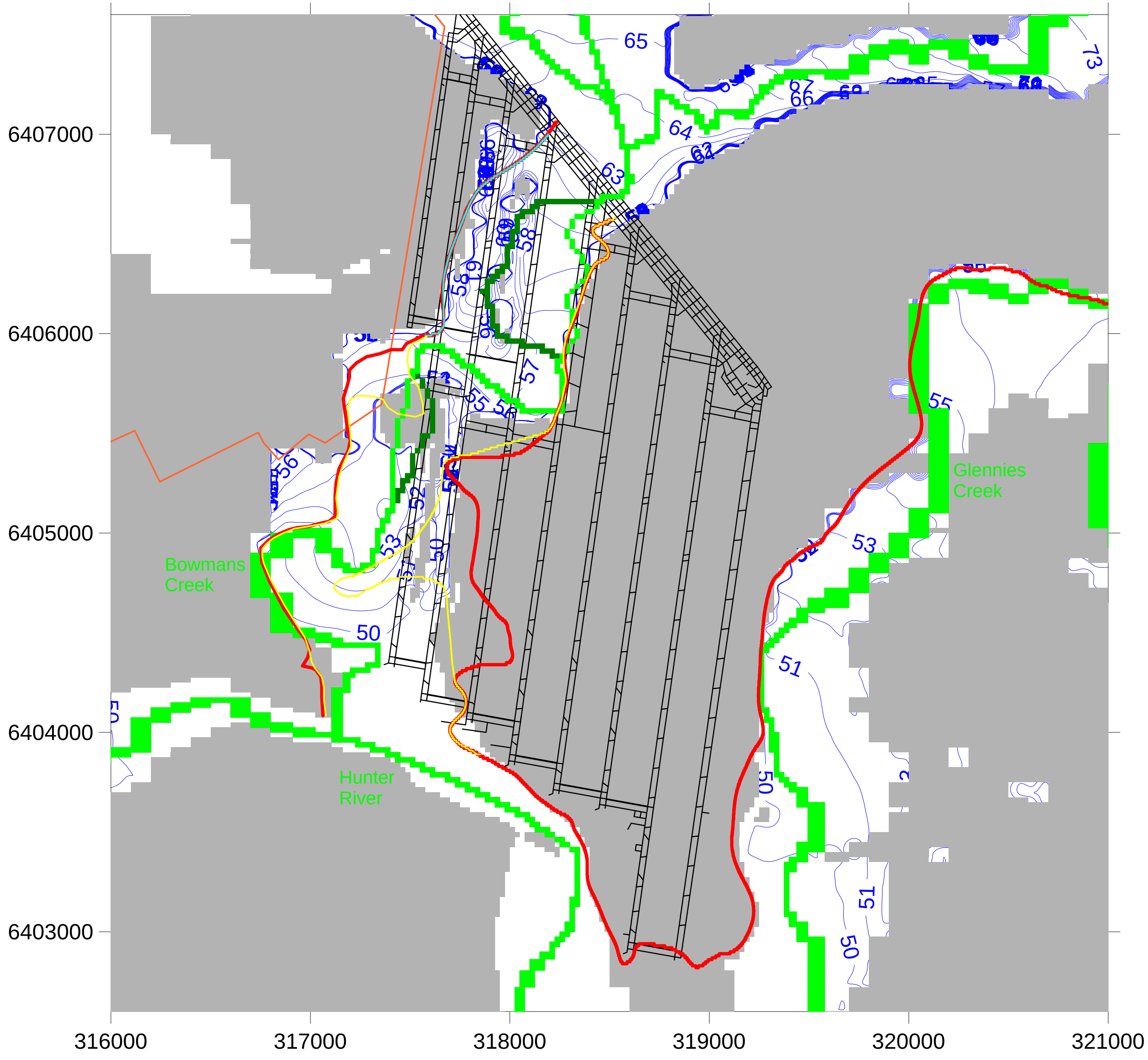
Date	21/02/2012	Scale	As Shown
Initials	HZ	Project	S55J
Drawing Number	S55J-213a	Revision	G

RPS Aquaterra

Ashton Coal Operations Ltd

Predicted Groundwater Level at the End of ULD LW4 (2014) in the Alluvium and Regolith (Layer1)

Figure 15

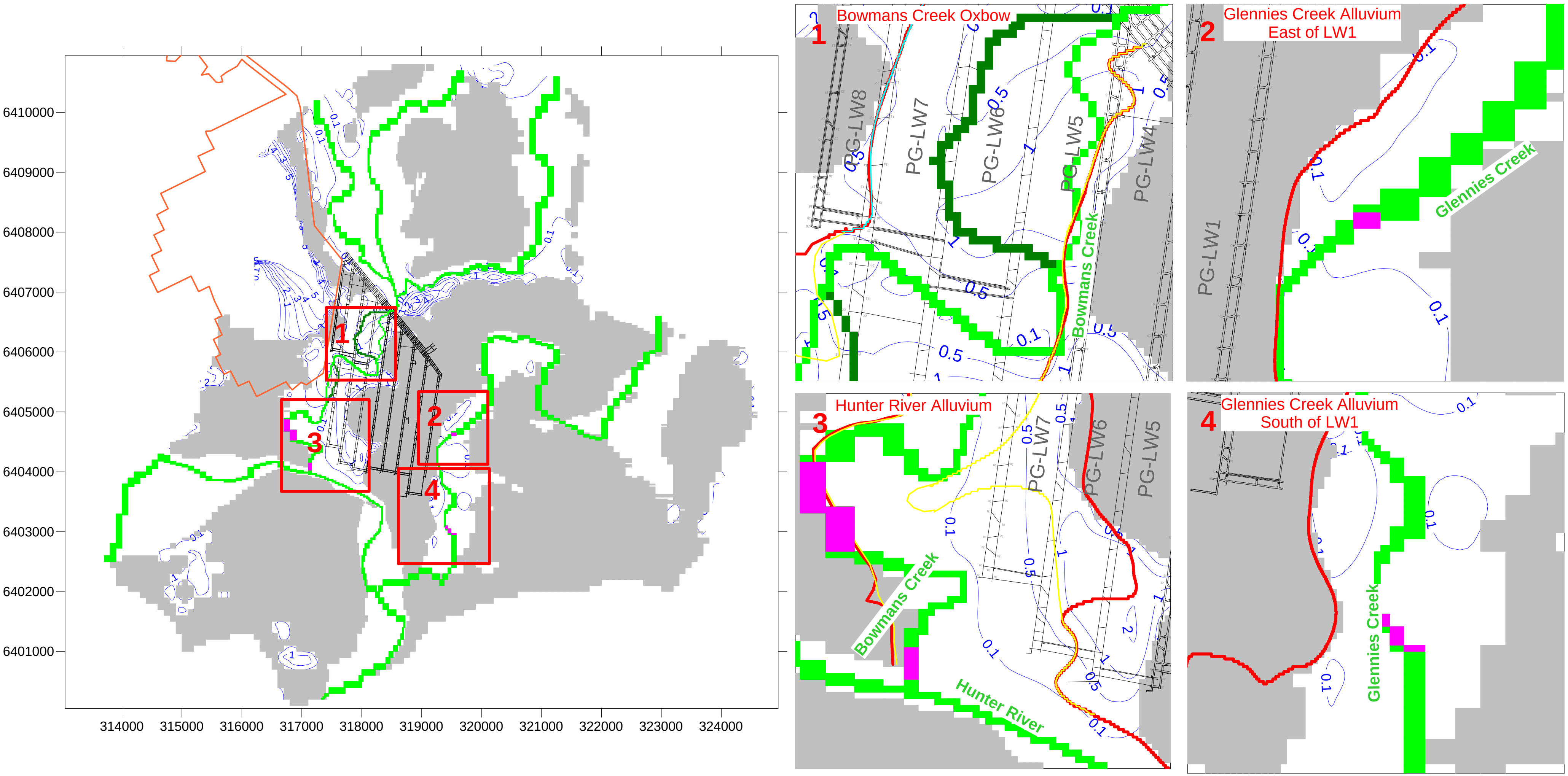


Predicted Groundwater Levels (mAHD)	Upper Liddell Mine Plan LW1-8	Date **21/02/2012**	Scale **As Shown**
Dry Cells	Ravensworth Mine Plan	Initials **HZ**	Project **S55J**
Alluvium Boundary	Rivers or Creeks	Drawing Number **S55J-214a**	Revision **G**
Extent of Saturated Alluvium	Former Bowmans Creek Channel	RPS Aquaterra	

Ashton Coal Operations Ltd

Predicted Groundwater Level at the End of ULD LW8 (2016) in the Alluvium and Regolith (Layer1)

Figure 16



Predicted Groundwater Drawdown (m)
Dry Cells
River Red Gum Stand
Alluvium Boundary
Extent of Saturated Alluvium
Pikes Gully Mine Plan
Ravensworth Mine Plan
Rivers or Creeks
Former Bowmans Creek Channel

Date	21/02/2012	Scale	As Shown
Initials	HZ	Project	S55J
Drawing Number	S55J-215b	Revision	G

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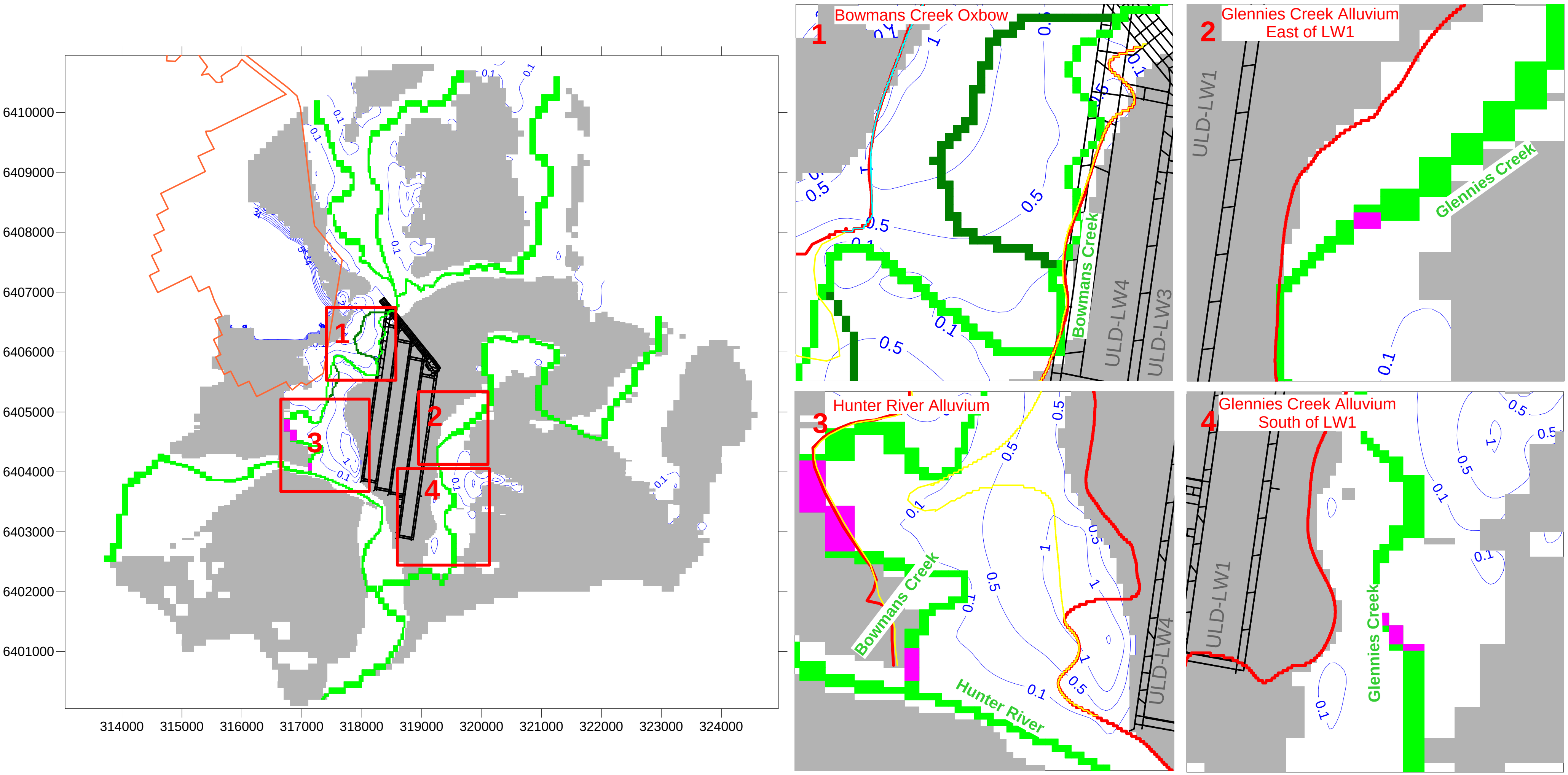
Ashton Coal Operations Ltd

Predicted Groundwater Drawdown at the End of PG Mining (2012) in the Alluvium and Regolith (Layer1) Since Mining Commencement

Figure 17



Predicted Groundwater Drawdown (m)	Upper Liddell Mine Plan LW1-4		
Dry Cells	Ravensworth Mine Plan		
River Red Gum Stand	Rivers or Creeks		
Alluvium Boundary	Former Bowmans Creek Channel		
Extent of Saturated Alluvium			

Date	21/02/2012	Scale	As Shown
Initials	HZ	Project	S55J
Drawing Number	S55J-216b	Revision	G

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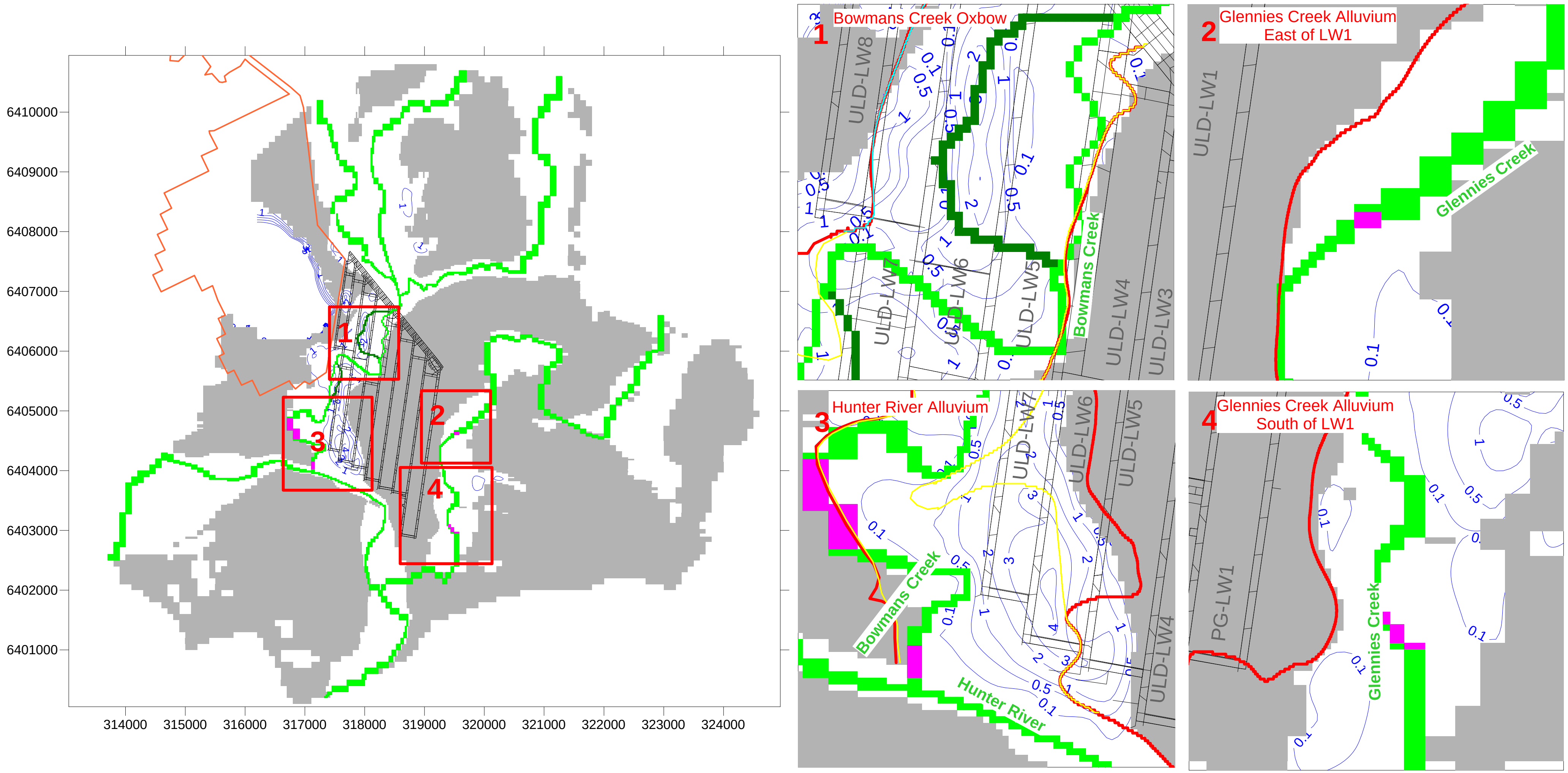
Ashton Coal Operations Ltd

Additional Predicted Groundwater Drawdown at the End of ULD LW4 (2014) in the Alluvium and Regolith (Layer1) Post PG Mining Cessation

Figure 18



Predicted Groundwater Drawdown (m)	Upper Liddell Mine Plan LW1-8
Dry Cells	Ravensworth Mine Plan
River Red Gum Stand	Rivers or Creeks
Alluvium Boundary	Former Bowmans Creek Channel
Extent of Saturated Alluvium	

Date	21/02/2012	Scale	As Shown
Initials	HZ	Project	S55J
Drawing Number	S55J-217b	Revision	G

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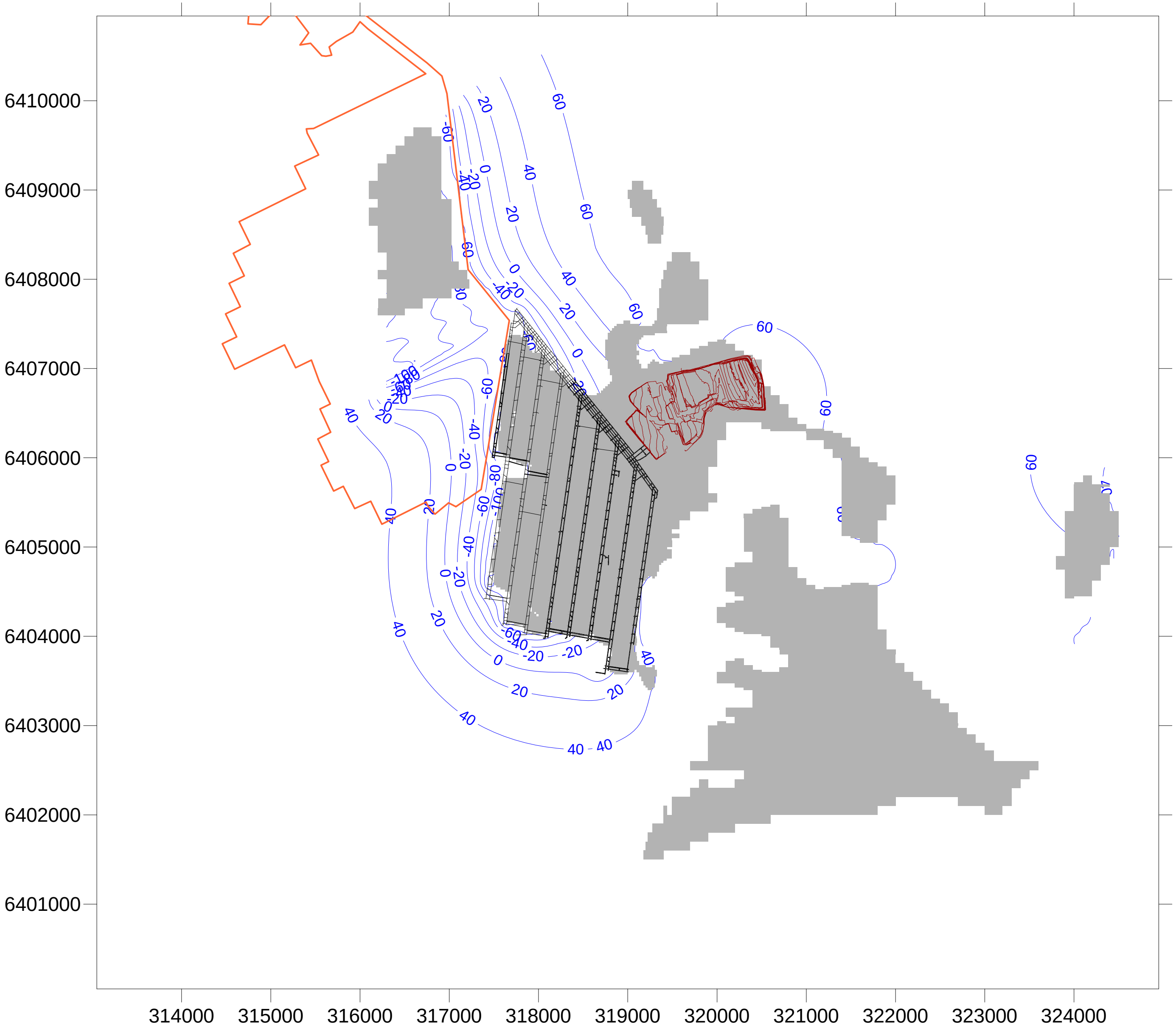
Ashton Coal Operations Ltd

Additional Predicted Groundwater Drawdown at the End of ULD LW8 (2016) in the Alluvium and Regolith (Layer1) Post PG Mining Cessation

Figure 19



50 Predicted Groundwater Levels (mAHD)

Dry Cells

Pikes Gully Mine Plan

Ravensworth Mine Plan

NEOC Mine Plan

Date	21/02/2012	Scale	As Shown
Initials	HZ	Project	S55J
Drawing Number	S55J-218a	Revision	G

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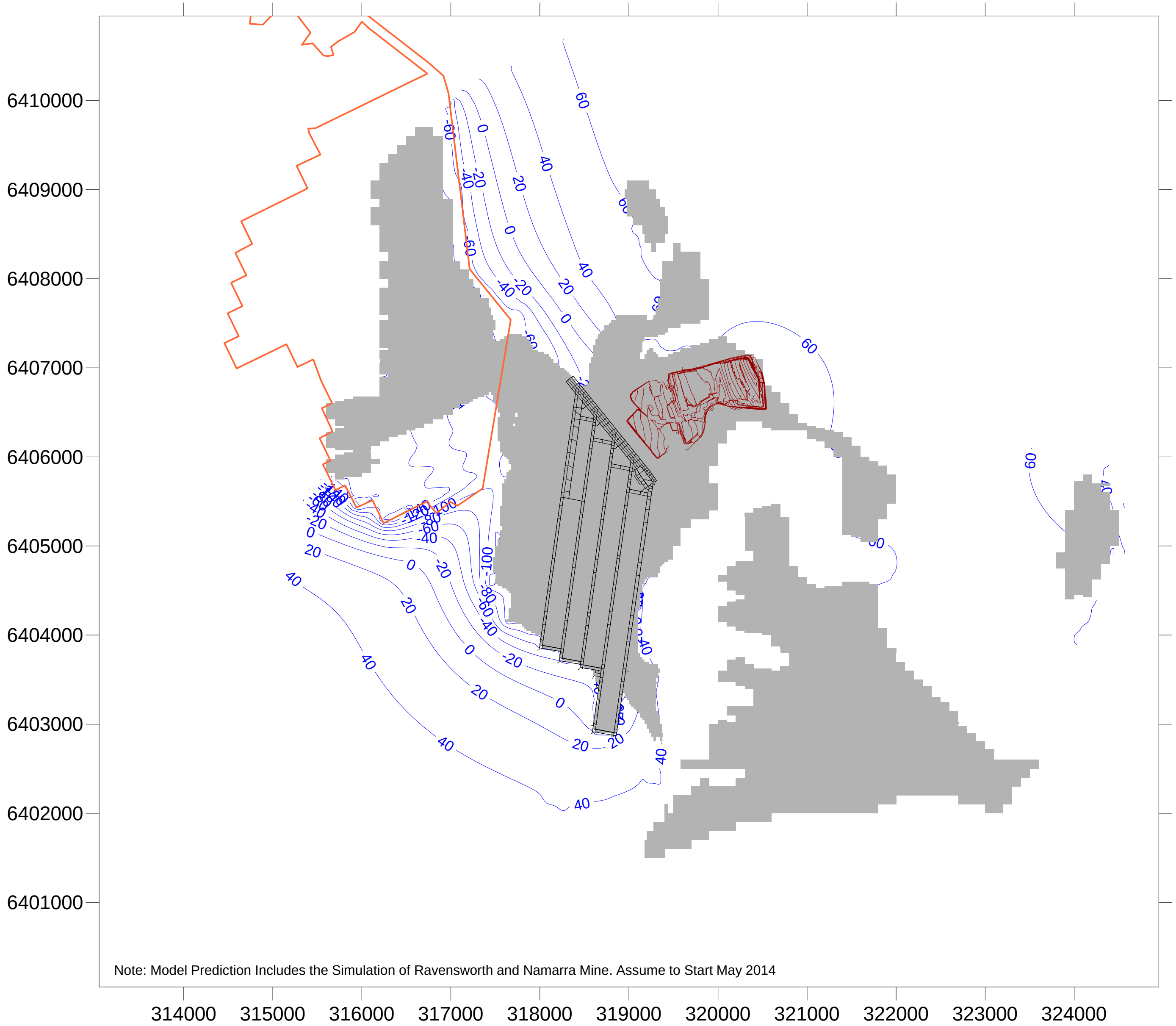
Predicted Groundwater Level at the End of PG Mining (2012) in the Pikes Gully Seam (Layer8)

Figure 20



50 Predicted Groundwater Levels (mAHD)

Dry Cells

Upper Liddell Mine Plan LW1-4

Ravensworth Mine Plan

NEOC Mine Plan

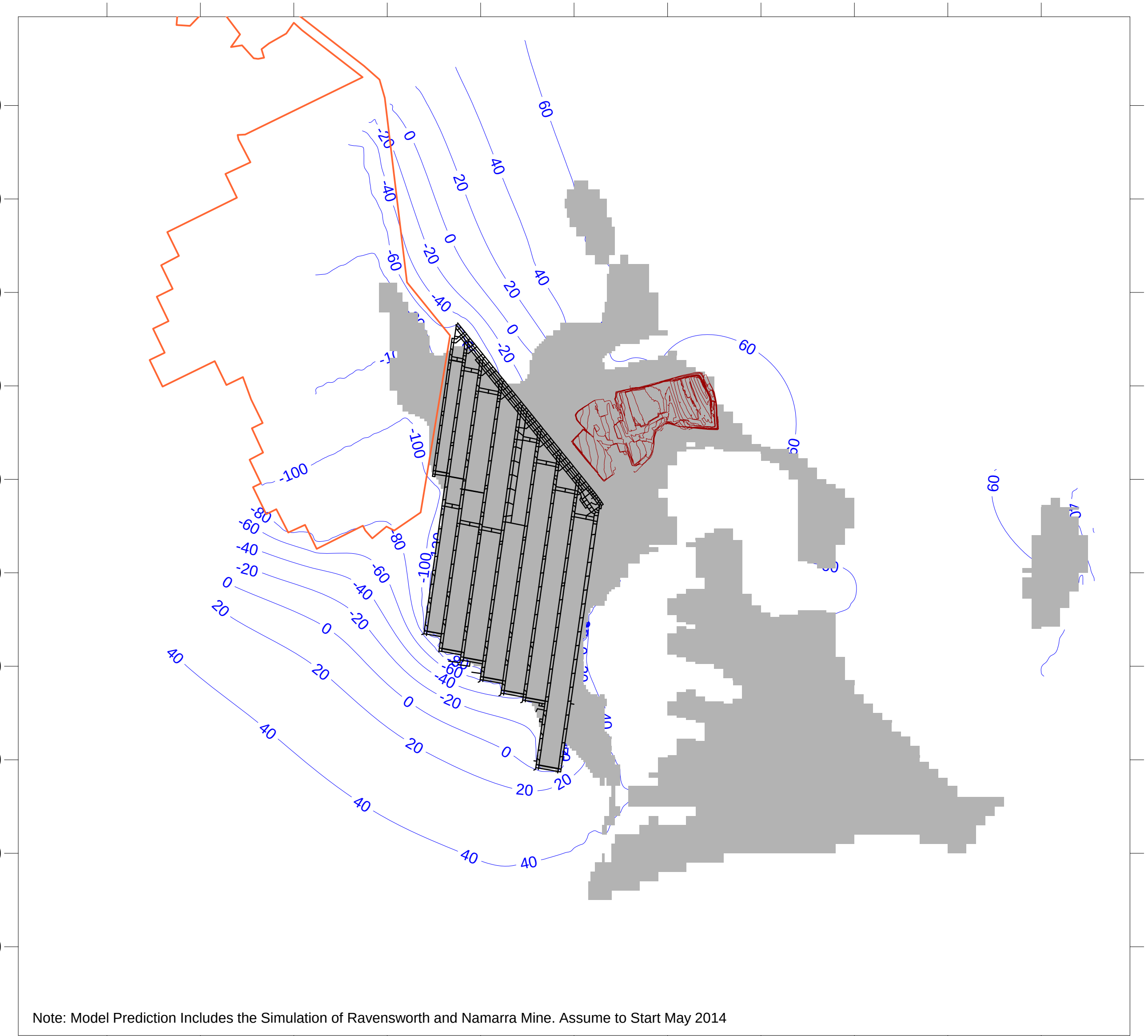
Date	21/02/2012	Scale	As Shown
Initials	HZ	Project	S55J
Drawing Number	S55J-219a	Revision	G

RPS Aquaterra

Ashton Coal Operations Ltd

Predicted Groundwater Level at the End of ULD LW4 (2014) in the Pikes Gully Seam (Layer8)

Figure 21



50 Predicted Groundwater Levels (mAHD)

Dry Cells

Upper Liddell Mine Plan LW1-8

Ravensworth Mine Plan

NEOC Mine Plan

Date	21/02/2012	Scale	As Shown
Initials	HZ	Project	S55J
Drawing Number	S55J-220a	Revision	G

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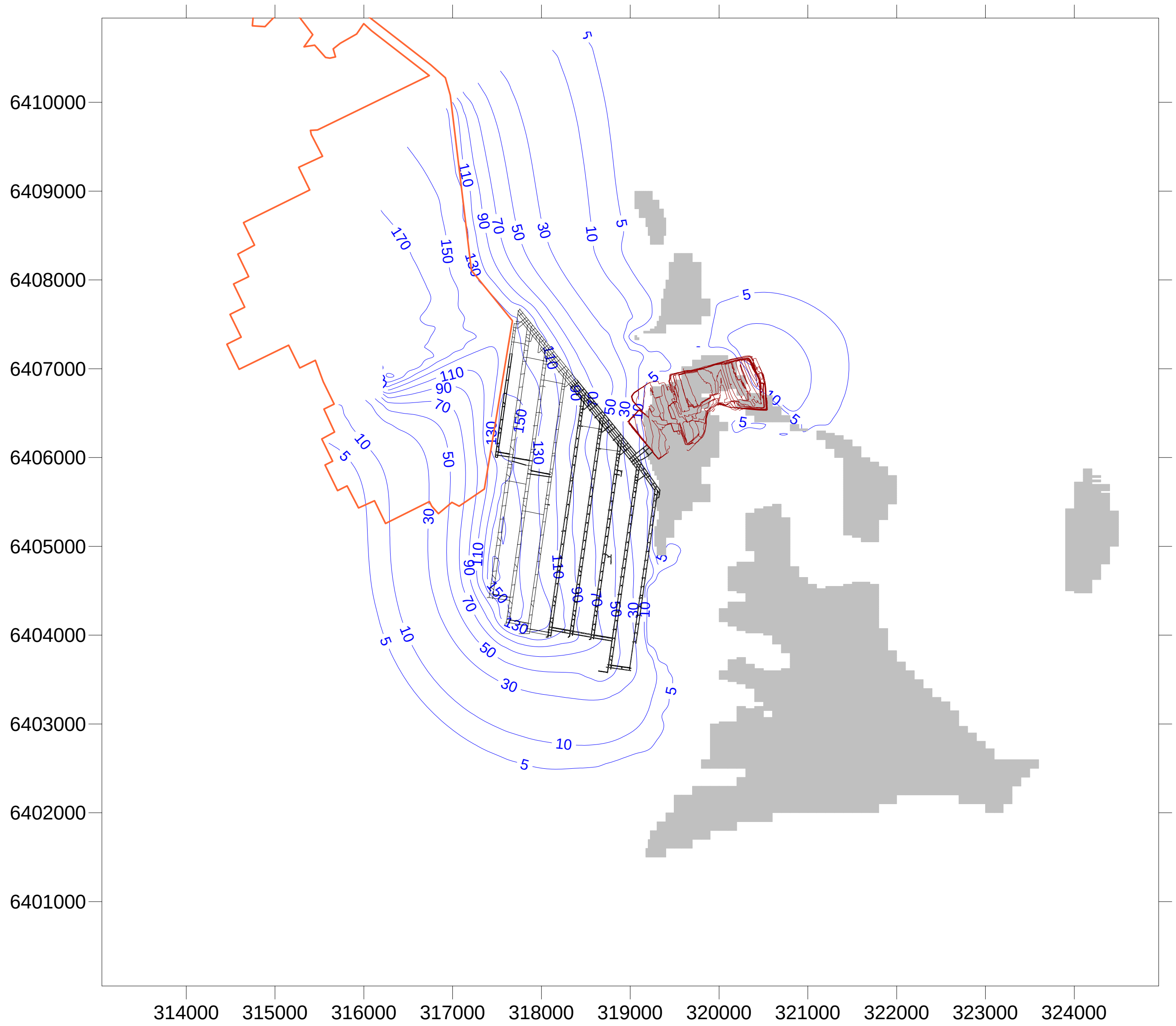
Ashton Coal Operations Ltd

Predicted Groundwater Level at the End of ULD LW8 (2016) in the Pikes Gully Seam (Layer8)

Figure 22



Predicted Groundwater Drawdown (m)

Dry Cells

Pikes Gully Mine Plan

Ravensworth Mine Plan

NEOC Mine Plan

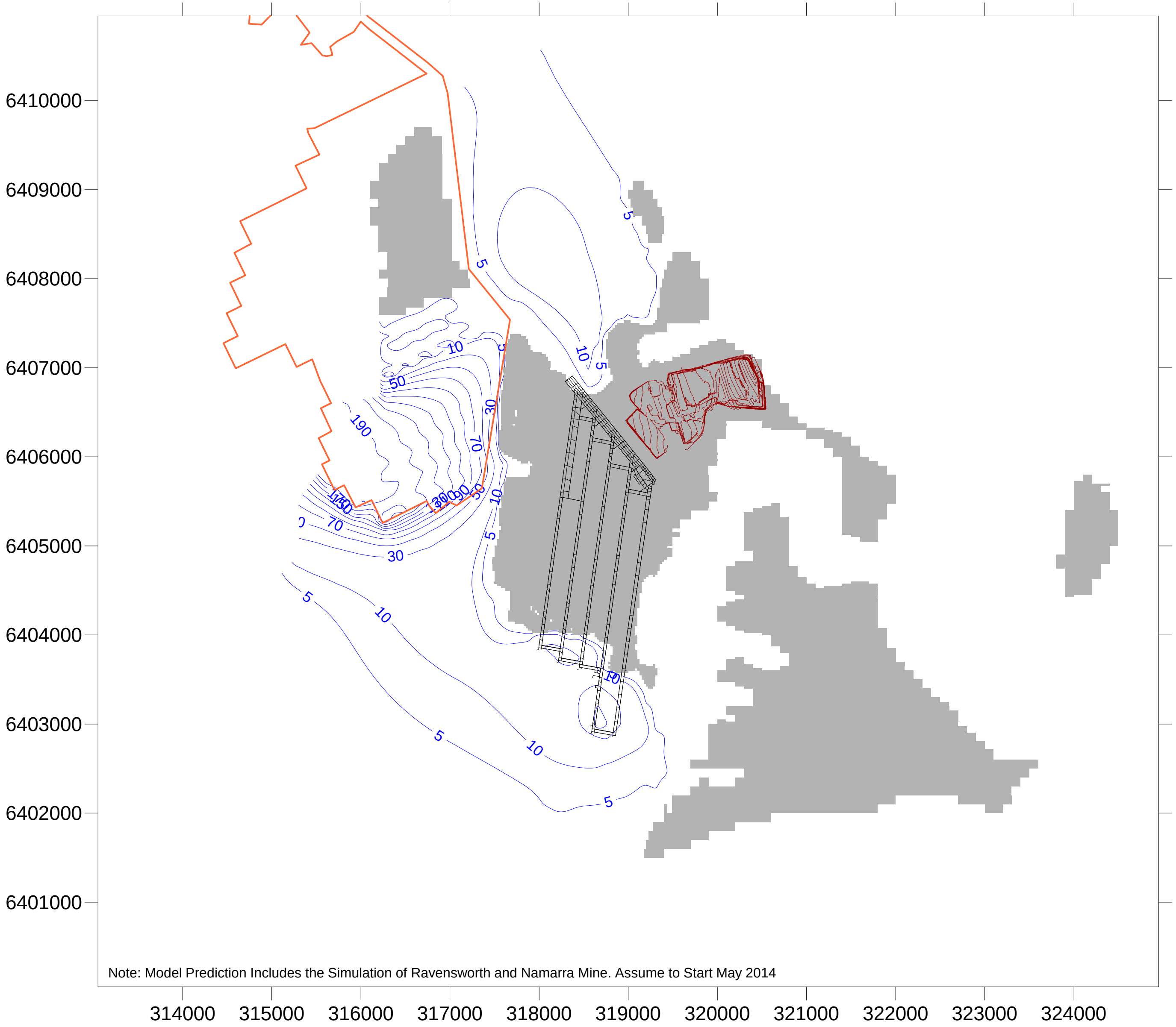
Date	21/02/2012	Scale	As Shown
Initials	HZ	Project	S55J
Drawing Number	S55J-221a	Revision	G

RPS Aquaterra

Ashton Coal Operations Ltd

Predicted Groundwater Drawdown at the End of PG Mining (2012) in the Pikes Gully Seam (Layer8) Since Mining Commencement

Figure 23



Predicted Groundwater Drawdown (m)

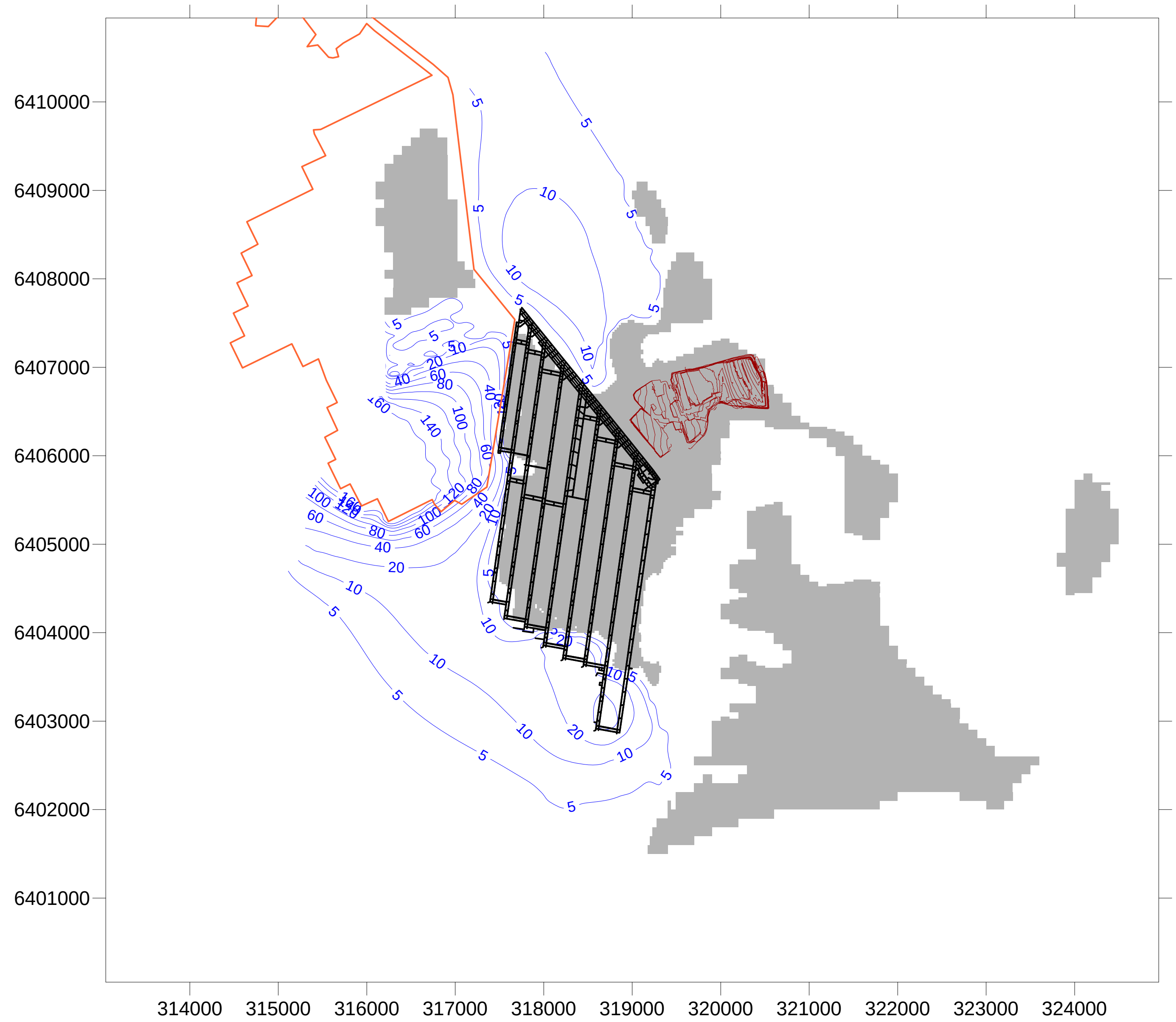
Dry Cells

Upper Liddell Mine Plan LW1-4

Ravensworth Mine Plan

NEOC Mine Plan

Date **21/02/2012**	Scale **As Shown**	**Ashton Coal Operations Ltd**	
Initials **HZ**	Project **S55J**	**Additional Predicted Groundwater Drawdown at the End of ULD LW4 (2014) in the Pikes Gully Seam (Layer8) Post PG Mining Cessation**	**Figure 24**
Drawing Number **S55J-222a**	Revision **G**		
RPS Aquaterra			



Predicted Groundwater Drawdown (m)

Dry Cells

Upper Liddell Mine Plan LW1-8

Ravensworth Mine Plan

NEOC Mine Plan

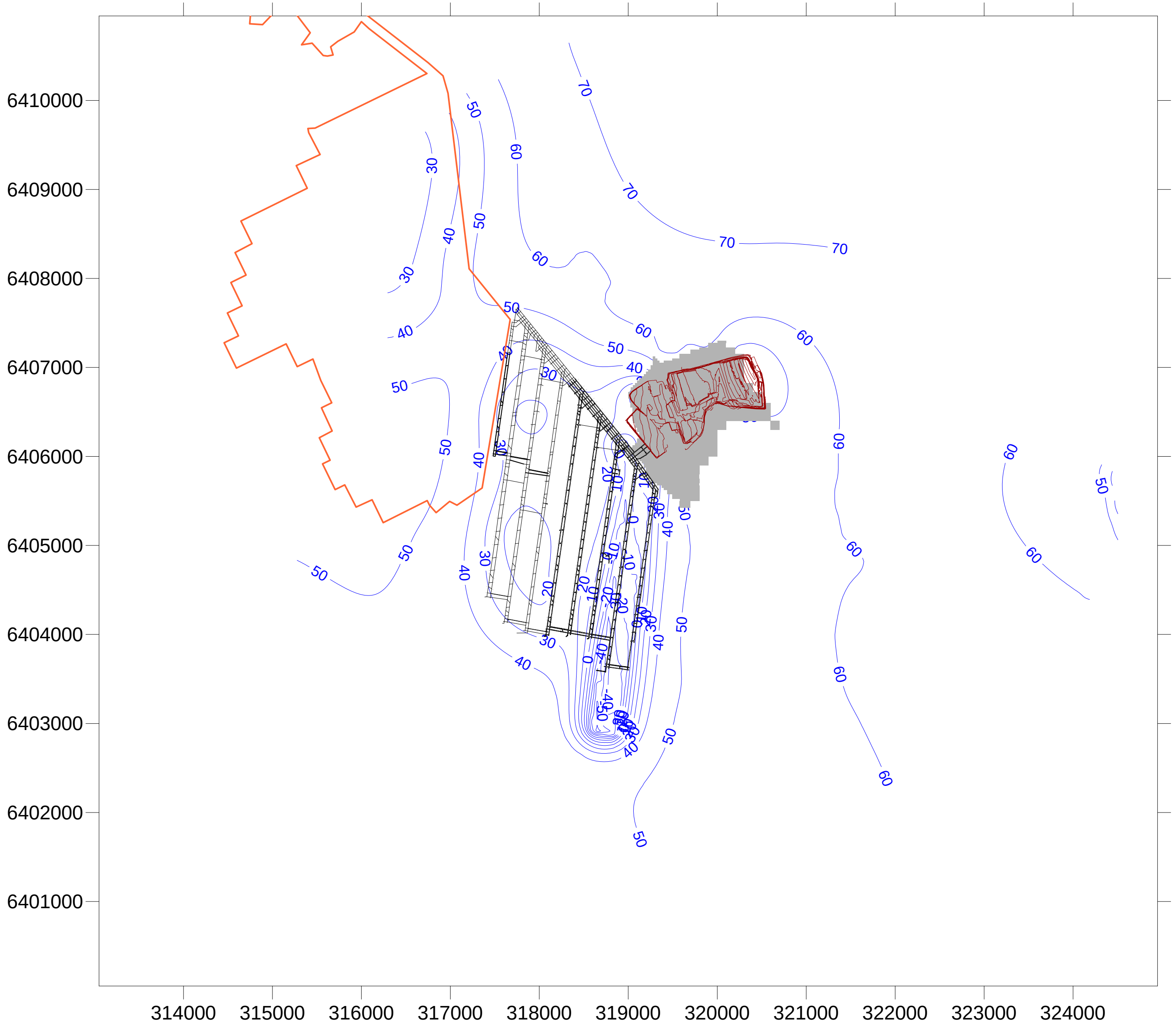
Date	21/02/2012	Scale	As Shown
Initials	HZ	Project	S55J
Drawing Number	S55J-223a	Revision	G

RPS Aquaterra

Ashton Coal Operations Ltd

Additional Predicted Groundwater Drawdown at the End of ULD LW8 (2016) in the Pikes Gully Seam (Layer8) Post PG Mining Cessation

Figure 25



50 Predicted Groundwater Levels (mAHD)

Dry Cells

Pikes Gully Mine Plan

Ravensworth Mine Plan

NEOC Mine Plan

Date	21/02/2012	Scale	As Shown
Initials	HZ	Project	S55J
Drawing Number	S55J-224a	Revision	G

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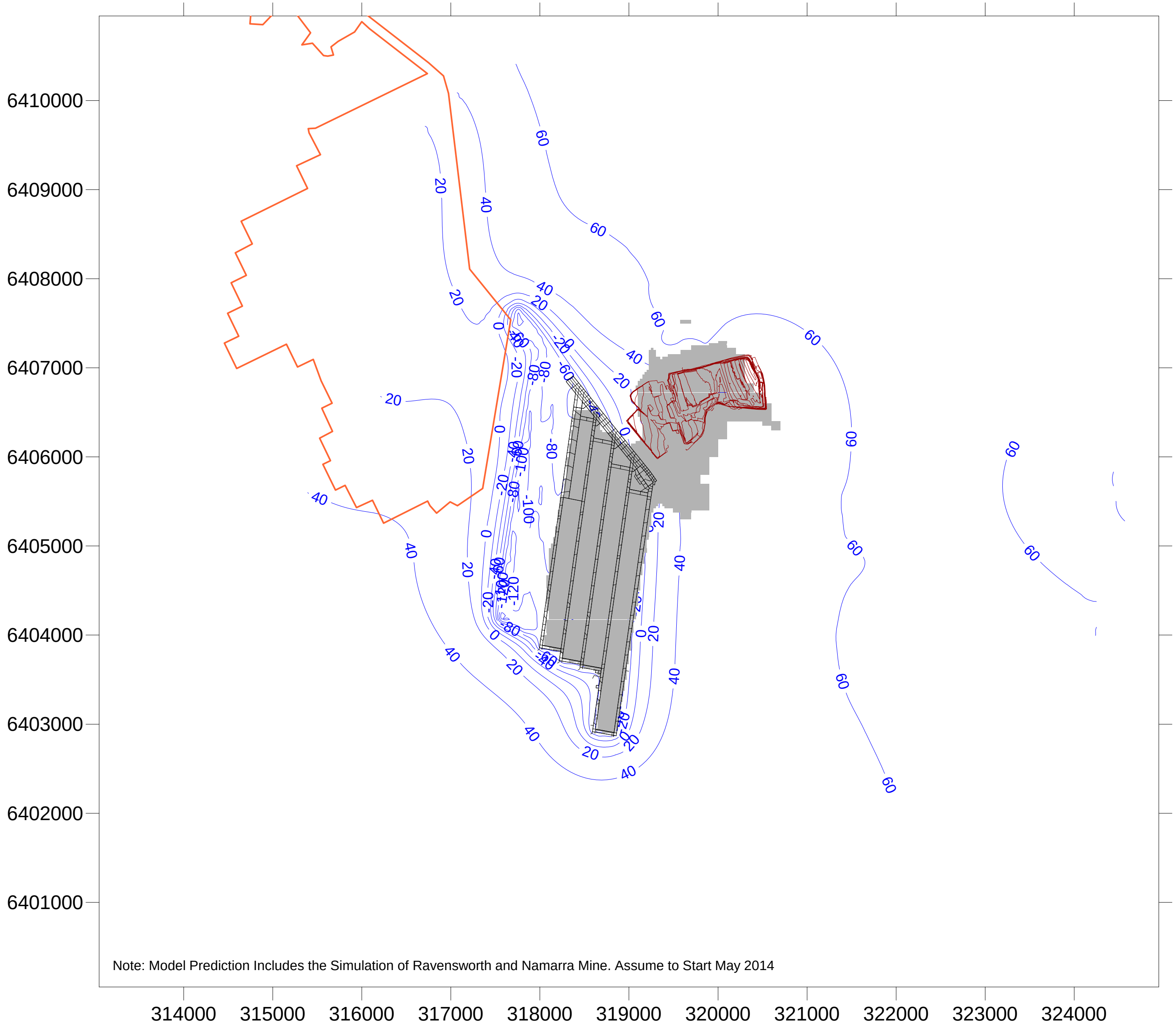
Ashton Coal Operations Ltd

Predicted Groundwater Level at the End of PG Mining (2012) in the Upper Liddell Seam (Layer10)

Figure 26



50 Predicted Groundwater Levels (mAHD)	Upper Liddell Mine Plan LW1-4
Dry Cells	Ravensworth Mine Plan
	NEOC Mine Plan

Date	21/02/2012	Scale	As Shown
Initials	HZ	Project	S55J
Drawing Number	S55J-225a	Revision	G

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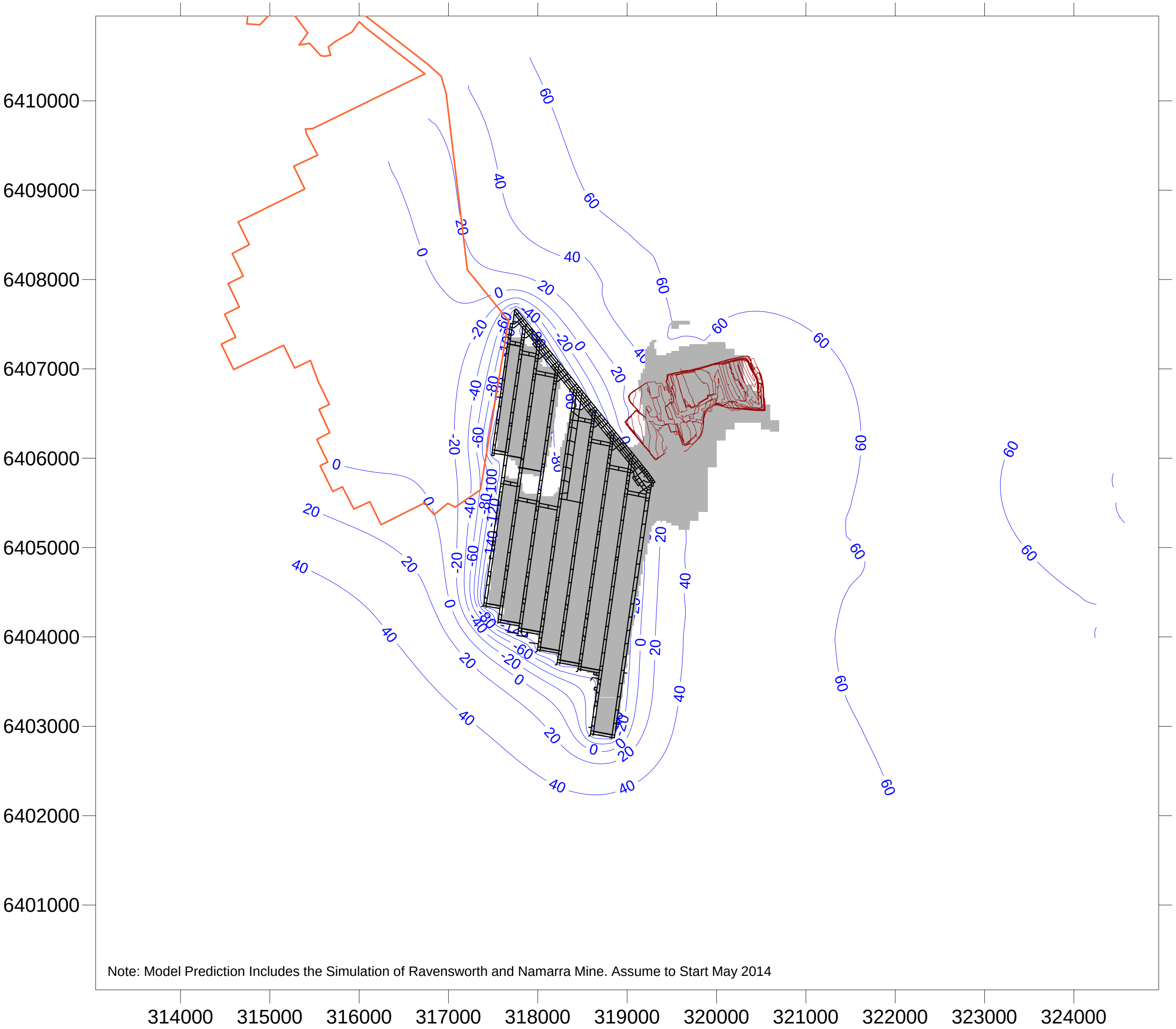
Ashton Coal Operations Ltd

Predicted Groundwater Level at the End of ULD LW4 (2014) in the Upper Liddell Seam (Layer10)

Figure 27



50 Predicted Groundwater Levels (mAHD)

Dry Cells

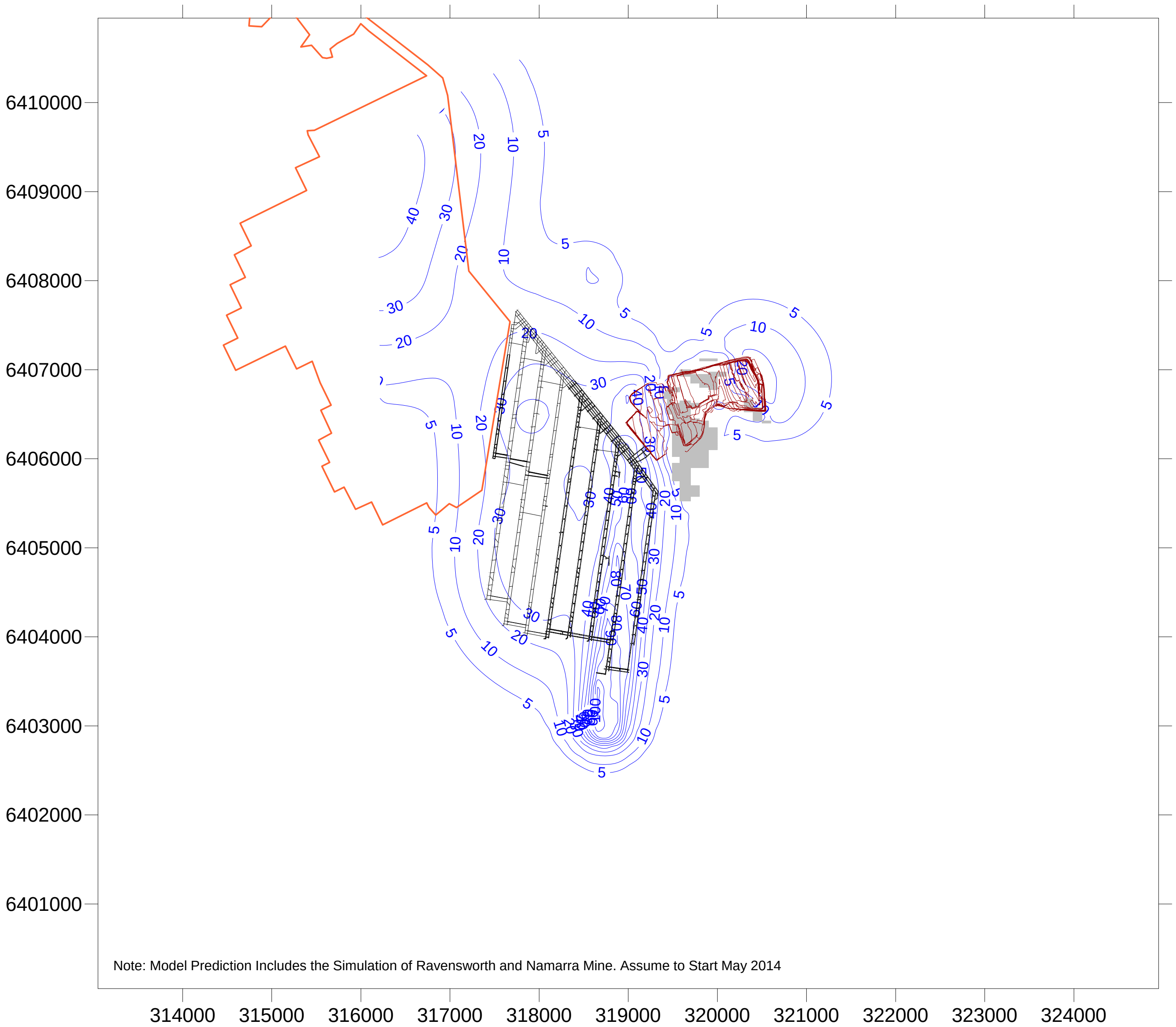
Upper Liddell Mine Plan LW1-8

Ravensworth Mine Plan

NEOC Mine Plan

Date	**21/02/2012**	Scale **As Shown**	**Ashton Coal Operations Ltd**
Initials	**HZ**	Project **S55J**	**Predicted Groundwater Level at the End of ULD LW8 (2016) in the Upper Liddell Seam (Layer10)**
Drawing Number	**S55J-226a**	Revision **G**	**Figure 28**

RPS Aquaterra



Predicted Groundwater Drawdown (m)

Dry Cells

Pikes Gully Mine Plan

Ravensworth Mine Plan

NEOC Mine Plan

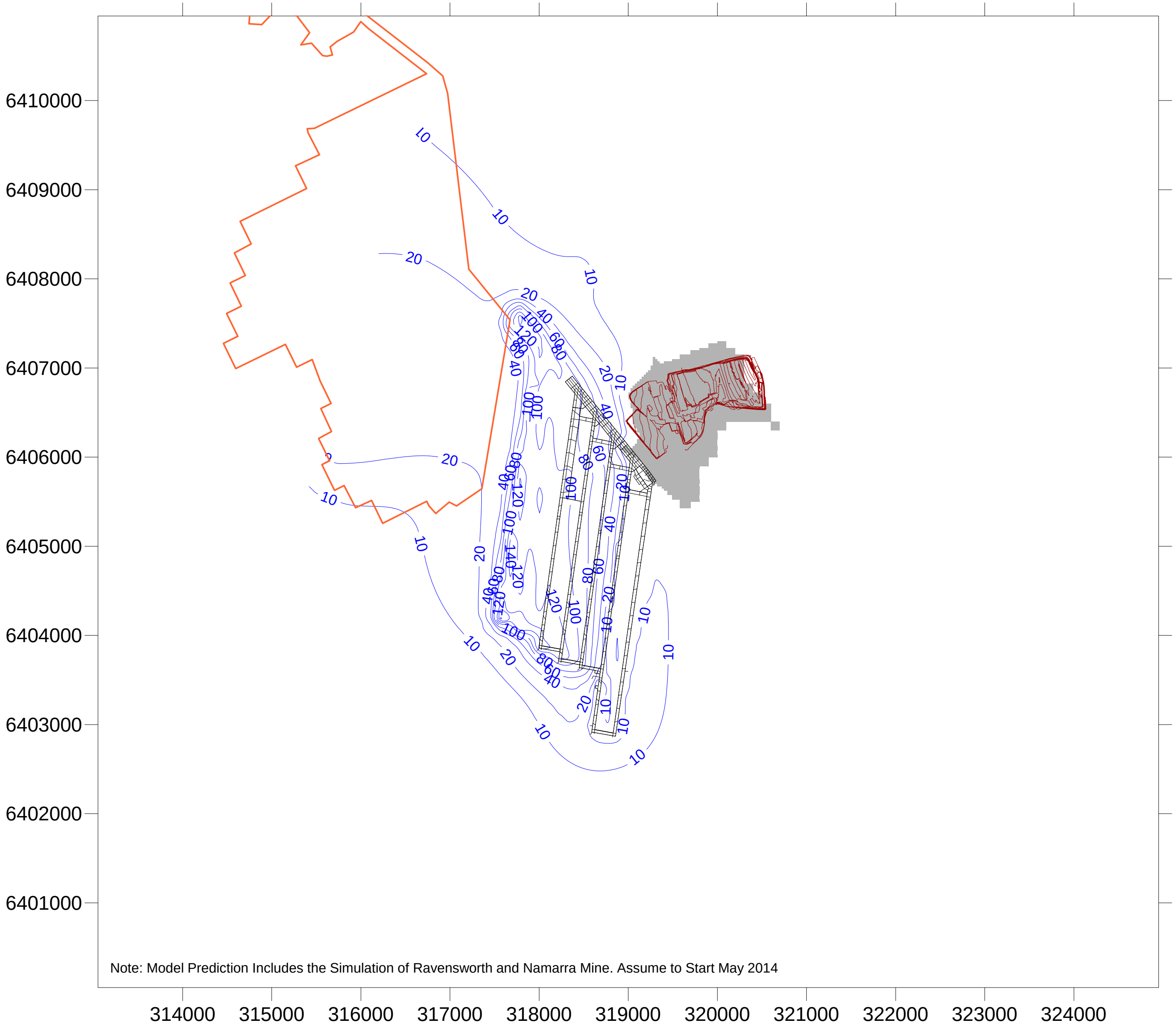
Date	21/02/2011	Scale	As Shown
Initials	HZ	Project	S55J
Drawing Number	S55J-227a	Revision	G

RPS Aquaterra

Ashton Coal Operations Ltd

Predicted Groundwater Drawdown at the End of PG Mining (2012) in the Upper Liddell Seam (Layer10) Since Mining Commencement

Figure 29



Predicted Groundwater Drawdown (m)

Dry Cells

Upper Liddell Mine Plan LW1-4

Ravensworth Mine Plan

NEOC Mine Plan

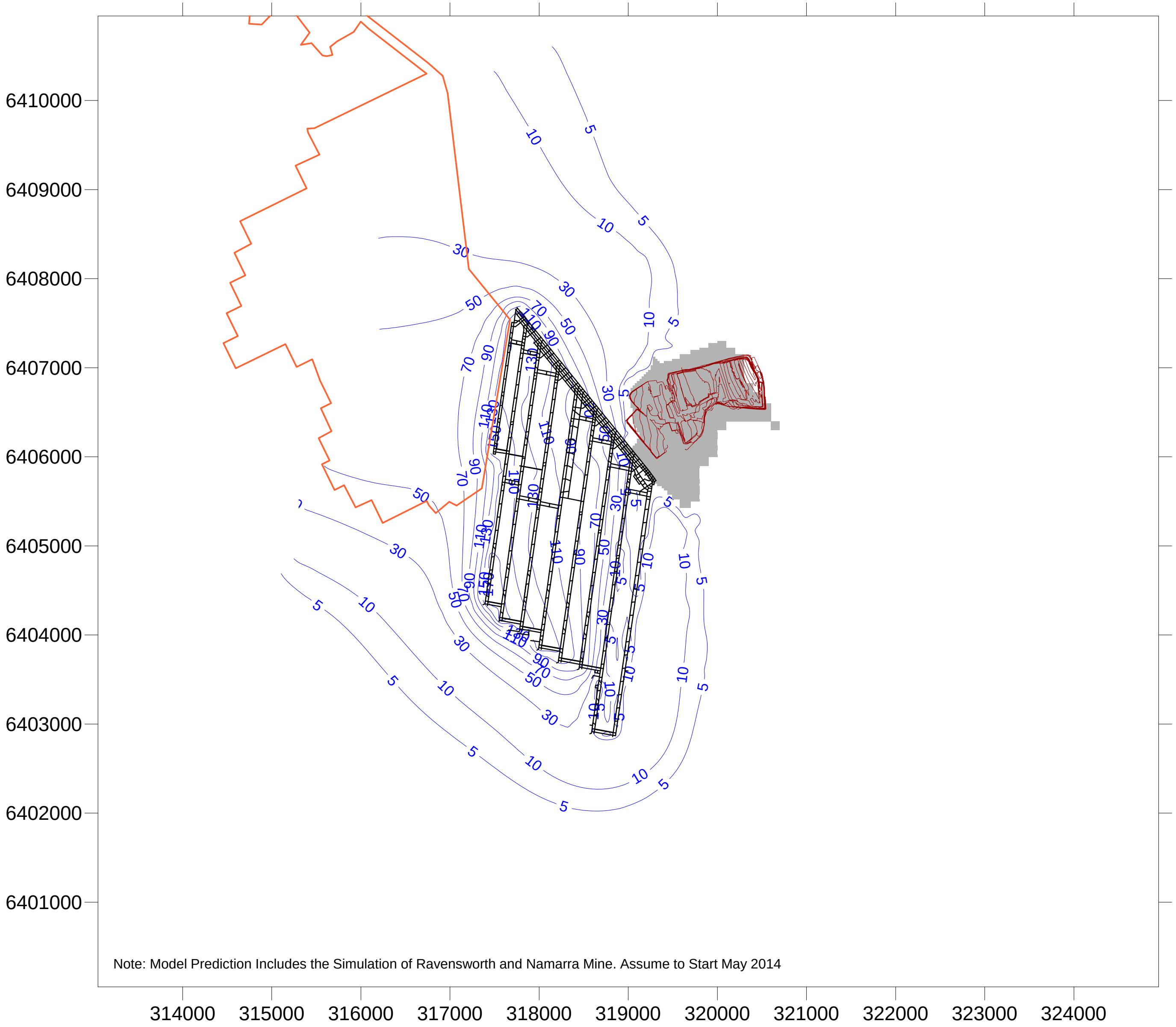
Date **21/02/2012**	Scale **As Shown**
Initials **HZ**	Project **S55J**
Drawing Number **S55J-228a**	Revision **G**

RPS Aquaterra

Ashton Coal Operations Ltd

Additional Predicted Groundwater Drawdown at the End of ULD LW4 (2014) in the Upper Liddell Seam (Layer10) Post PG Mining Cessation

Figure 30



Predicted Groundwater Drawdown (m)

Dry Cells

Upper Liddell Mine Plan LW1-8

Ravensworth Mine Plan

NEOC Mine Plan

Date **21/02/2012**	Scale **As Shown**
Initials **HZ**	Project **S55J**
Drawing Number **S55J-229a**	Revision **G**

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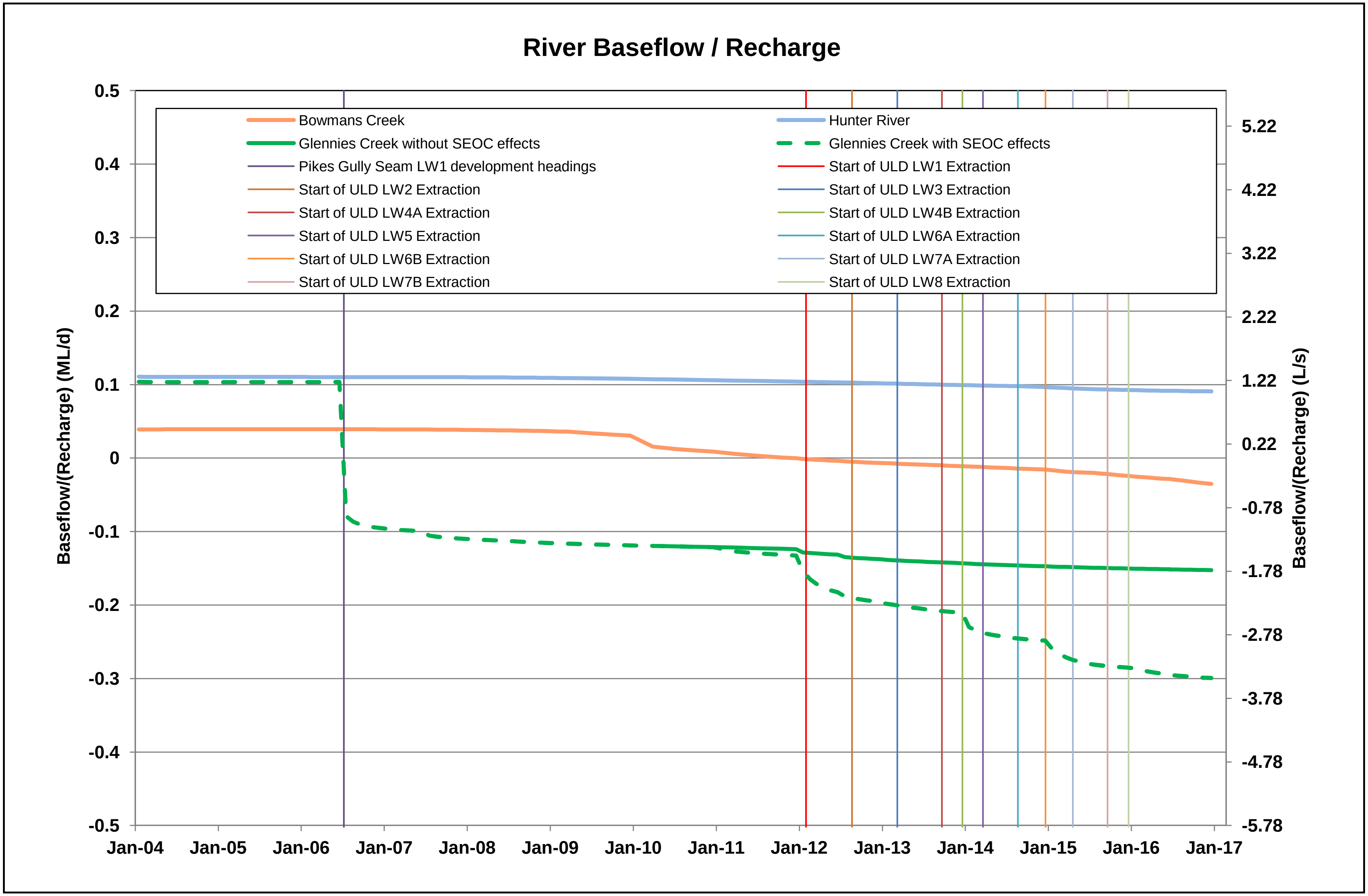
Ashton Coal Operations Ltd

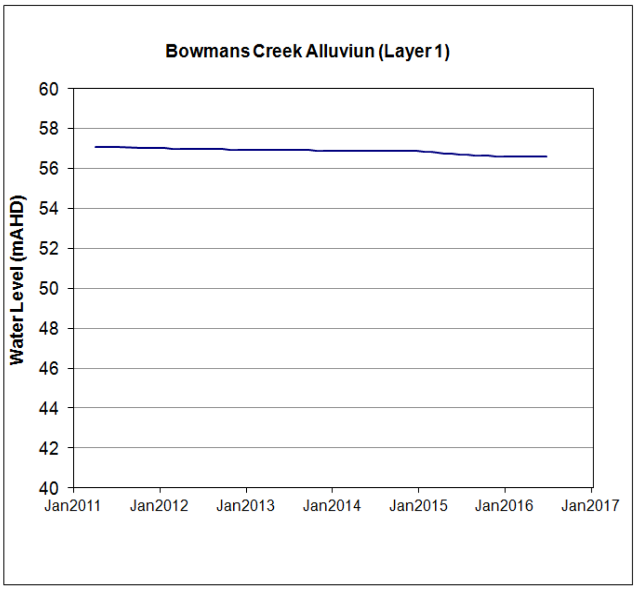
Additional Predicted Groundwater Drawdown at the End of ULD LW8 (2016) in the Upper Liddell Seam (Layer10) Post PG Mining Cessation

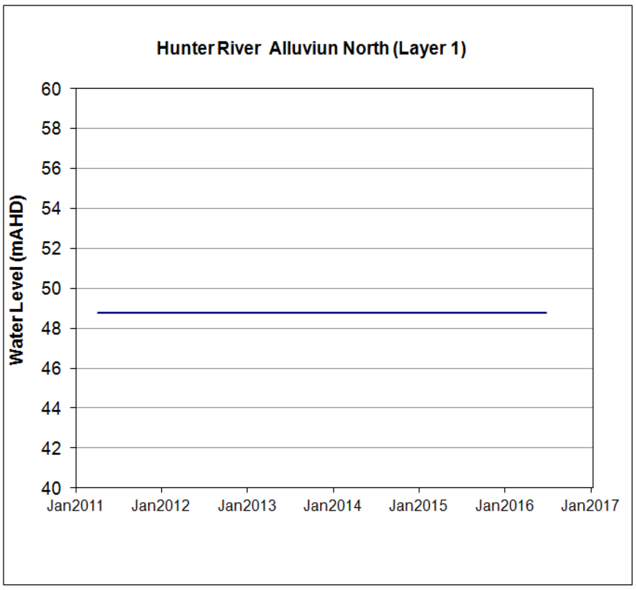
Figure 31

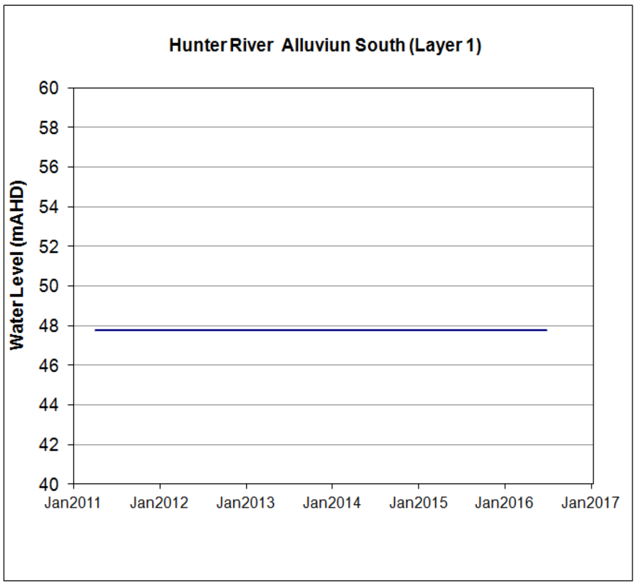


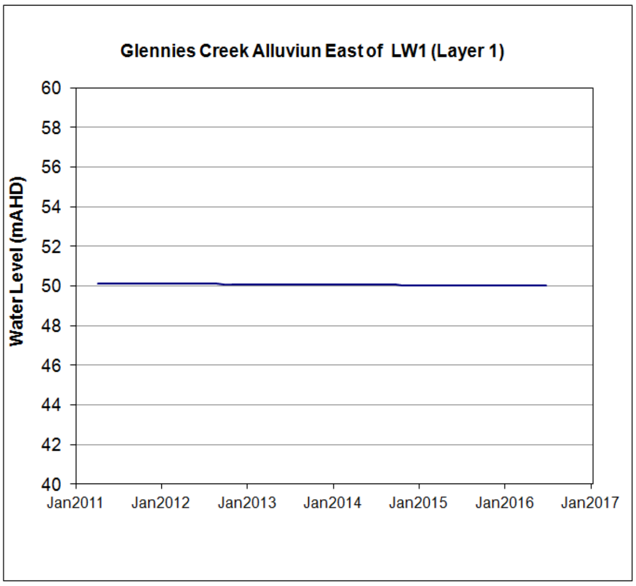
RPS Aquaterra

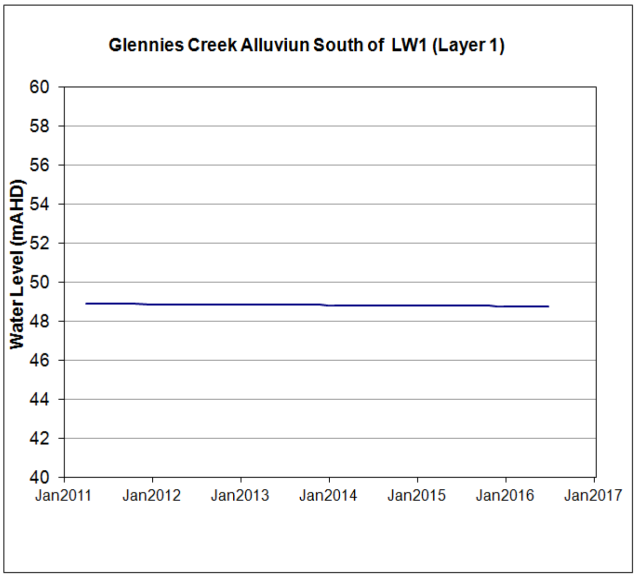
Model Predictions of Baseflow FIGURE 32











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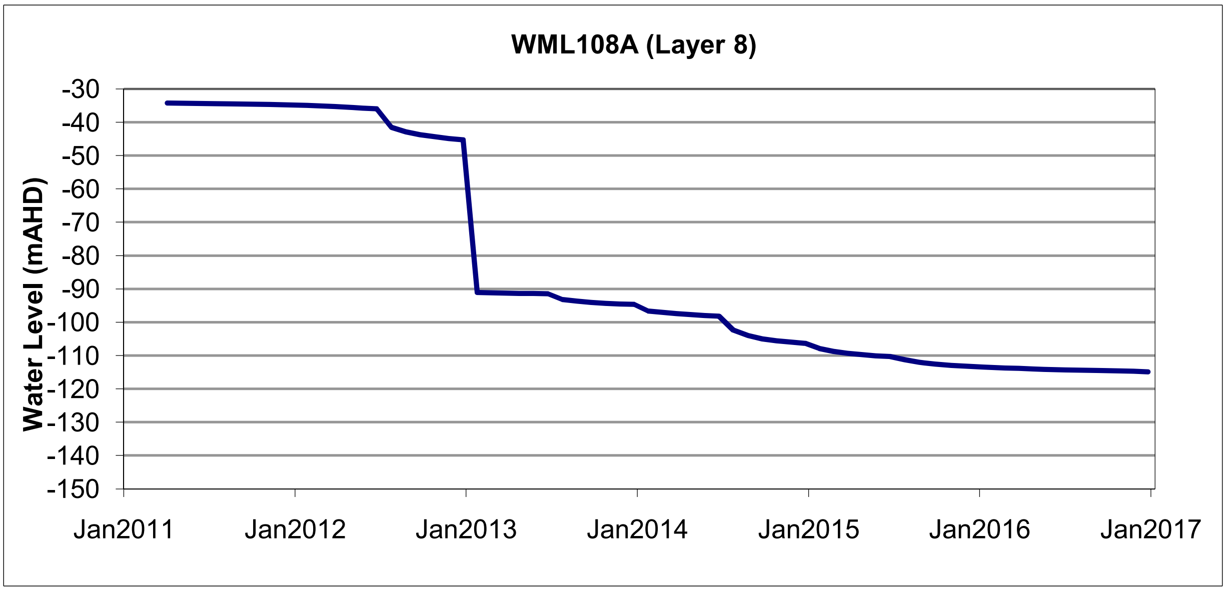
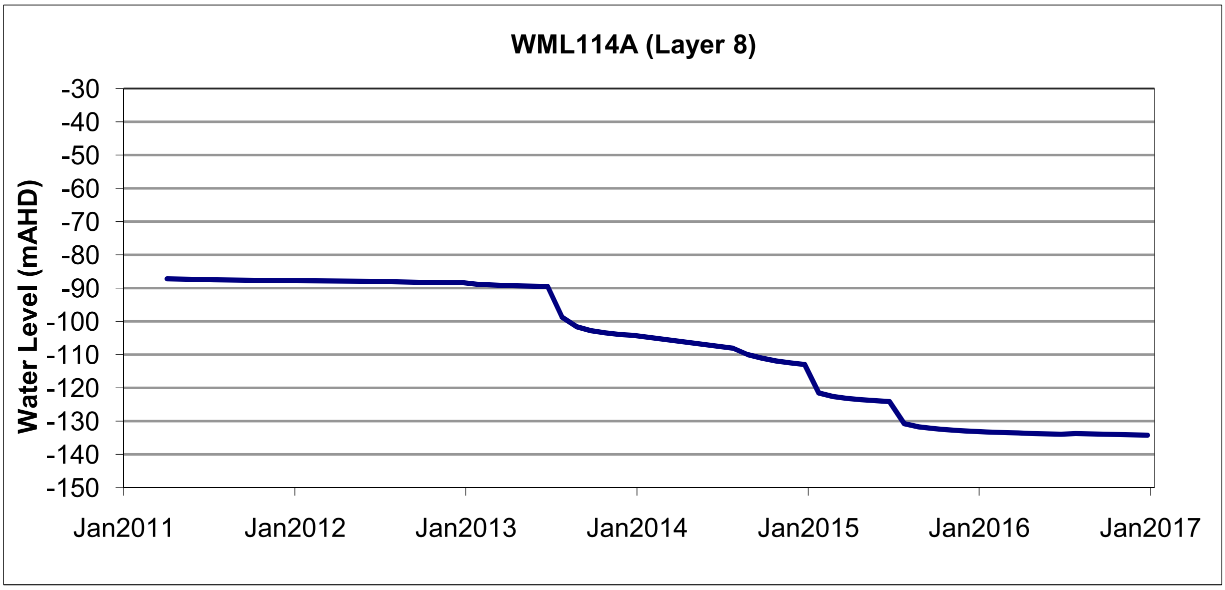
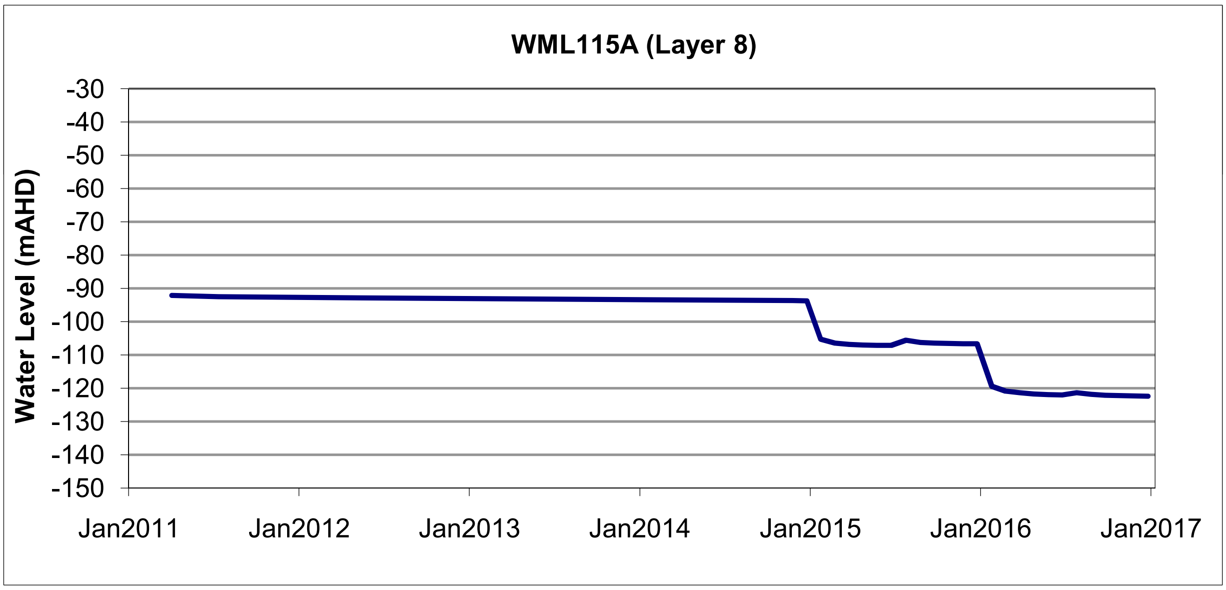
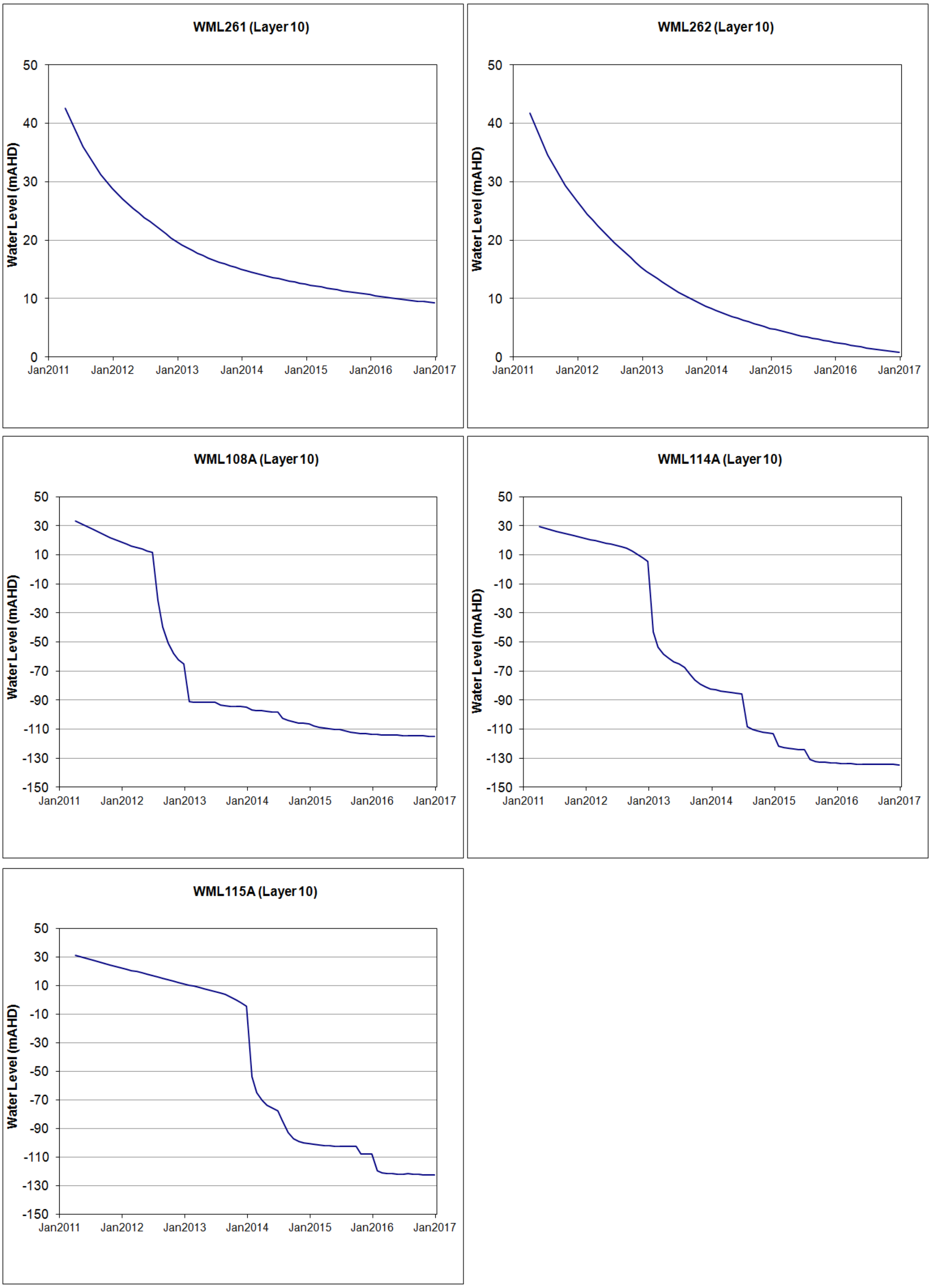
Predicted Target Hydrographs in Alluvium FIGURE 33







Predicted Target Hydrographs in Pikes Gully Seam FIGURE 34



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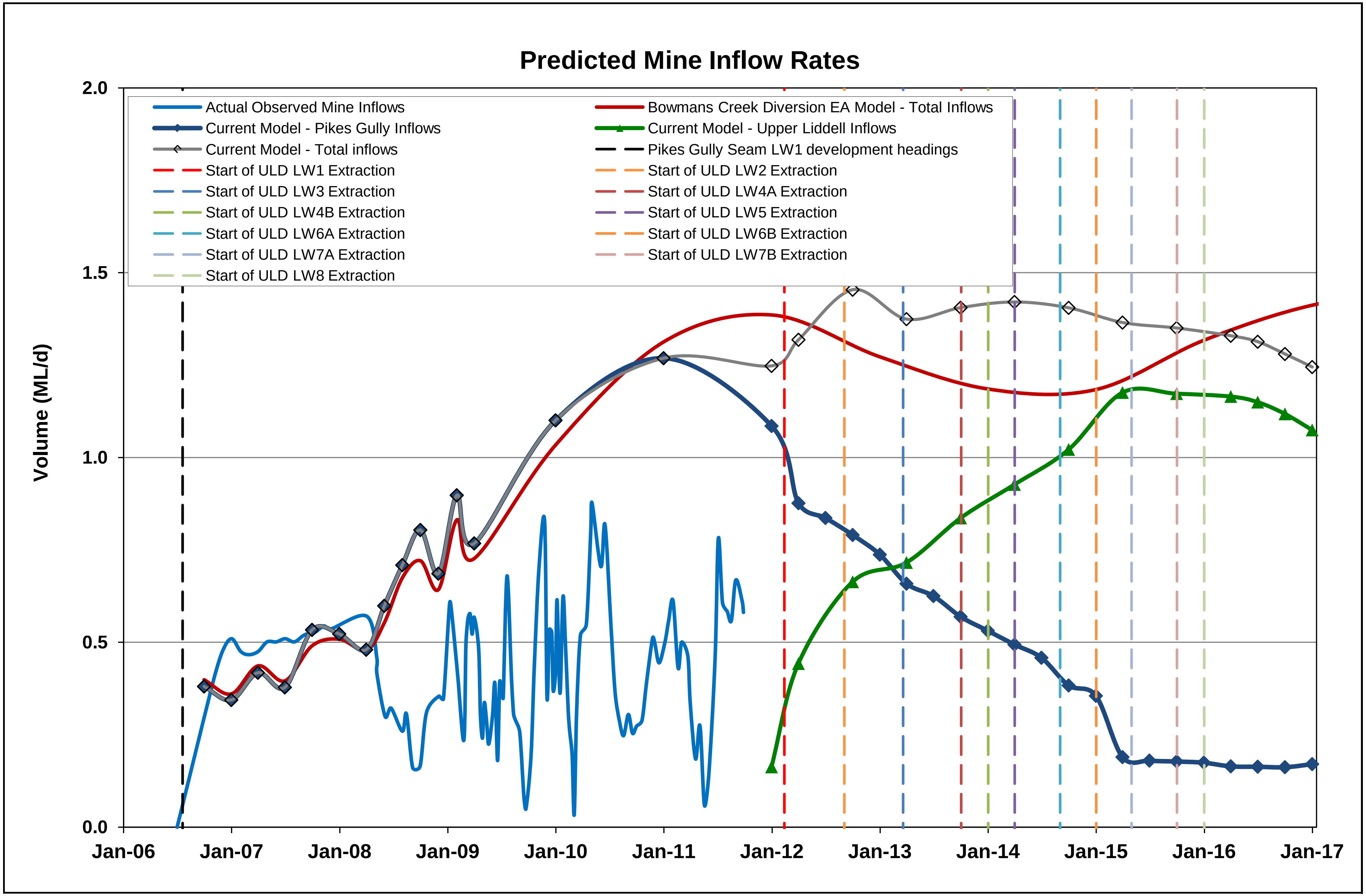
Predicted Target Hydrographs in Upper Liddell Seam FIGURE 35



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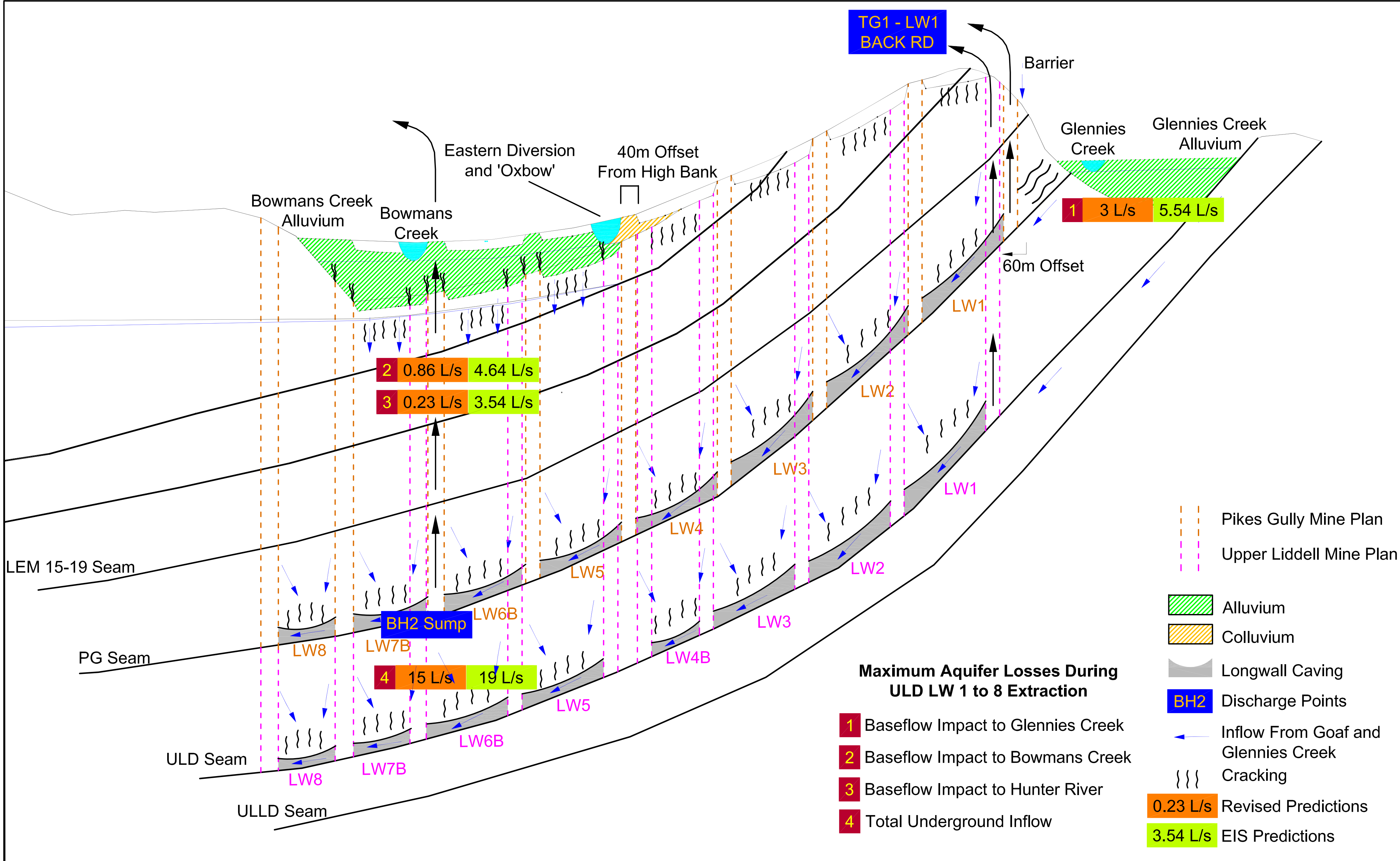
Model Predictions of Mine Inflows FIGURE 36



DATE: 28 November 2011	SCALE: N/A	**ASHTON COAL PTY LTD**
AUTHOR: HZ CHECKED: JVDA	PROJECT NO: S55J	**Groundwater Flow and Management for the ACP During ULD LW 1 to 8 Extraction**
DRAWING NO: S5J-011	REVISION: A	
RPS Aquaterra		**Figure 37**

APPENDIX A:
RELEVANT DEVELOPMENT CONSENT CONDITIONS & WATER LICENCES

APPENDIX B: EXISTING HYDROGEOLOGICAL ENVIRONMENT

APPENDIX C:
GROUNDWATER MODELLING REPORT

APPENDIX D:
DETAILS OF MONITORING BORES

APPENDIX E:
HYDRAULIC TESTING RESULTS

APPENDIX F:
WATER QUALITY MONITORING RESULTS