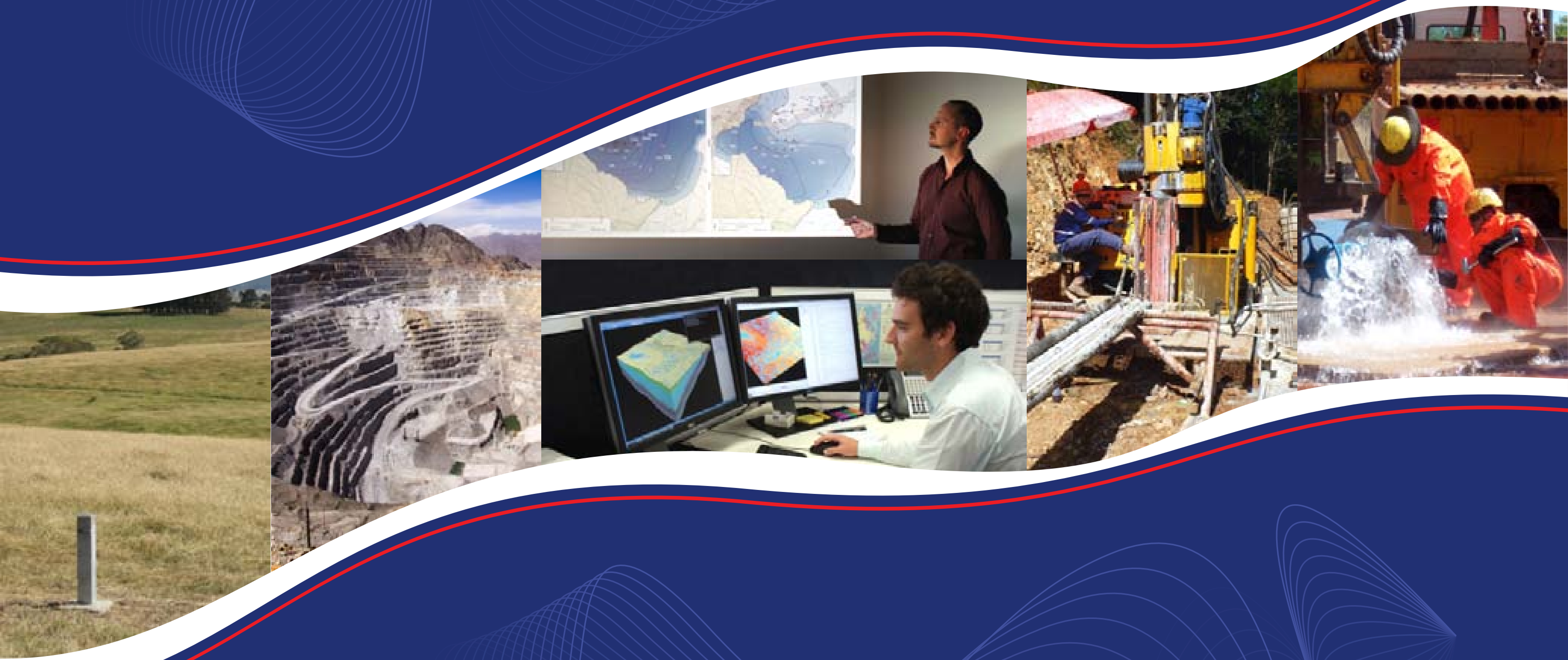
Australasian
Groundwater
and Environmental
Consultants Pty Ltd
(AGE)



Report on

Bylong Coal Project

Response to Submissions on Groundwater

Prepared for

Hansen Bailey Pty Ltd

Project No. G1606E   March 2016
www.ageconsultants.com.au   ABN 64 080 238 642

Document details and history

Document details

Project number	G1606
Document title	Bylong Coal Project – Response to Submissions on Groundwater
Site address	Bylong, NSW
File name	G1606.Response_to_Submissions_v04.docx

Document status and review

Edition	Comments	Author	Authorised by	Date
v1	First draft issued to client	JST/NM	JST	22/02/2016
v2	Second draft issued to client	JST	JST	01/03/2016
v3	Third draft issued to client	JST	JST	14/03/2016
v4	Fourth and final issued to client	JST	JST	22/3/2016

AGE Head Office
Level 2 / 15 Mallon Street,
Bowen Hills, QLD 4006, Australia
T. +61 7 3257 2055
F. +61 7 3257 2088
brisbane@ageconsultants.com.au

AGE Newcastle Office
4 Hudson Street,
Hamilton, NSW 2303, Australia
T. +61 2 4962 2091
F. +61 2 4962 2096
newcastle@ageconsultants.com.au

Table of contents

Table of contents

Page No.

Table of contents

Page No.

List of figures

Table of contents

Page No.

Table of contents

Page No.

List of tables

List of appendices

Report on

Bylong Coal Project
Response to Submissions on Groundwater

1 Introduction and background

KEPCO Bylong Australia Pty Ltd (KEPCO) is planning to develop an open cut and underground coal mine in the Bylong Valley (the Project), which is located in Mid-Western Region of New South Wales (NSW).

Hansen Bailey Environmental Consultants Pty Ltd (Hansen Bailey) engaged Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) to assess groundwater issues for the Project on behalf of their client Worley Parsons Services Pty Ltd (WorleyParsons). The Project has been subject to two levels of assessment, according to the NSW Regulatory Regime. The first was an initial groundwater assessment addressing the requirements of the NSW Gateway Certificate Assessment process. The second stage of work was a groundwater impact assessment prepared for the Environmental Impact Statement (EIS), which described the field investigations and impact assessment using numerical modelling.

This supplementary report responds to questions on the EIS raised by a variety of stakeholders during the public exhibition period and will be included within an overarching Response to Submissions report being prepared by Hansen Bailey. This report presents new data and additional work conducted since submission of the EIS as well as drawing on the data information gathered in the previous stages of work.

2 Summary of submissions on EIS

As part of the Government's approvals process, submissions were invited upon public exhibition of the EIS. Queries and commentary relating to groundwater aspects of the Project were compiled by AGE into the following broad subject categories:

- geological characterisation;
- baseline hydrogeological conditions and historic trends;
- conceptual understanding of groundwater regime;
- numerical model fitness for purpose;
- water security;
- water licensing;
- water quality impacts; and
- groundwater monitoring and management.

Extensive follow-on work has been undertaken since the lodgement of the EIS, which addresses the groundwater related issues raised by stakeholders during the public exhibition period. The majority of this work has involved using additional data, which has been collected in the intervening period, to revise and update the site conceptual model developed within the EIS. This has subsequently been input to the groundwater numerical model, which has been refined and run to provide suitable responses to stakeholder queries. In some cases, submissions were framed as commentary and recommendations regarding site development and operation, rather than questions. Sections below describe in more detail the issues and comments raised by various stakeholders, and where they are addressed within this report.

2.1.1 Geological characterisation

Stakeholders requested more refined delineation of the alluvium/colluvium boundary to give increased accuracy to the proposed set-backs. More detail on the 'weathered zone' within the Project Boundary was also sought, and more cross sections to aid visualisation of the geology within and adjacent to the Project.

These items are addressed as follows:

- Section 3 provides additional information on the geology within and adjacent to the Project Boundary; and
- Section 6.4 discusses the work program conducted prior to the development of the EIS to define the limit of the alluvial sediments adjacent to the proposed mining area.

2.1.2 Baseline conditions and historic trends

Stakeholders requested commentary on historic trends in groundwater levels, particularly the downward trend identified in the alluvium. A more expansive groundwater level and quality monitoring regime was suggested to assess baseline conditions.

Section 4 provides the more recent groundwater level measurements collected from the monitoring bore network and vibrating wire piezometers since the EIS was submitted. It also provides the entire monitoring record for completeness, and discusses the trends identified in groundwater levels over the period of baseline monitoring. The magnitude of decline in groundwater levels is identified and the rate of recharge over the baseline period discussed along with updates to the numerical model. Section 5.3 provides a verification and further calibration of the groundwater model to the baseline groundwater level data.

2.1.3 Conceptual understanding of groundwater regime

In terms of characterising the hydrogeology of the area, numerous submissions requested further information on the piezometry of individual aquifers and the occurrence and magnitude of potential inter-aquifer vertical connectivity. Some comments identified the need for pumping tests to develop the conceptual model further and confirm the presence of highly productive and less productive aquifers. The modelled long term recovery profile for regional water levels post-mining was also queried, as was the nature of perched groundwater systems in the area.

Section 4 contains additional information on the groundwater regime to support the conceptualisation. It provides additional maps that show the water table and potentiometric surface for key geological units, as well as the depth to water recorded in the bores. For the unconfined systems, the saturated thickness of the groundwater systems are also provided. There have been several drilling campaigns within the Project Boundary and composite borehole logs graphically showing the lithological units intersected during drilling, as well as the borehole constructions, are included within Appendix A.

2.1.4 Numerical model fitness for purpose

Stakeholders reviewed the numerical model and provided comments and suggestions to improve reliability and/or increase the information obtained from the model. Recommendations were given concerning input parameters and boundary condition values, also the use of alternate methods to model streamflow and its interaction with the alluvium. Further sensitivity analyses were requested, as were fate and transport modelling and assessment of per-aquifer water balances.

Section 5 discusses the updates made to the numerical model, including verification, further calibration and sensitivity analysis.

2.1.5 Water security

Stakeholders requested further information regarding the potential impact of the Project on the ongoing availability of groundwater resources. Of particular interest was security of supply for landowners, identified groundwater dependent ecosystems (GDEs) and the Goulburn River. Also, there were comments that there may not be sufficient groundwater to allow the mine to operate during periods of sustained drought.

Section 5 presents additional numerical modelling conducted to further assess potential yields from a borefield within the alluvial aquifer. The modelling further considers climatic influences, as well as the influence of aquifer storage and permeability on the ability of the aquifer to yield water. Impacts on landholder bores and GDEs are also discussed.

2.1.6 Water licensing

Stakeholders commented that KEPCO does not currently hold a licence under Part 5 of the *Water Act 1912* to account for the take of water from the Permo-Triassic groundwater system (coal measures). Since submission of the EIS, KEPCO lodged a water licence application under Part 5 of the *Water Act 1912* to account for the predicted water takes from the Permo-Triassic groundwater system. This application is currently being reviewed by DPI-Water.

It is important to highlight that the approach to water management for the hard rock aquifers in the Hunter Valley has recently changed with the release of the draft 'Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources'. This Water Sharing Plan (WSP) was released for public exhibition from 8 February 2016 to 20 March 2016. This WSP is due to commence in July 2016 and will replace provisions under the *Water Act 1912* and bring the management of groundwater from the hard rock aquifers under the *Water Management Act 2000*.

Stakeholders also noted that whilst KEPCO currently holds entitlement for take of surface and alluvial waters, the seasonal availability of this water might mean the full entitlement may not be obtainable during dry periods.

Section 6.3 and Section 7 discusses these issues in more detail and the proposed approach to accommodate the revised water licensing regulations and water shortages. KEPCO will prepare and implement a Water Management Plan for the Project. It will detail a program to monitor water yields and availability from the borefield, particularly if there are extended periods of drought. The WMP will detail trigger levels to monitor against and if reached, the Project will implement a contingency plan to ensure the supply of water to the Project. The contingency plan may include the expansion of the borefield (subject to approval), temporarily reducing KEPCO's agricultural activities (and temporarily transferring associated water entitlements to the Project) and in a worst case scenario, progressively adjusting mining-related activities (such as coal processing) to match the available water supplies.

2.1.7 Water quality impacts

The EIS provided salinity data for the alluvial aquifer and estimated the potential for an increased salt load during operations, particularly related to the open cut mining areas. Stakeholders provided submissions requesting that further baseline characterisation of water quality be undertaken, for all hydrostratigraphic units. More information on the likely changes to groundwater salinity during and after mining operations was requested.

Section 6.5 and Section 7.2.8 discuss the water quality impacts and proposed monitoring program to be implemented.

2.1.8 Groundwater monitoring and management

Stakeholders provided submissions requesting clarifications and/or commitments regarding monitoring of the groundwater regime to identify impacts and management of those impacts. More detail on the establishment of a groundwater monitoring regime was requested, in particular the development of groundwater quantity and quality trigger levels and the make-good process that will be implemented. Uncertainty around the current groundwater licencing and cease-to-pump framework for the area was raised. More information on the remedial strategy for subsidence and fracturing associated with longwall mining was also requested.

Section 7 discusses groundwater monitoring and management measures and provides commitments to be included within the Water Management Plan for the Project.

3 Geology

3.1 Geology

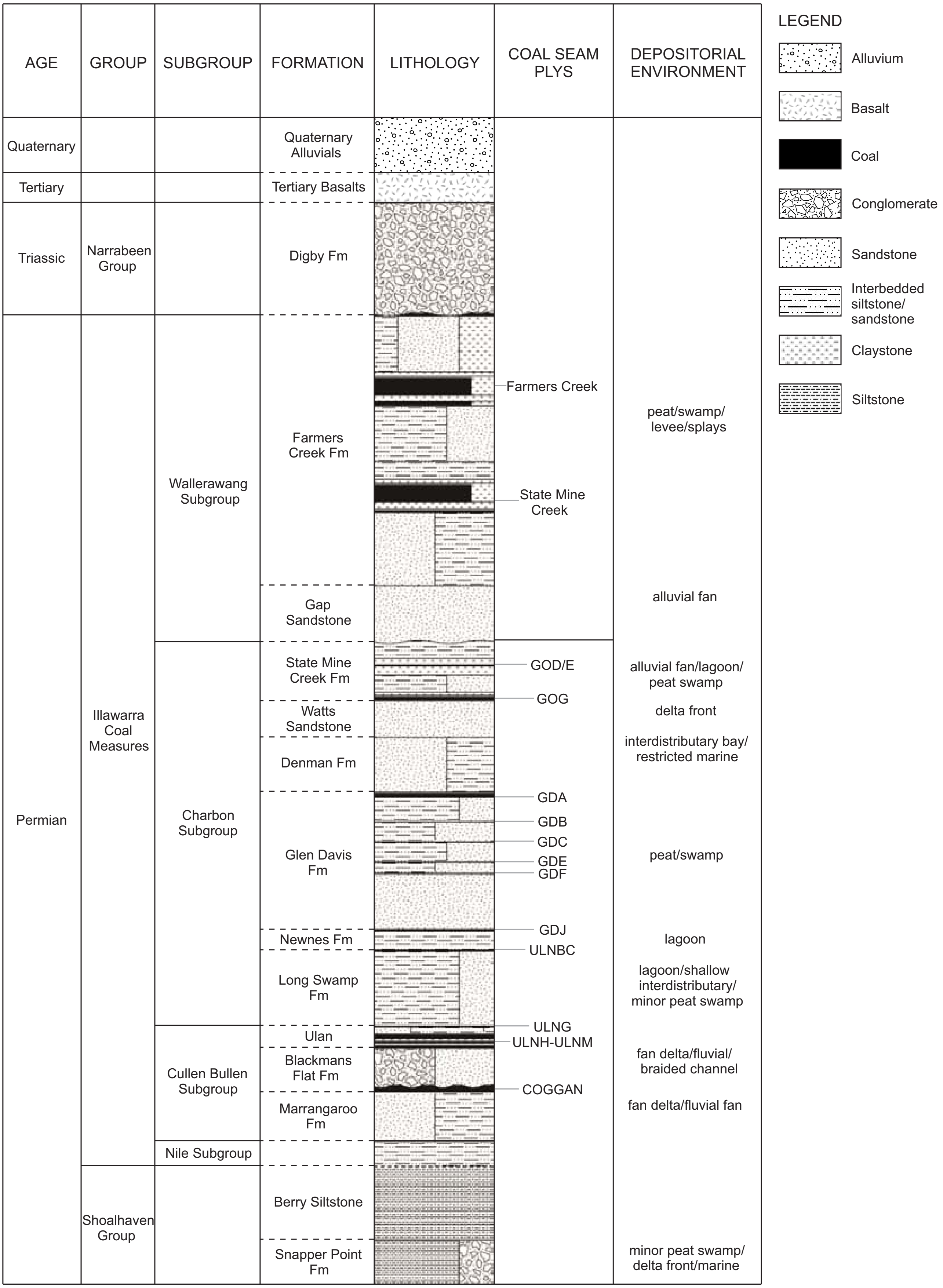
Stakeholders commented that the description of the geology and naming conventions for the geology and hydrogeology (aquifers or aquitards) was not consistent and unclear within the EIS. Stakeholders also requested additional information on the properties of the formations overlying and underlying the coal seams proposed for extraction, including the relevant borehole logs.

Sections 3.1 to 3.5 provide more detail on the key geological formations, whilst Section 4.2 to Section 4.4 discuss further details on the hydrogeological properties of the key geological formations within the Project Boundary. Appendix A contains the borehole logs that graphically illustrate the monitoring bore construction and lithological layers intersected during installation of each borehole.

During the preparation of the response to submissions, KEPCO engaged Douglas Partners to drill an additional five bores along the alignment of Dry Creek to characterise the nature of any alluvial sediments along the creek line, and the potential for this material to form an aquifer that could support deep rooted vegetation. The borehole logs for these new bores (AGE16 – AGE20) are contained within Appendix A. Sections 4.1 and 4.2 present further information on the results of this additional investigation.

Figure 1 below shows the stratigraphic groups that have been identified within the Project Boundary. The groups are further subdivided into sub-groups and formations. The column has been revised and extended in this report to show the basalt and alluvium layers that lie unconformably over the older units. Appendix B contains a series of vertical sections through the Project Boundary identifying the main coal seams within each of the stratigraphic units.

Sections below describe the geology of the key stratigraphic units based upon regional information presented by Yoo et al (2001) and site specific information provided by the proponent.



Stratigraphic column

Adapted from information provided by Anthony Leone, Worley Parsons, 2016

Figure 1

Bylong Coal Project (G1606)

3.2 Cainozoic units

3.2.1 *Quaternary alluvium*

Quaternary (and possibly Tertiary) age alluvial sediments associated with local rivers and creeks infill the valley floors within and surrounding the Project Boundary. Investigative drilling has shown that these sediments consist of silt, clay, sand and gravel. Whilst the sequence is generally variable, the upper layers of the alluvium generally contains more fine sediments of silt and clay compared with the deeper basal layers of which contain more sand and gravel. The alluvium in the Project Boundary is up to 20 m in thickness.

3.2.2 *Tertiary volcanics*

Tertiary igneous units are found across the region occurring primarily as basalts flows. A basalt flow caps the plateau above where longwall mining is proposed. The basalt cover is typically overlain by a thin layer of soil. The thickness of the basalt varies from 10 m to 40 m and unconformably overlies sediments of the Narrabeen Group.

3.3 Triassic Narrabeen Group

Rocks of the Narrabeen Group form characteristic escarpments features across the wider region. Near continuous and mesa like plateaus are also most common within the region. However there are no escarpment features or plateaus located within the Project Boundary as described within the subsidence report prepared for the EIS. The Narrabeen Group overlies the Illawarra coal measures, with the contact generally considered to be conformable and is comprised of massive sandstones and conglomerates.

3.4 Mesozoic igneous units

Mesozoic igneous units also occur across the region, typically as intrusions and primarily of phonolite, latite, syenite, trachyte, or teschenite.

The largest intrusion is the Coggan sill which covers an area of approximately 12 km^2 within the western portion of the Project Boundary (refer Figure 15 within the main EIS document). It is believed to be one of a suite of Mesozoic intrusions present throughout the region. The sill is variable in nature and in certain drillholes has split into two intervals varying from 0.2 m to 5.1 m thick. The sill variably affects the Ulan and Coggan Coal Seams and in parts replaces the seam and cokes and de-volatises the coal adjacent to the sill.

Doleritic dykes have been intersected in a number of drillholes. Typically the intersections in drillholes are thinner than 1.5 m, but exhibit a maximum thickness of 33 m.

3.5 Permian Illawarra Coal Measures

The Illawarra coal measures contain the economic coal seams proposed to be mined. The Illawarra coal measures have been divided into subgroups, which are a succession of two or more formations with common lithologic properties. There are four subgroups described in descending stratigraphic order below:

- Wallerawang Subgroup;
- Charbon Subgroup;
- Cullen Bullen Subgroup; and
- Nile Subgroup.

The sections below summarise the geology of each of these subgroups.

3.5.1 Wallerawang Subgroup

The Wallerawang Subgroup consists of two formations, the Gap sandstone, a major marker horizon in the Western Coalfield, and the overlying Farmers Creek formation. The top of the Wallerawang Subgroup, which is also the top of the Illawarra coal measures, is defined by the topmost coal or carbonaceous claystone below an unconformable boundary with the lower most massive sandstone of the Narrabeen Group.

Farmers Creek Formation

The Farmers Creek formation within the Project Boundary consists of claystone, carbonaceous claystone, siliceous claystone, siltstone, sandstone, coal and oil shale. It includes the Middle River coal member at the base and the top is marked by the overlying Katoomba coal. The formation also contains several thin coal layers of variable thickness above the Middle River coal member.

Gap Sandstone

The Gap sandstone is an off white upward fining medium to coarse grained quartz lithic to lithic sandstone which exhibits high angle cross bedding. The formation commonly contains pebbles at the base. The Gap sandstone has a sharp erosive base.

3.5.2 Charbon Subgroup

The Charbon subgroup occurs below the Wallerawang Subgroup and contains six formations described in descending stratigraphic order below.

State Mine Creek Formation

State Mine Creek formation consists of claystone, mudstone, siltstone, minor sandstone and coal seams. Worm burrows and plant remains are common. Coal seams are generally present in the formation including: the Moolarben coal member, Turill coal member and the Lennox seam or Goulburn seam. Some of the seams consist of carbonaceous claystone and thin coal layers.

Watts Sandstone

The Watts sandstone is a coarsening up lithic sandstone overlying the Denman formation with gradational contact. It underlies the State Mine Creek formation with a sharp contact. The Watts sandstone is different from the sandstone of the overlying State Mine Creek formation in being white in colour, coarser grained, and with calcareous cement.

Denman Formation

Denman formation represents a widespread marine incursion. It grades vertically upwards from dark grey claystone and fine sandstone with common bioturbation into finer grained lithic sandstones.

Glen Davis Formation

Glen Davis formation consists of carbonaceous claystone, claystone, siltstone, sandstone and thin coal seams.

Newnes Formation

Newnes formation consists generally of a fine to medium grained, lithic sandstone, and interbedded siltstone and claystone in regions.

Long Swamp Formation

Long Swamp formation comprises claystone, siltstone, tuff, sandstone and thin discontinuous coal layers. The claystone and siltstone are commonly bioturbated.

3.5.3 Cullen Bullen Subgroup

The Cullen Bullen Subgroup consists of conglomerates, lithic-quartz sandstones and thick economic coal seams including the Ulan and Coggan seams proposed to be mined by the Project. It includes three main formations described below.

Ulan coal seams

The Ulan coal formation consists of predominantly dull coal with minor bright coal layers, thin claystone, carbonaceous and tuffaceous claystone and siltstone. The formation is subdivided into upper and lower sections by a thin tuffaceous claystone layer. The tuffaceous layer is persistent through a large part of the Western Coalfield.

Within the Bylong area 13 coal plies and two tuffaceous claystone marker bands are recognised within the Ulan Coal Seams and can be correlated across the Project Boundary. The individual plies are generally <1 m thick and total coal thickness is generally around 7 m over a total interval of average 20 m.

The Ulan Coal Seam is the major economic seam mined at the Ulan and Wilpinjong Mines located 30 km and 20 km respectively to the northwest. Between the Ulan Mine and the Bylong Project Boundary the seam deteriorates and splits and the upper plies are not present at Bylong.

Blackmans flat formation

The Ulan Coal Seam is separated from the underlying Coggan Coal Seam by the Blackmans flat conglomerate. This unit is an upward fining sequence of primarily coarse, pebble bearing quartzose sandstone which often has a basal conglomerate unit. In other areas, the unit grades upwards into siltstone. The unit forms the roof of the Coggan Coal Seam and is comprised of between 50% and 90% sandstone, averaging around 70% sandstone.

The Coggan coal seam is the major economic coal seam in the Project Boundary and overlies the bench forming Marrangaroo formation. The Coggan Coal Seam has a thickness from approximately 2 m on the western margin of the Project Boundary to approximately 5 m near the eastern boundary.

Marrangaroo formation

The Marrangaroo formation crops out persistently throughout the Western Coalfields, ranging in thickness from 2 m to 16 m. The Formation commonly has a sharp erosional basal contact. Within the Project Boundary, the Marrangaroo formation consists of fine to medium grained, well cemented sandstone 3 m to 5 m thick, which can be mapped from its prominent bench forming geomorphology.

3.5.4 Nile Subgroup

The Nile Subgroup is the basal unit in the Illawarra coal measures and is comprised of sandy siltstone, sandstone and pebble bearing mudstone.

3.6 Shoalhaven Group

The lowermost group is the Shoalhaven Group which comprises the Berry Siltstone and the Snapper Point Formation.

3.7 Structure

The structure of the deposit is relatively simple with stratigraphy dipping gently (1° to 3°) to the north-northeast. The Ulan and Coggan Coal Seams are present across most of the Project Boundary and sub-crop in the south and west of the Project Boundary. The upper seams are generally only present outside of the valleys under the escarpments. Coal interval thicknesses and interburden thicknesses are relatively consistent across the deposit although there are localised variations and broad trends. No large displacement faults are currently defined in the Project Boundary through drilling and modelling.

4 Hydrogeology

There are two main groundwater systems within the Project Boundary. The first is the shallow alluvial groundwater system that is highly connected to the surface waters. The second is the Permian Coal Measures, in particular the Coggan Coal Seam and to a lesser extent the Ulan Coal Seam. A third minor perched groundwater system occurs at the base of the Tertiary basalt cap in plateau area overlying the proposed underground extraction area. New data collected from the ongoing monitoring of these systems (primarily water level measurements) since submission of the EIS is presented and discussed in sections below. Where relevant, information (again primarily water level measurements) presented within the EIS are also reproduced for context.

4.1 Monitoring bore network

A stakeholder submission has requested further detail on the existing groundwater monitoring network. Specifically local-scale location maps that identify bores based on the aquifer they monitor. The bore summary table from the EIS (based on Table 6.1 in the EIS groundwater report) has been developed further to better identify monitored aquifer units in more details. It is presented as Table 1 below.

Location maps showing the position of the groundwater monitoring network are presented as Figure 2 and Figure 3. The maps show the monitoring bores and the vibrating wire piezometer network separately and the geology of the screen and sensor zones. Figure 2 also shows the locations of the new monitoring bores installed along the alignment of Dry Creek to determine the nature and extent of alluvial sediments within this area.

Figure 2 and Figure 3 show the geographic spread of groundwater monitoring sites within, and proximal to the Project Boundary. Each hydrostratigraphic unit is included in the network with the Quaternary alluvium containing the majority of monitoring points. The alluvium is considered the most sensitive unit to potential changes in groundwater abstraction and hence many of the monitoring bores follow its mapped extent.

In addition to monitoring bores screened within discrete geologic units, there is also an array of vibrating wire piezometers as part of the monitoring network. These provide groundwater pressure readings from multiple depths at the same location and give information on vertical hydraulic connectivity as well as temporal water pressure changes within individual zones. Assessment of observed water levels is presented on a per unit basis later in this section.

During the development and operational stages of the Project, the existing groundwater monitoring network will be augmented with additional bores. Ongoing groundwater monitoring and management is discussed in Section 7.

Table 1 Summary table of groundwater monitoring network

Bore ID	Revised Bore ID	Easting (m) GDA94 Z56	Northing (m) GDA94 Z56	Elevation (mRL)	Total depth (mbgl)	Stickup (magl)	Screened interval (mbgl)	Bore type	Unit	Lithology	Date installed
A01-D		230112.43	6412947.21	247.25	20.6	0.64	15.6-18.6	MB	Alluvium - Lower	Gravel/Sand and Residual Clay	26/08/2011
A01-S		230425.12	6404123.10	299.73	3.8	0.74	0.8-3.8	MB	Alluvium - Upper	Clay and Gravel/Sand	26/08/2011
A02-D		230426.19	6404123.04	299.76	8.5	0.73	5.5-8.5	MB	Alluvium - Lower	Soil/Sandy Clay	28/02/2012
A02-S		230425.12	6404123.10	299.73	3.8	0.74	0.8-3.8	MB	Alluvium - Upper	Silty Clay/ Clayey Silt	28/02/2012
A03-D		232474.86	6405317.43	288.08	9.4	0.84	6.4-9.4	MB	Alluvium - Lower	Clay/Silty Clay/Clayey Silt	30/05/2012
A03-S		232474.91	6405318.87	288.08	3.5	0.62	0.5-3.5	MB	Alluvium - Upper	Sandy Clay/Clayey Sand	30/05/2012
A04		233787.53	6405925.52	294.59	5.2	0.73	0.8-5.2	MB	Alluvium - Upper	Sand	16/05/2012
A06-D		231263.58	6407412.54	275.32	10.0	0.52	7.0-10.0	MB	Alluvium - Lower	Sandy Clay and Gravelly Clay	28/02/2012
A06-S		231263.45	6407411.12	275.34	4.5	0.60	1.5-4.5	MB	Alluvium - Upper	Silty Clay and Silty Sand and Sand	28/02/2012
A06-VW1		231260	6407410	275.3	12.6	na	12.6	VWP	Long Swamp Fm	Coal seam	12/09/2013
A06-VW2		231260	6407410	275.3	17.1	na	17.1	VWP	Ulan Coal Seam	Coal seam	12/09/2013
A06-VW3		231260	6407410	275.3	27.0	na	27.0	VWP	Coggan Coal Seam	Coal seam	12/09/2013
A06-VW4		231260	6407410	275.3	36.7	na	36.7	VWP	Marrangaroo Sandstone	Siltstone	12/09/2013
A08-D		230228.54	6408487.47	267.14	8.6	0.78	5.6-8.6	MB	Alluvium - Lower	Clay/Sand	23/05/2012
A08-S		230227.13	6408489.10	267.14	5.0	0.89	2.0-5.0	MB	Alluvium - Upper	Clay/Sand	23/05/2012
A09	A09/SW2	228645.01	6409926.89	255.97	6.6	0.74	0.6-6.6	MB	Alluvium - Upper	Alluvium	26/07/2012
A10		230453.79	6406647.50	278.25	9.0	0.79	3.0-9.0	MB	Alluvium - Upper	Sand/ Clay/ Sandy Clay	24/05/2012
A11-D		230165.93	6402188.79	312.50	12.2	0.57	6.2-12.2	MB	Alluvium - Lower	Sand and Sandy Clay/Clayey Sand	1/03/2012

Bore ID	Revised Bore ID	Easting (m) GDA94 Z56	Northing (m) GDA94 Z56	Elevation (mRL)	Total depth (mbgl)	Stickup (magl)	Screened interval (mbgl)	Bore type	Unit	Lithology	Date installed
A11-S		230165.87	6402187.47	312.52	3.9	0.55	0.9-3.9	MB	Alluvium - Upper	Silty Clay and Sand and Sandy Gravel	1/03/2012
A12	A12/SW7	229870.65	6398592.86	341.80	6.2	0.80	0.2-6.2	MB	Alluvium - Upper	Sand and Sandy Clay/Clayey Sand	17/05/2012
A13		229512.16	6411279.12	251.58	7.6	0.66	1.2-7.2	MB	Alluvium - Upper	Clay and Sand and Sand/Gravel	26/08/2011
A14	A12/SW5	225357.07	6406838.83	280.17	8.3	0.69	2.1-8.3	MB	Alluvium - Upper	Alluvium	27/07/2012
A15	A12/SW1	234817.03	6405882.93	299.99	6.3	0.74	0.3-6.3	MB	Alluvium - Upper	Alluvium	16/05/2012
A16	A12/SW6	226405.21	6416909.90	220.01	1.3	0.81	0.2-1.3	MB	Alluvium - Upper	Alluvium	26/07/2012
A17-D		230059.46	6401190.67	321.11	11.3	0.65	7.3-11.3	MB	Alluvium - Lower	Alluvium	28/02/2012
A17-S		230060.51	6401190.43	321.09	4.15	0.65	1.2-4.2	MB	Alluvium - Upper	Alluvium	28/02/2012
A18	A18/SW9	229979.01	6400327.55	327.63	6.2	0.65	0.2-6.2	MB	Alluvium - Upper	Sandy Silt/Gravelly Sand	21/05/2012
A19	A19/SW4	229994.66	6412727.94	246.29	5.2	0.74	2.2-5.2	MB	Alluvium - Upper	Clay /Clayey Sand/ Gravelly Sand	24/07/2012
A20	A20/SW8	231186.36	6407756.08	273.73	7.2	0.68	1.2-7.2	MB	Alluvium - Upper	Sandy Clay/Clay/Silty Clay	10/07/2012
A21		233693.28	6403938.79	313.68	14.95	0.63	8.3-14.3	MB	Alluvium - Upper	Alluvium	30/04/2013
A22		230567.69	6401122.03	333.42	9.4	0.63	3.4-9.4	MB	Alluvium - Upper	Clayey sand, clay & Sandstone	22/10/2012
A23		230567.69	6401122.03	333.42	9.4	0.63	3.4-9.4	MB	Alluvium - Upper	Clayey sand, sand, gravelly sand	15/10/2012
A23W		230567.63	6401124.12	333.28	16.4	0.54	10.4-16.4	MB	Illawarra C.M.	Weathered Zone	23/10/2012
A24-D		230808.88	6400665.51	342.42	8.6	0.46	5.6-8.6	MB	Alluvium - Lower	Alluvium	16/10/2012
A24-S		230810.08	6400663.99	342.48	5.4	0.58	2.4-5.4	MB	Alluvium - Upper	Gravelly sand and clay	16/10/2012
A25		231231.06	6400351.88	351.49	5.5	0.61	2.5-5.5	MB	Alluvium - Lower	Gravel, sand and sandstone	17/10/2012
AGE01A-D		229452.11	6414924.63	237.36	9.4	0.60	6.4-9.4	MB	Alluvium - Lower	Sandy gravel	22/10/2012

Bore ID	Revised Bore ID	Easting (m) GDA94 Z56	Northing (m) GDA94 Z56	Elevation (mRL)	Total depth (mbgl)	Stickup (magl)	Screened interval (mbgl)	Bore type	Unit	Lithology	Date installed
AGE01A-S		229452.90	6414924.53	237.35	4.8	0.72	1.8-4.8	MB	Alluvium - Upper	Clay and sandy gravel	15/10/2012
AGE01-VW1		229453	6414926	237.3	27.7	na	27.7	VWP	Denman Fm	Carbonaceous siltstone with interbedded tuff	16/04/2013
AGE01-VW2		229453	6414926	237.3	67.1	na	67.1	VWP	Long Swamp Fm	Sandstone	30/04/2013
AGE01-VW3		229453	6414926	237.3	120.2	na	120.2	VWP	Ulan Coal Seam	Coal, sandstone and siltstone	30/04/2013
AGE01-VW4		229453	6414926	237.3	128.2	na	128.2	VWP	Coggan Coal Seam	Interburden and coal seam	30/04/2013
AGE01-VW5		229453	6414926	237.3	140.7	na	140.7	VWP	Marrangaroo Sandstone	Sandstone/ siltstone	30/04/2013
AGE01W		229450.88	6414924.81	237.38	20.5	0.51	14.45-20.45	MB	Illawarra C.M.	Weathered siltstone/ sandstone	23/10/2012
AGE02-D		230106.57	6413814.11	248.80	11.5	0.51	5.5-11.5	MB	Alluvium - Lower	-	28/02/2012
AGE02-S		230105.50	6413814.87	248.81	4.8	0.57	1.8-4.8	MB	Alluvium - Upper	-	26/02/2011
AGE02-VW1		230102	6413816	248.8	38	na	38.0	VWP	Glen Davis Fm	Sandstone	26/09/2013
AGE02-VW2		230102	6413816	248.8	52	na	52.0	VWP	Newnes Fm	Sandstone	26/09/2013
AGE02-VW3		230102	6413816	248.8	91	na	91.0	VWP	Long Swamp Fm	Coal seam	26/09/2013
AGE02-VW4		230102	6413816	248.8	101	na	101.0	VWP	Ulan Coal Seam	Coal seam	26/09/2013
AGE02-VW5		230102	6413816	248.8	110	na	110.0	VWP	Coggan Coal Seam	Coal seam	26/09/2013
AGE02-VW6		230102	6413816	248.8	123	na	123.0	VWP	Marrangaroo Sandstone	Sandstone	26/09/2013
AGE03-VW1		230106	6412878	247.7	31.2	na	31.2	VWP	Glen Davis Fm	Fresh Sandstone	30/04/2013
AGE03W		230107.64	6412878.03	246.93	24.15	0.65	18.0-24.15	MB	Illawarra C.M.	Siltstone/ sandstone	16/10/2012
AGE04		228634.90	6411382.00	257.08	66.17	0.68	57.17-63.17	MB	Coggan Coal Seam	Coal seam	16/10/2012
AGE04-D		228636.91	6411382.67	257.07	17.3	0.56	14.3-17.3	MB	Alluvium - Lower	Sand and gravel	17/10/2012
AGE04-S		228637.65	6411382.90	257.05	11.3	0.52	5.3-11.3	MB	Alluvium - Upper	Silty sand and sand	23/11/2012

Bore ID	Revised Bore ID	Easting (m) GDA94 Z56	Northing (m) GDA94 Z56	Elevation (mRL)	Total depth (mbgl)	Stickup (magl)	Screened interval (mbgl)	Bore type	Unit	Lithology	Date installed
AGE04W		228635.88	6411382.32	257.06	25.95	0.57	19.95-25.95	MB	Illawarra C.M.	Siltstone, minor tuff and coal	23/11/2012
AGE05		227890.76	6410501.47	259.92	50.9	0.57	41.9-47.9	MB	Coggan Coal Seam	Coal seam	29/11/2012
AGE05A		227889.84	6410500.11	259.91	8.4	0.57	5.4-8.4	MB	Alluvium - Upper	Gravelly sand	29/11/2012
AGE05W		227891.49	6,410502.59	259.88	15.7	0.62	9.7-15.7	MB	Illawarra C.M.	Siltstone/ sandstone	29/11/2012
AGE07		228648.82	6409111.16	270.68	42.03	0.67	24.1-36.1	MB	Coggan Coal Seam	Coal seam	9/05/2013
AGE07W		228647.04	6409111.72	270.68	20.00	0.64	9.5-17.0	MB	Illawarra C.M.	Weathered Zone	9/05/2013
AGE08		231144.41	6407146.65	282.09	36.4	0.61	29.4-33.9	MB	Coggan Coal Seam	Coal seam	13/12/2012
AGE08W		231144.14	6407147.66	282.03	13.8	0.72	7.8-13.8	MB	Illawarra C.M.	Sandstone and coal	13/12/2012
AGE09	BY0173CH	229945.09	6406679.91	285.69	36.45	0.63	24.1-28.6	MB	Coggan Coal Seam	Coal seam	3/04/2013
AGE09W		229944.95	6406677.52	285.81	18.06	0.69	7.56-15.06	MB	Illawarra C.M.	Weathered Zone	2/05/2013
AGE10	BY0206/ AGE10	231810.02	6405355.85	298.30	54.24	0.50	41.0-45.5	MB	Coggan Coal Seam	Coal seam	6/04/2013
AGE10W		231809.03	6405352.84	298.47	20.98	0.54	12.0-18.0	MB	Illawarra C.M.	Weathered Zone	30/04/2013
AGE11W		230633.50	6402142.12	326.05	14.2	0.63	5.2-14.2	MB	Illawarra C.M.	Sandstone	4/12/2012
AGE12W		230011.41	6400310.11	327.69	22.6	0.43	13.4-22.6	MB	Illawarra C.M.	Siltstone	29/10/2012
AGE13		231057.20	6401937.49	354.97	45.1	0.60	37.6-43.6	MB	Coggan Coal Seam	Sandstone and coal	6/12/2012
AGE13W	AGE13	231057.16	6401936.48	355.05	14.1	0.56	4.1-14.1	MB	Illawarra C.M.	Siltstone	6/12/2012
AGE14		229440.46	6406002.33	309.36	27.0	0.54	22.7-25.7	MB	Coggan Coal Seam	Coal seam	4/12/2013
AGE15		229850.02	6405267.65	303.23	30.3	0.50	13.9-30.34	MB	Illawarra C.M.	Sandstone	3/12/2013
AGE16		231078*	6412159*	TBC	4.1	0.7	1.4-4.1	MB	Alluvium	Sandy clay/clayey sand	8/3/2016
AGE18		231567*	6411761*	TBC	7.8	0.7	4.4-7.4	MB	Alluvium	Gravelly sand	6/3/2016
AGE19		231834*	6411591*	TBC	2.0	0.7	0.85-1.95	MB	Alluvium	Clayey gravelly sand	7/3/2016
AGE20		232073*	6411477*	TBC	1.5	0.6	0.6-1.5	MB	Alluvium	Sandy clay	7/3/2016

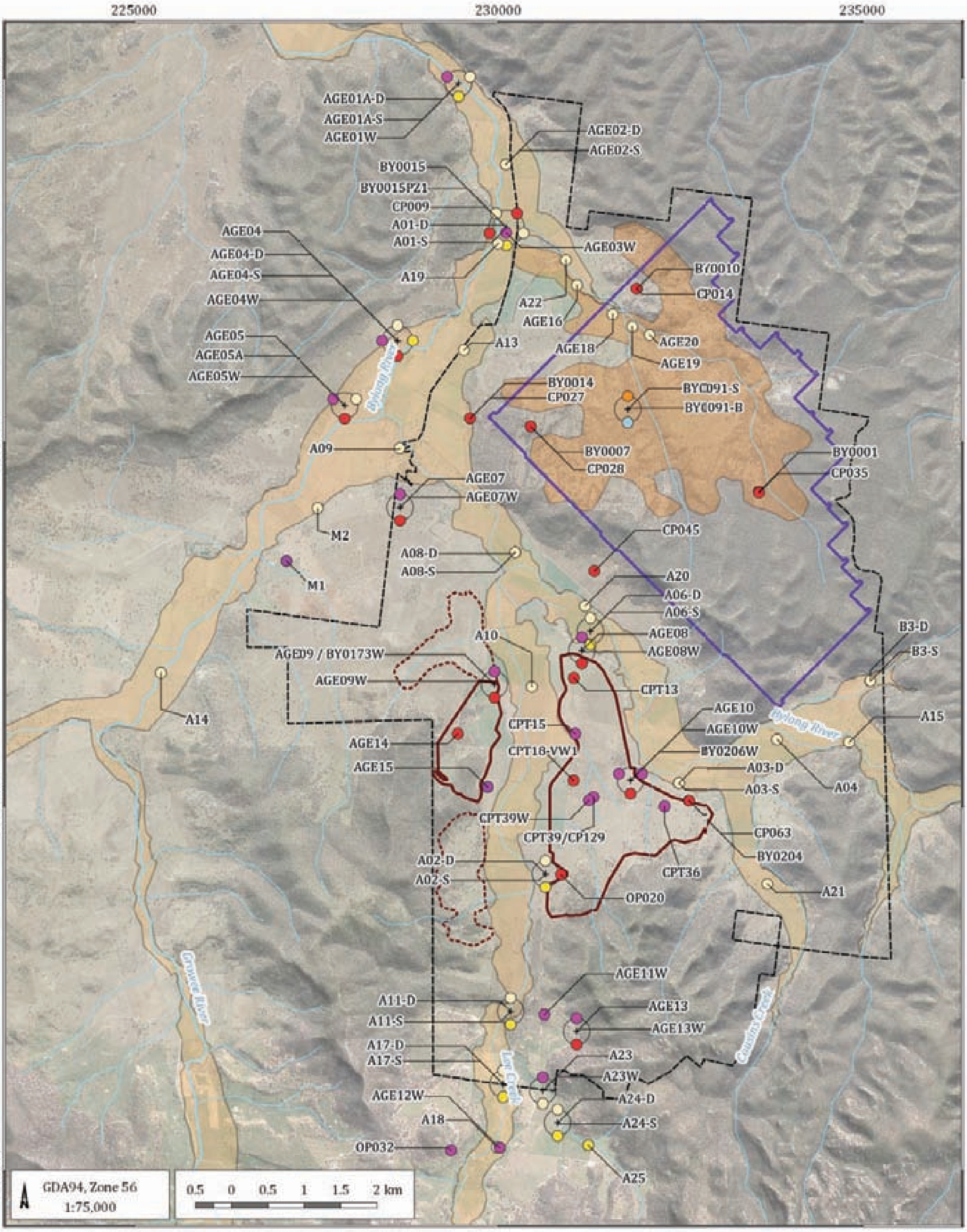
Bore ID	Revised Bore ID	Easting (m) GDA94 Z56	Northing (m) GDA94 Z56	Elevation (mRL)	Total depth (mbgl)	Stickup (magl)	Screened interval (mbgl)	Bore type	Unit	Lithology	Date installed
B3-D		235107	6406726	300.55	18	0.5	15.7-18.0	MB	Alluvium - Lower	-	28/11/2013
B3-S		235109	6406728	300.55	13.7	0.5	10.15-13.65	MB	Alluvium - Upper	-	27/11/2013
B3-VW1		235109	6406728	300.55	38	na	38.0	VWP	Glen Davis Fm	Coal seam	14/11/2013
B3-VW2		235109	6406728	300.55	52	na	52.0	VWP	Long Swamp Fm	Coal seam	14/11/2013
B3-VW3		235109	6406728	300.55	91	na	91.0	VWP	Ulan Coal Seam	Coal seam	14/11/2013
B3-VW4		235109	6406728	300.55	101	na	101.0	VWP	Coggan Coal Seam	Coal seam	14/11/2013
B3-VW5		235109	6406728	300.55	110	na	110.0	VWP	Marrangaroo Sandstone	Sandstone	14/11/2013
BY0001	BY0001CH	233581.28	6409309.91	375.92	195.0	0.84	185-191	MB	Coggan Coal Seam	Coal seam	10/5/2011
BY0007	BY0007CH	230443.10	6410217.48	368.85	169.5	0.35	161-167	MB	Coggan Coal Seam	Coal seam	1/11/2011
BY0010	BY0010CH	231893.40	6412109.72	301.40	139.0	0.74	133-139	MB	Coggan Coal Seam	Coal seam	1/11/2011
BY0011-VW1		232963	6411410	360.2	77	na	77.0	VWP	Watts Sandstone	Sandstone	17/05/2013
BY0011-VW2		232963	6411410	360.2	151	na	151.0	VWP	Long Swamp Fm	Sandstone	1/11/2011
BY0011-VW3		232963	6411410	360.2	194	na	194.0	VWP	Ulan Coal Seam	Sandstone, minor coal	1/11/2011
BY0011-VW4		232963	6411410	360.2	205	na	205.0	VWP	Coggan Coal Seam	Coal seam	1/11/2011
BY0011-VW5		232963	6411410	360.2	223	na	223.0	VWP	Marrangaroo Sandstone	Sandstone	1/11/2011
BY0014	BY0014CH	229610.69	6410330.43	259.38	56.2	0.73	50.2-56.2	MB	Coggan Coal Seam	Coal seam	28/7/2011
BY0015	BY0015CH	230110.74	6412947.42	247.28	96.0	0.70	90-96	MB	Coggan Coal Seam	Coal seam	1/11/2011
BY0016	BY0016CH	231315.42	6408236.37	292.79	47.5	0.69	39.8-45.8	MB	Coggan Coal Seam	Coal seam	13/7/2011
BY0020	BY0020CH	230574.00	6401202.00	332.37	36.00	0.64	NA	VWP	Marrangaroo Sandstone	Sandstone	1/12/2011

Bore ID	Revised Bore ID	Easting (m) GDA94 Z56	Northing (m) GDA94 Z56	Elevation (mRL)	Total depth (mbgl)	Stickup (magl)	Screened interval (mbgl)	Bore type	Unit	Lithology	Date installed
BY0077-VW1		230750	6411475	297.3	48.3	na	48.3	VWP	Newnes Fm	Sandstone, siltstone	1/11/2011
BY0077-VW2		230750	6411475	297.3	107.9	na	107.9	VWP	Ulan Coal Seam	Sandstone and coal	28/09/2012
BY0077-VW3		230750	6411475	297.3	118.8	na	118.8	VWP	Coggan Coal Seam	Coal seam	28/09/2012
BY0077-VW4		230750	6411475	297.3	139.8	na	139.8	VWP	Marrangaroo Sandstone	Sandstone	28/09/2012
BY0080-VW1		233295	6409002	405.9	177.2	na	177.2	VWP	Long Swamp Fm	Siltstone/ sandstone	28/09/2012
BY0080-VW2		233295	6409002	405.9	200	na	200.0	VWP	Ulan Coal Seam	Coal seam	5/11/2012
BY0080-VW3		233295	6409002	405.9	210.7	na	210.7	VWP	Coggan Coal Seam	Coal seam	5/11/2012
BY0080-VW4		233295	6409002	405.9	230	na	230.0	VWP	Marrangaroo Sandstone	Sandstone	5/11/2012
BY0091-B		231771.61	6410453.69	363.78	23.0	0.59	17.0-23.0	MB	Tertiary Basalt	Basalt	21/11/2012
BY0091-S		231770.52	6410452.08	363.79	36.0	0.64	30.0-36.0	MB	Marrangaroo Sandstone	Sandstone	27/11/2012
BY0091-VW1		231773	6410454	363.9	57	na	57.0	VWP	Denman Fm	Sandstone	23/11/2012
BY0091-VW2		231773	6410454	363.9	103.4	na	103.4	VWP	Newnes Fm	Sandstone/ siltstone	23/11/2012
BY0091-VW3		231773	6410454	363.9	172.5	na	172.5	VWP	Coggan Coal Seam	Coal seam	23/11/2012
BY0091-VW4		231773	6410454	363.9	185	na	185.0	VWP	Marrangaroo Sandstone	Sandstone	23/11/2012
BY0188		230858.02	6404063.52	326.48	35.50	0.62	26.5-32.5	MB	Coggan Coal Seam	Coal seam	5/04/2013

Bore ID	Revised Bore ID	Easting (m) GDA94 Z56	Northing (m) GDA94 Z56	Elevation (mRL)	Total depth (mbgl)	Stickup (magl)	Screened interval (mbgl)	Bore type	Unit	Lithology	Date installed
BY0204	BY0204CH	232615.78	6405078.96	296.75	62.50	0.74	55.0-61.0	MB	Coggan Coal Seam	Coal seam	
BY0208-VW1		234269	6403672	327.1	37.3	na	37.3	VWP	Long Swamp Fm	Igneous	16/04/2013
BY0208-VW2		234269	6403672	327.1	60	na	60.0	VWP	Long Swamp Fm	Siltstone/ sandstone	16/04/2013
BY0208-VW3		234269	6403672	327.1	87.5	na	87.5	VWP	Coggan Coal Seam	Coal seam	16/04/2013
BY0208-VW4		234269	6403672	327.1	98.5	na	98.5	VWP	Marrangaroo Sandstone	Sandstone	16/04/2013
CPT13	BY0174CH	231033.87	6406771.27	290.93	36.40	0.62	28.9-33.4	MB	Coggan Coal Seam	Coal seam	
CPT15		231051.06	6405928.40	285.63	14.91	0.64	7.21-13.21	MB	Illawarra C.M.	Weathered Zone	29/05/2013
CPT18-VW1		230967.96	6405353.76	297.37	19.00	0.47	11.5-19.0	VWP	Coggan Coal Seam	Coal seam	29/05/2013
CPT36		232343.35	6404982.41	301.42	15.50	0.64	8.0-15.5	MB	Illawarra C.M.	Weathered Zone	23/05/2013
CPT36-VW1		232278	6405003	302.8	49.0	na	49.0	VWP	Ulan Coal Seam	Coal seam	
CPT36-VW2		232278	6405003	302.8	58.1	na	58.1	VWP	Coggan Coal Seam	Coal seam	
CPT39-VW1		231241	6405086.0	306.5	25.0	na	25.0	VWP	Ulan Coal Seam	Coal seam	??
CPT39-VW2		231241	6405086	306.5	33.0	na	33.0	VWP	Coggan Coal Seam	Coal seam	??
CPT39W	CP129	231241.22	6405086.38	306.47	22.10	0.63	16.0-22.1	MB	Weathered Zone	Weathered Zone	??
M1		227089.13	6408369.69	277.77	23.0	0.45	15.5-23.0	MB	Illawarra C.M.	Sandstone	11/12/2013
M2		227518.53	6409099.11	262.80	5.9	0.50	2.9-5.9	MB	Alluvium	-	11/12/2013
OP032		229258.08	6400152.31	382.99	6.4	0.56	4.8-6.35	MB	Illawarra C.M.	Weathered Zone	12/12/2012

Notes: *na – not applicable*

** Approximate location by handheld GPS. Locations to be confirmed by survey*



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Project Boundary
- Quaternary alluvium
- Tertiary basalt
- Major drainage
- Minor drainage

Monitoring bore - geology unit

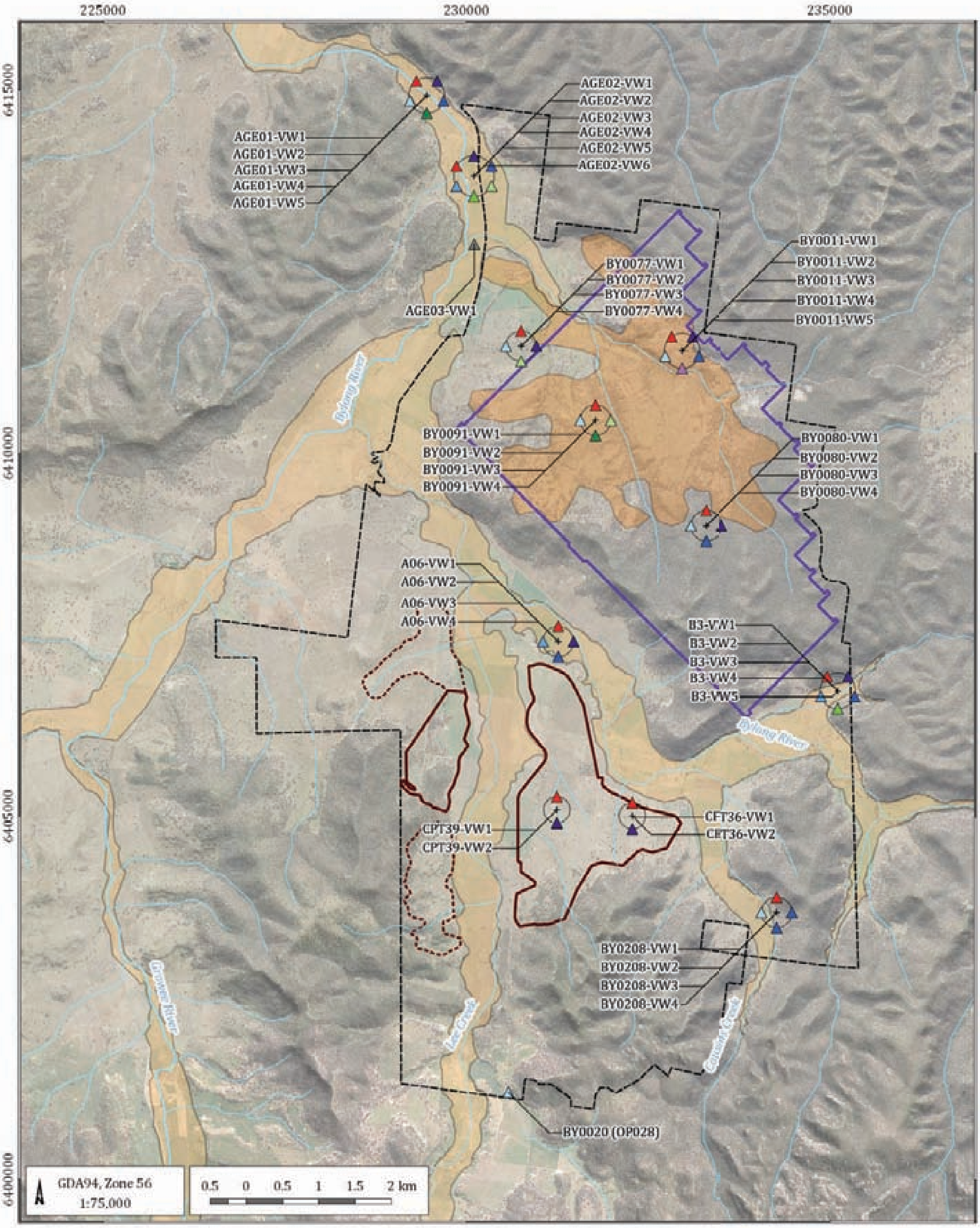
- Alluvium - Upper
- Alluvium - Lower
- Basalt
- Coggan Coal Seam
- Marangaroo Sandstone
- Sandstone
- Weathered Permian

Bylong Coal Project (G1606E)

Monitoring bore network

DATE 14/3/2016

FIGURE No: 2



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Project Boundary
- Quaternary alluvium
- Tertiary basalt
- Major drainage
- Minor drainage

VWP - geology unit

- Coggan Coal Seam
- Ulan Coal Seam
- Denman Fm
- Glen Davis Fm
- Newnes Fm
- Long Swamp Fm
- Shoalhaven Gp
- Marangaroo Sandstone
- Watts Sandstone
- Unknown

Bylong Coal Project (G1606E)

Vibrating wire piezometer network

AGE
GROUNDWATER & ENVIRONMENTAL

DATE
1/3/2016

FIGURE No:
3

4.2 Alluvial aquifer

4.2.1 Extent and thickness

Stakeholder submissions requested more detail on the alluvial aquifer including:

- monitoring bore construction and lithology logs for the alluvium;
- geological cross sections; and
- information on the saturated thickness of the alluvial material.

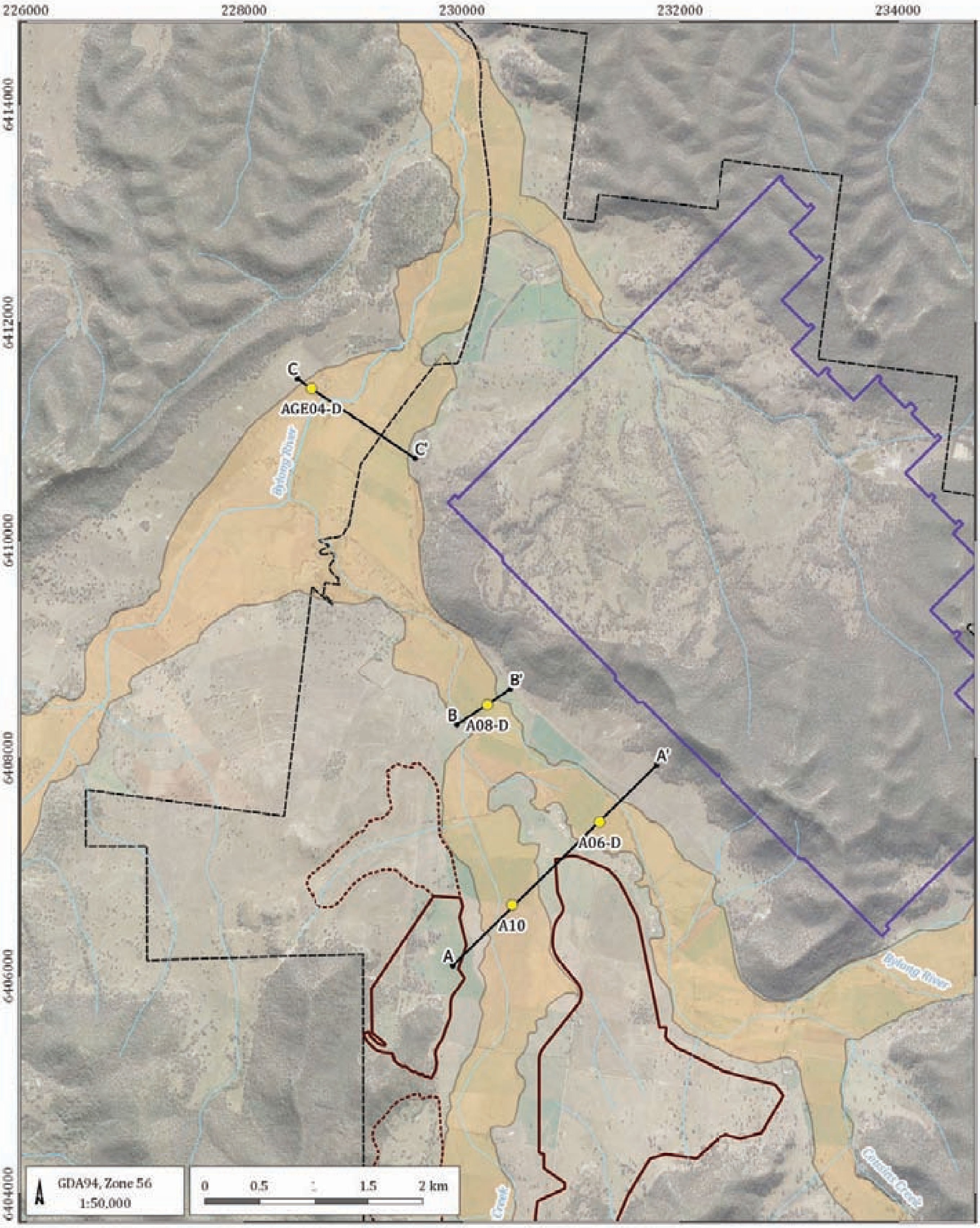
Appendix A contains the borehole logs that show graphically the monitoring bore construction and lithological layers within the alluvium. A series of cross sections were also generated across the alluvial flood plain where detail on lithology was available from monitoring bores illustrating the layers within alluvium.

Figure 4 shows the locations of the sections with Figure 5 to Figure 7 showing the cross sections for each site. The alluvial layers presented within the sections are a simplified representation of the lithology based on the relative permeability. Clean porous sands are separated from less permeable silty sands, clayey sands and clays. The depth of groundwater recorded below the surface is also noted on the cross sections.

KEPCO engaged Douglas Partners to supervise the drilling of five additional boreholes along the alignment of Dry Creek during the preparation of the response to submissions. Four of the boreholes were drilled with solid flight augers to permit observations of groundwater during drilling, whilst unstable sediments within one borehole (AGE18) required use of the casing advance method. The bores were drilled to depths of 1.5 m to 7.8 m and were terminated where bedrock was encountered an prevented further drilling with augers. Four of the boreholes were cased with PVC and constructed as permanent monitoring bores (AGE16, AGE18, AGE19 and AGE20). AGE17 could not be cased and was grouted to the surface with cement grout.

Fluids used to hydrate the bentonite seals and for the drilling of AGE18 were removed by bailing and no influx of groundwater was noted following development.

The new monitoring bores indicate Dry Creek has not developed a significant sequence of alluvium along its alignment and that within the Project area, the Dry Creek alluvium is dry. It is however noted that there is not a long term record of monitoring within the new monitoring bores, and therefore as discussed within the EIS, it is possible a thin zone of perched water occurs ephemerally at the interface between the alluvium and the less permeable rock along the alignment of Dry Creek. However, given the fact the monitoring bores were installed at the end of the summer wet season, this outcome is considered unlikely.



LEGEND

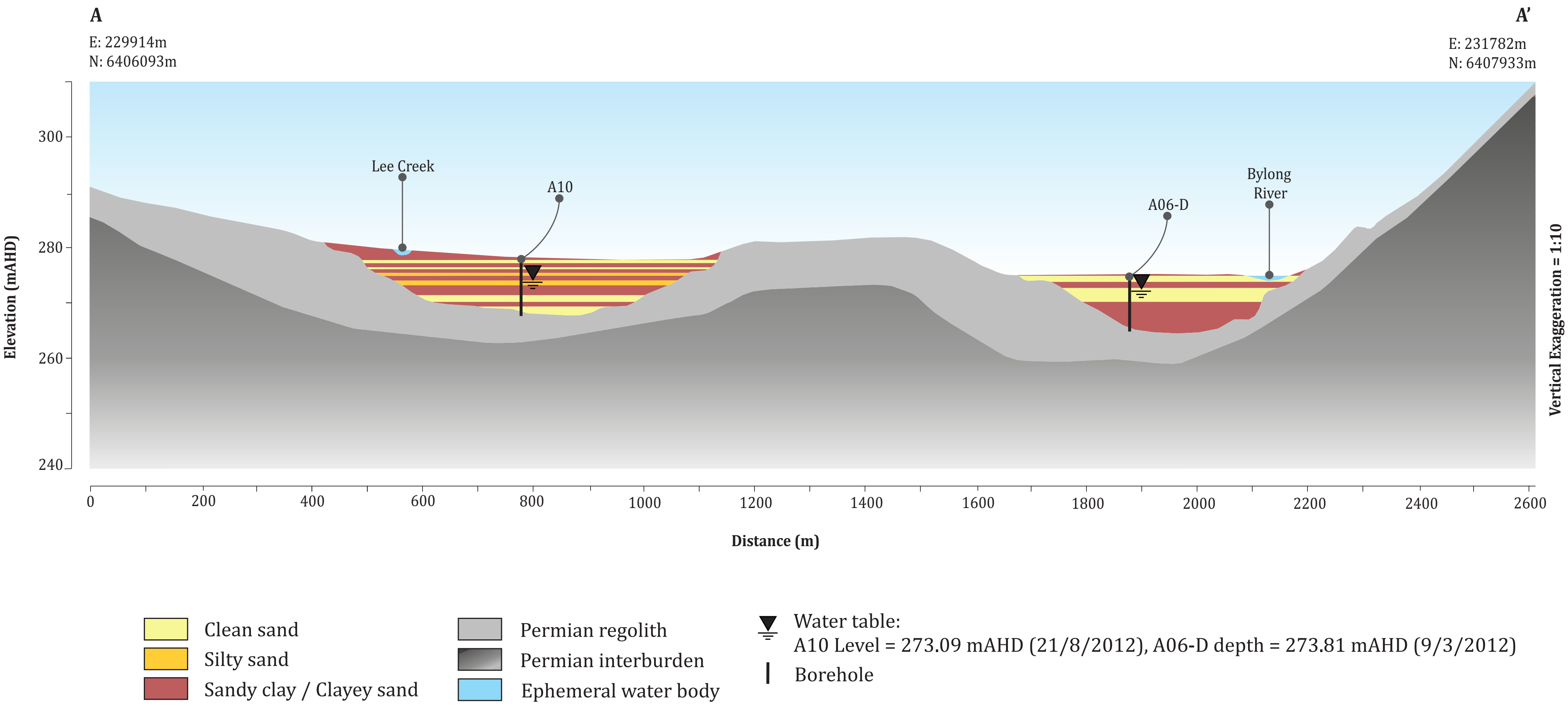
- Cross sections
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Project Boundary
- Quaternary alluvium
- Major drainage
- Minor drainage

Bylong Coal Project (G1606E)

Location of cross sections through alluvium

DATE 1/3/2016

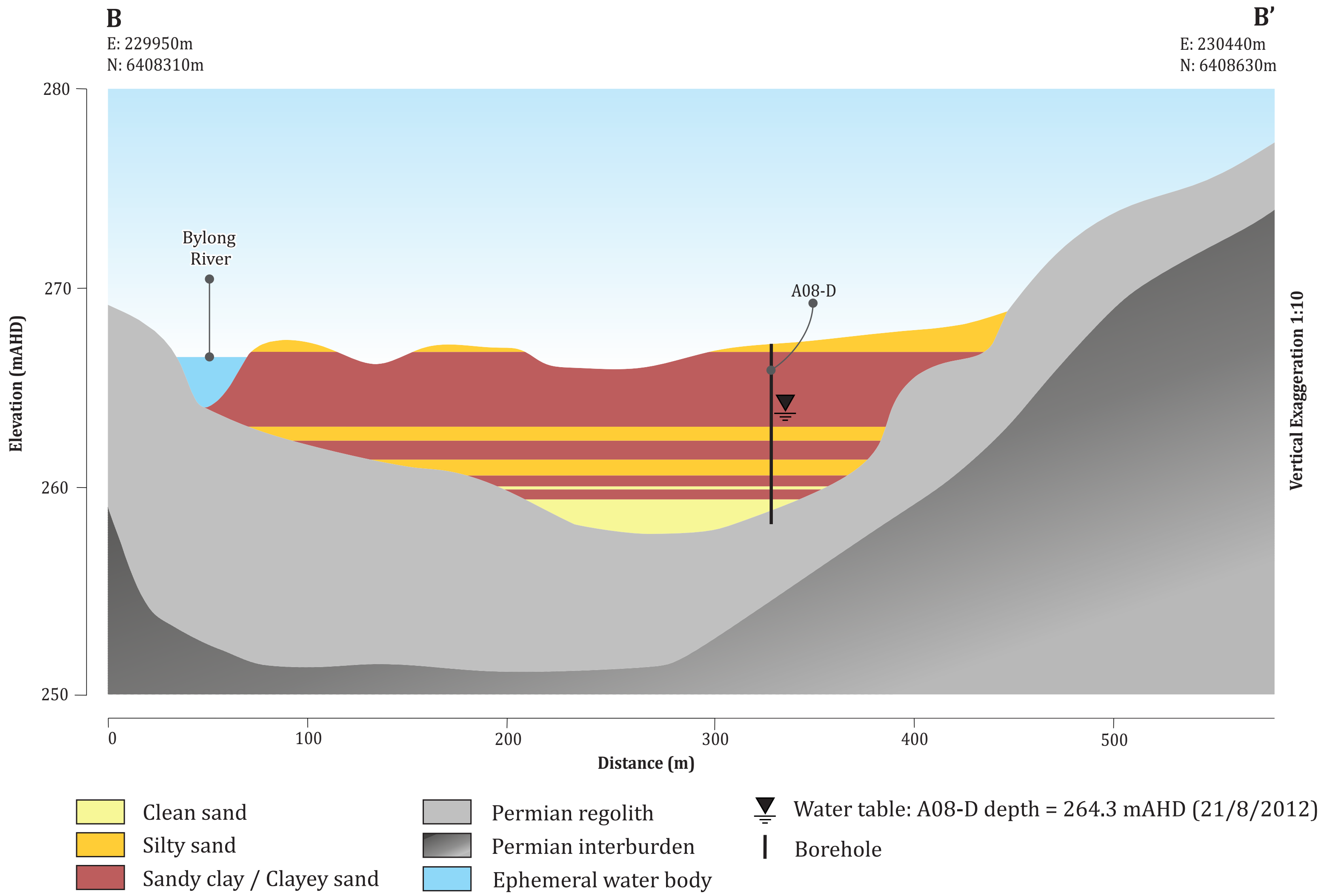
FIGURE No: 4



Alluvial cross section A - A'

Figure 5

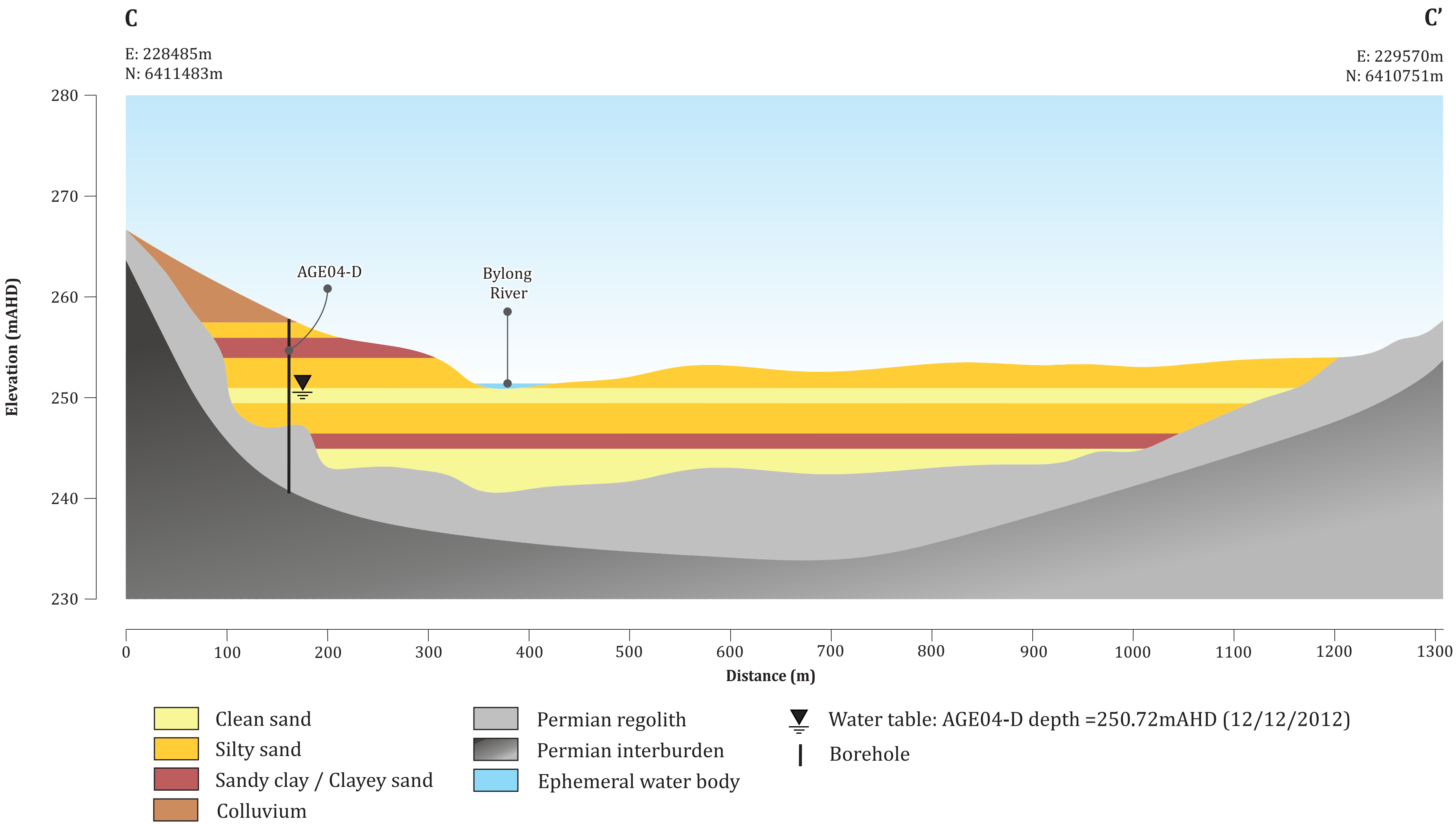
Bylong Coal Project (G1606E)



Alluvial cross section B - B'

Figure 6

Bylong Coal Project (G1606E)



Alluvial cross section C - C'

Figure 7

Bylong Coal Project (G1606E)

4.2.2 Water level monitoring and mapping

A stakeholder requested additional groundwater contour maps for each individual aquifer identified within the Project Boundary with bores labelled with a representative rest water level. KEPCO have continued to monitor groundwater levels within the alluvial groundwater systems since submission of the EIS. Figure 2 shows the locations of the monitoring bores constructed within the alluvial sediments. There is now up to four years of baseline water level data available for the Project. Appendix C contains water level hydrographs for the alluvial monitoring bores, as well water level data for the bores installed in the other geological units (a number of bores have only a single measurement of water level and therefore time trends cannot be plotted). Data collected prior to 2015 was presented within the EIS, but is reproduced along with new data collected since 2015. The water level records for each bore are plotted with the cumulative rainfall departure (CRD) using data from Wollar (Barrigan Street) recording station (Bureau of Meteorology Station Number 062032). A rising trend in the CRD indicates above average rainfall, whilst a declining trend occurs when rainfall is consistently below average. The CRD for the monitoring period indicates above average rainfall at the commencement of monitoring in late 2011/early 2012, followed by generally below average rainfall over much of the baseline monitoring. Some above average spikes in rainfall have occurred in the summer months, but overall the trend indicates a rainfall deficit in the Project Boundary during the monitoring period.

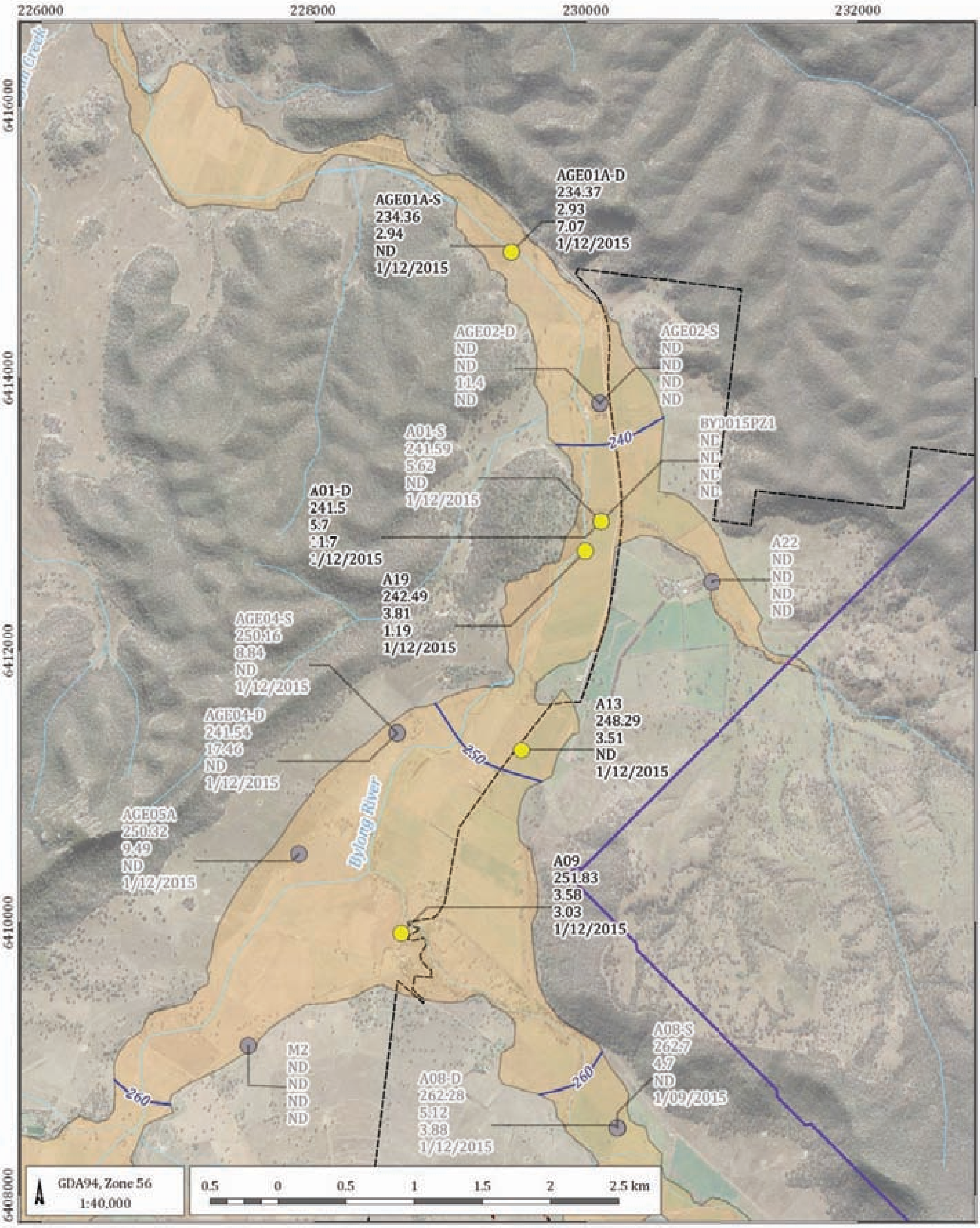
Measured groundwater levels within the alluvium correlate well with the CRD, with an observed general decline in groundwater levels over the baseline monitoring period of between 1.5 m and 3 m. This decline has likely occurred due to slow drainage of groundwater from the alluvium in response to low rainfall recharge, and potentially due to increased demand from irrigators. Section 4.2.4 discusses the estimated recharge rates over the baseline monitoring period.

The most recent groundwater monitoring, from December 2015, has been used to develop the requested contour maps inferring the water table elevation in the alluvium of the Project Boundary. Figure 8 and Figure 9 show the inferred water table at a local scale in the northern and southern portions of the Project Boundary respectively. The same water level data has been used to plot depth to the water table from ground surface and the saturated thickness of the alluvium. In some cases, December values were not available, or were considered erroneous, and so the last recorded data point was used or in some instances none at all.

The water table elevation maps (Figure 8 and Figure 9) for the alluvium shows an inferred hydraulic gradient that broadly matches the northerly direction of surface water flow through the channel system. This fits with a conceptual understanding of the river and creek system being a surface expression of the water table in general, with localised and temporal transitions between gaining and losing conditions. The direction of groundwater flow is towards the Goulburn River, which is considered the principal discharge point for water in the alluvium. The contours indicate a moderate hydraulic gradient (~1:100) through the centre of the Project Boundary that aligns with the local topography.

Figure 8 and Figure 9 show the depth to the water table at each alluvial monitoring bore which ranges from 3 m to 5 m below surface in December 2015. As discussed above, hydrographs of the alluvium monitoring bores show this to be deeper than when monitoring first commenced due to below average rainfall.

Figure 8 and Figure 9 also show the saturated thickness of the alluvial aquifer at each monitoring bore site (where available). For an unconfined aquifer the saturated thickness is the distance between the base of the aquifer and the water table surface. This map relies on the identification of geologic boundaries using borehole logs and includes an element of subjectivity. Because the water table surface data is used, corresponding caution has been taken where December 2015 values for water level were not available or were suspect. The figures show a highly variable saturated thickness at the monitoring bores ranging from 2 m to 12 m depending on location. This variability occurs because not all the bores are installed within the thickest part of the alluvial aquifer. This means bores installed closer to the edge of the alluvium or where it thins due to the subsurface features such as buried rock bars will record less saturated thickness than other monitoring bore sites installed within deeper parts of the alluvial channel.



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Groundwater level contour (mRL)
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Quaternary alluvium
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Saturated thickness
5. Date of measurement

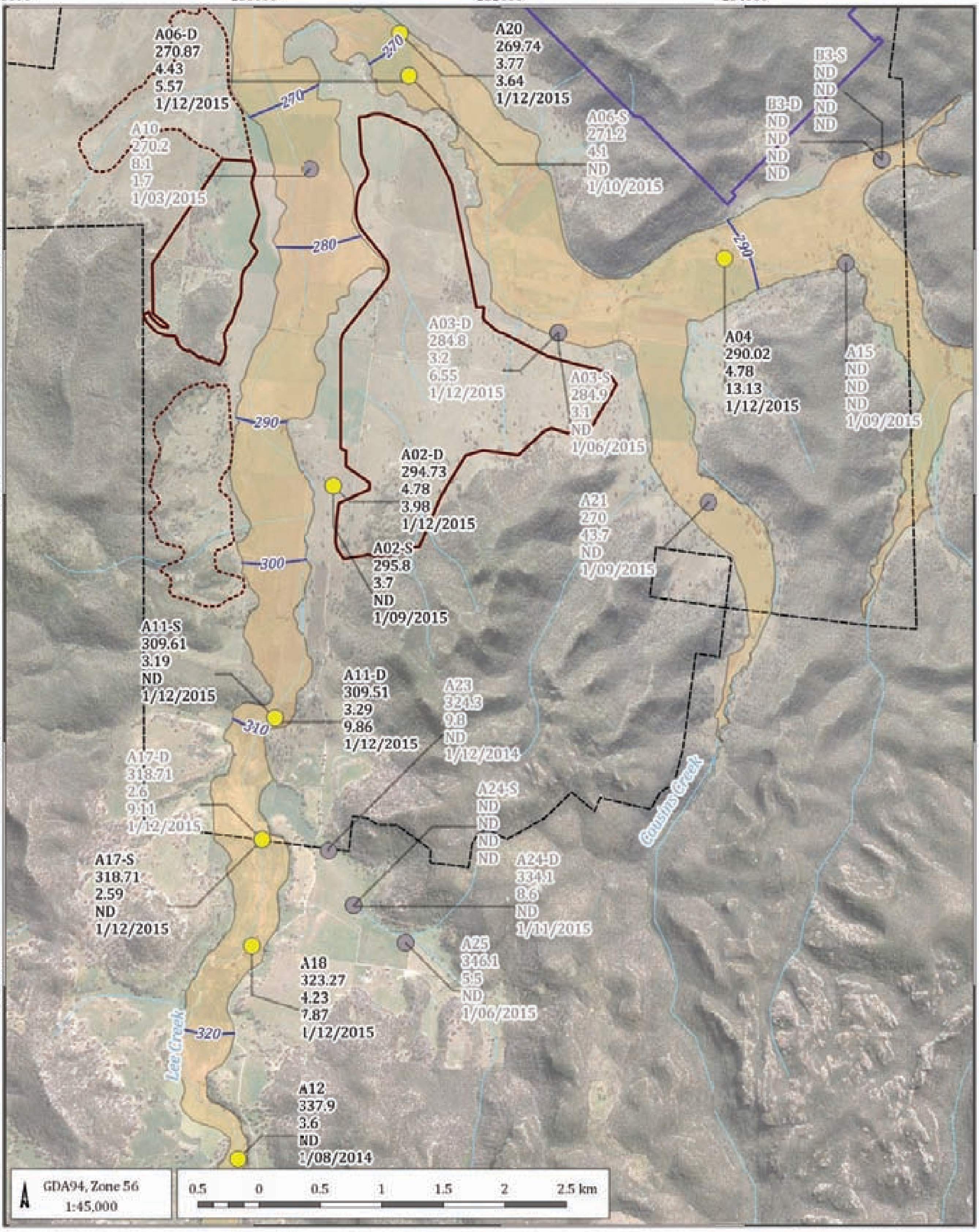
ND = no data

Bylong Coal Project (G1606E)

Water table within Quaternary alluvium - north - December 2015

DATE
1/3/2016

FIGURE No:
8



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Groundwater level contour (mRL)
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Quaternary alluvium
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Saturated thickness
5. Date of measurement

ND = no data

Bylong Coal Project (G1606E)

Water table within Quaternary alluvium - south - December 2015

DATE 1/3/2016

FIGURE No: 9

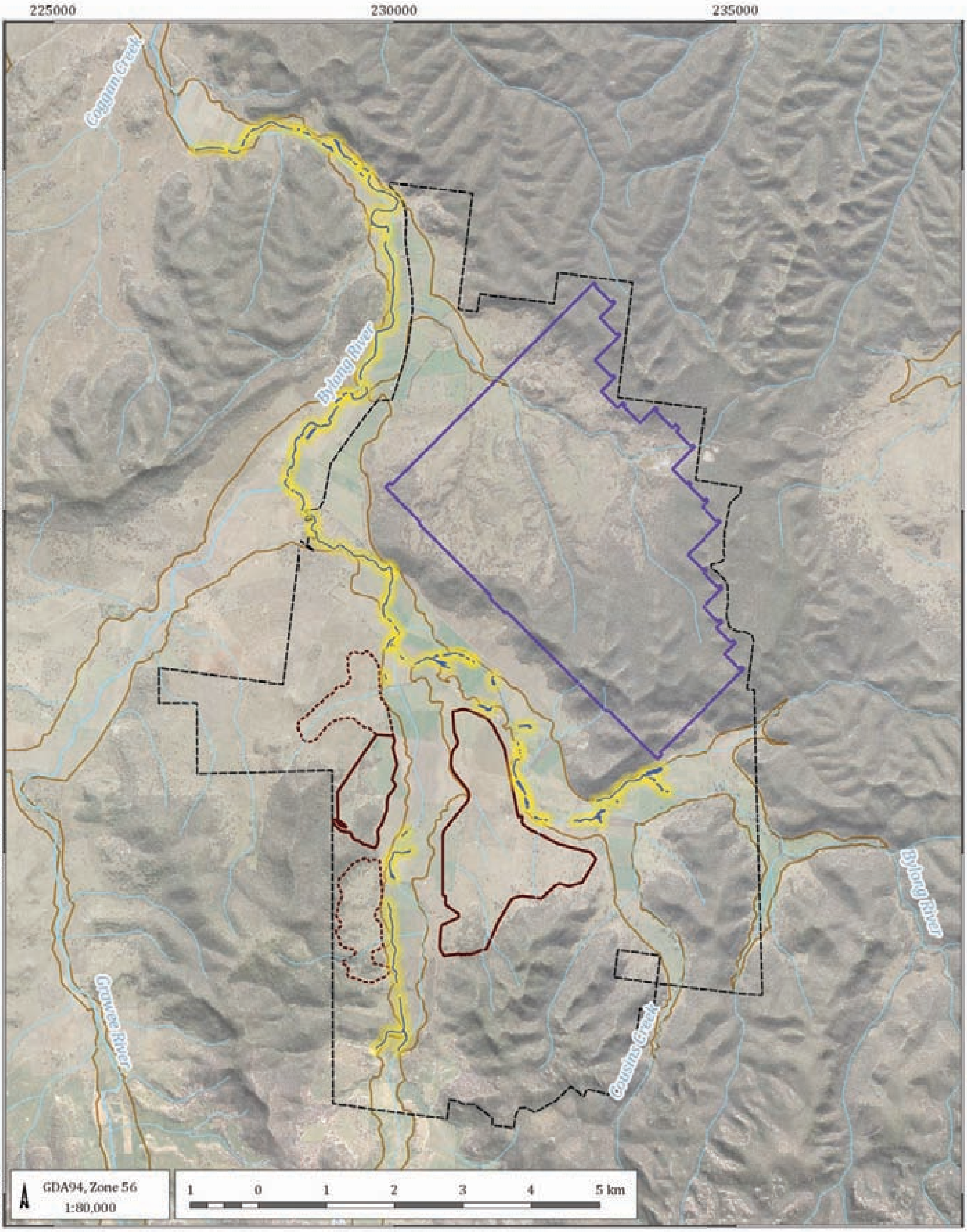
4.2.3 Connectivity with surface water

Some of the stakeholder submissions raised concerns about the nature of the connectivity between the surface water features in the Project Boundary and the water table. These concerns were primarily focussed on the potential for increased groundwater abstraction to lead to a declining water table that could affect flows in the creeks and rivers.

KEPCO commenced groundwater monitoring in 2011 following a prolonged period of above average rainfall that broke the 'Millennium drought'. At this time sustained rainfall had raised groundwater levels above the bed of the Bylong River and Lee Creek, resulting in a continuous flow of groundwater from the alluvial aquifer into the streams (i.e. baseflow). Figure 10 shows the areas where surface water could be identified in satellite imagery in September 2012 following the period of above average rainfall. It shows that the areas where the streams contain water and flow are separated by areas where no surface water is evident. This indicates the baseflow in the streams re-enters the groundwater system flowing underground, before emerging further downstream. This is evident at the site where streams are not clearly seen in the landscape.

Figure 11 shows where surface water could be identified in satellite imagery in February 2014, and indicates a significant reduction in the presence of water along the alignment of the streams. As discussed in Section 4.2.2, groundwater levels within the alluvium have generally fallen between 1.5 m and 3 m over the baseline monitoring period to December 2015. This has resulted in groundwater levels falling below the bed of the streams in many areas at both the Bylong River and Lee Creek as these systems are not deeply incised below the land surface along much of the flood plain. Therefore, during extended periods of below average rainfall, the streams form a chain of ponds along the drainage alignment which are windows to the water table, but with no continuous baseflow. During these periods, groundwater does continue to flow underground through the alluvium along the alignment of the water courses.

Section 5.2.2 describes adjustments made to the model represented to allow the water table to fall below the bed of the streams. It also includes modelled changes to surface water as a result of pumping from the proposed mine-supply borefield.



LEGEND

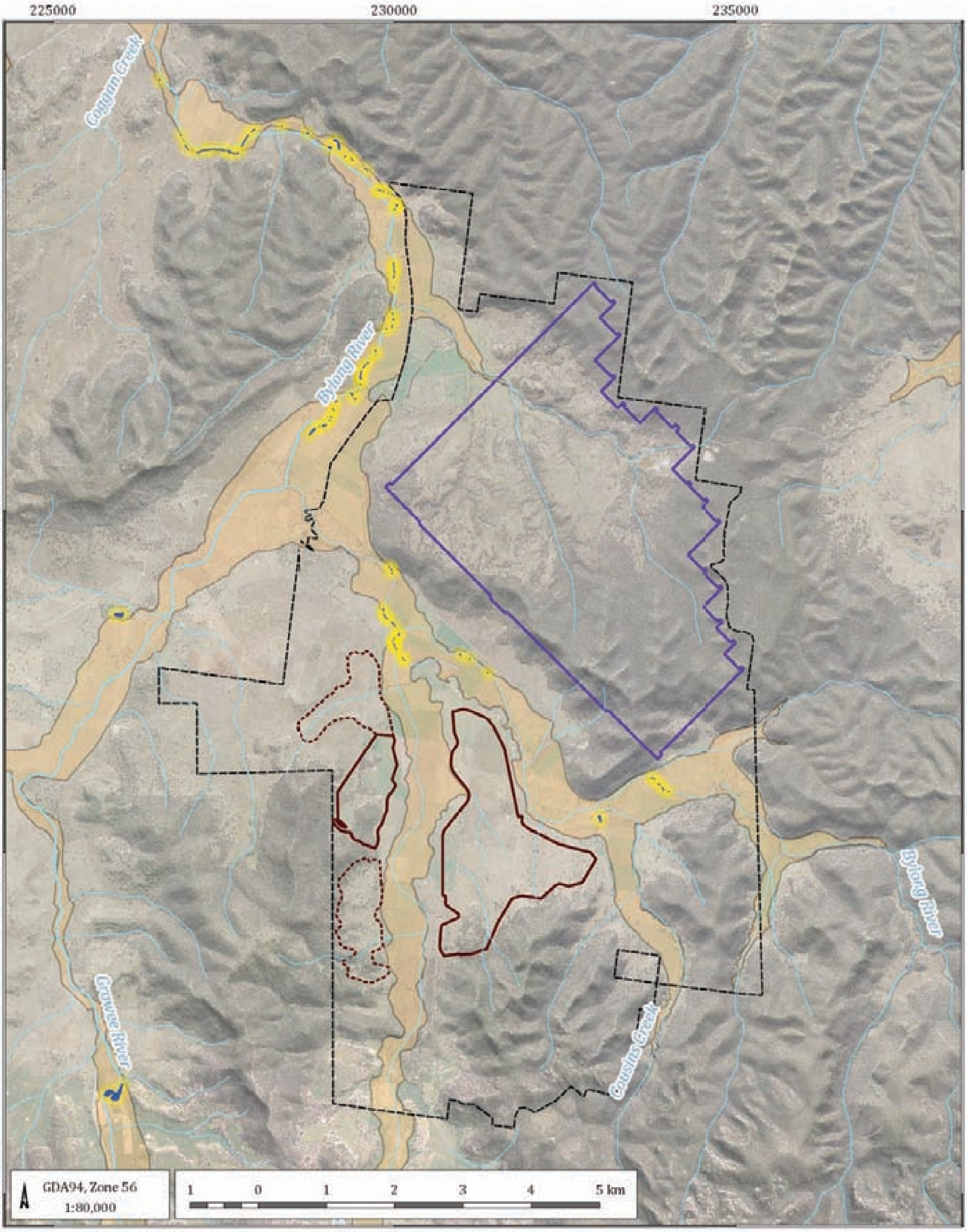
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Project Boundary
- Quaternary alluvium
- Surface water identified in aerial imagery September 2012
- Major drainage
- Minor drainage

Bylong Coal Project (G1606E)

Surface water - September 2012

DATE 1/3/2016

FIGURE No: **10**



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Project Boundary
- Quaternary alluvium
- Surface water identified in aerial imagery February 2014
- Major drainage
- Minor drainage

Bylong Coal Project (G1606E)

Surface water - February 2014

DATE 1/3/2016

FIGURE No: 11

4.2.4 Recharge

Stakeholders expressed concern that during periods of drought when recharge was low and the water demand from the Project is high, the extraction from the borefield might deplete the alluvial groundwater recourses. Information on recharge zones/areas for individual aquifers and how rainfall recharge was estimated was also requested.

Recharge to the alluvial groundwater system can be characterised as having two principal sources: direct rainfall recharge through the soil zone to the water table, and infiltration of surface water through streambeds. Stream leakage is only significant when the ephemeral rivers and creeks are flowing and surface water levels are higher than groundwater levels.

Rainfall recharge through the soil zone and unsaturated zone of the alluvial aquifer only occurs when soil moisture deficits are overcome sufficiently to allow drainage. In other words, the initial infiltrating rainfall must first saturate the ground before water will drain to the water table. Once the unsaturated profile has been sufficiently wet, its ability to hold water is exceeded and further infiltration will move under gravity – quickly through larger pores and more slowly through smaller ones, down to the water table. The upper limit to how much water a soil can hold is its field capacity. Field capacity is related to the soil's texture, with sand having a low value and clay having a high one. Fetter (1994) presents field capacity data as typically being in the range 10% to 40%.

During gentle rain, water is able to infiltrate the soil as rapidly as it falls, with no accumulation at the surface. However, with increased rainfall intensity the infiltration capacity may be exceeded, causing water to pond at the surface and lead to run-off.

As outlined in the EIS Groundwater Impact Assessment, a simple soil moisture balance was developed to estimate when recharge occurs and the approximate rate of recharge to the shallow groundwater system. The soil moisture balance was updated using rainfall and evapotranspiration for the Project Boundary from the SILO data source using the method described within Section 7.4 of the Groundwater Impact Assessment. The soil moisture balance assumed 35mm/day to reach field capacity and a maximum daily recharge rate of 25mm/day.

A soil moisture probe was installed in the Project Boundary as part of the additional monitoring phase. Data from the probe was compared against the results of the spreadsheet model where both datasets overlapped to validate the spreadsheet method. Figure 12 shows a modelled 'spike' in recharge (red curve) corresponding to a rise in water levels at two monitoring points as well as a clear increase in soil moisture, indicating field capacity was reached at the same time. This indicates the spreadsheet method for estimating when recharge events occur is valid.

Attempts to estimate fluxes of water through the stream beds were made during the EIS utilising seepage meters installed within the bed of the Bylong River. Due to the low rainfall conditions there have been no significant flow events within the Bylong River and therefore no opportunity for further estimates of stream bed recharge.

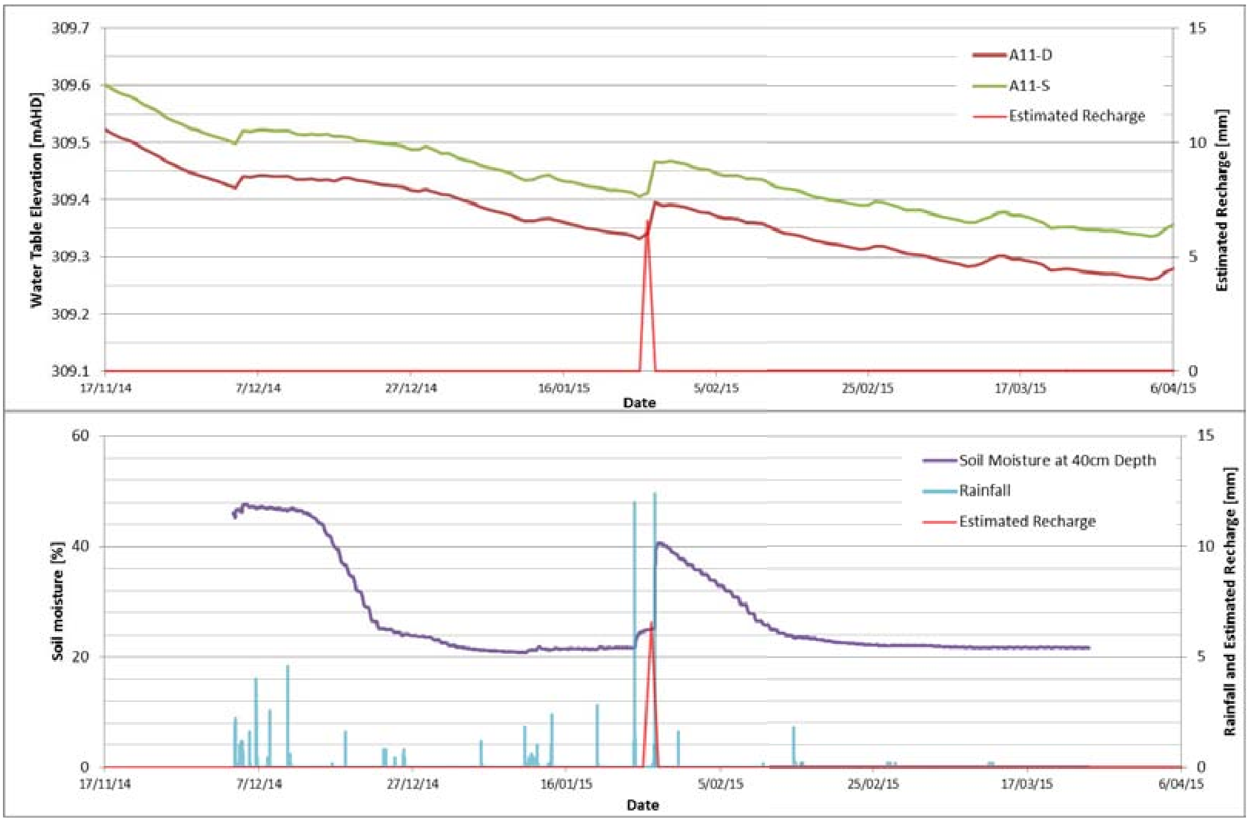


Figure 12 Modelled effective recharge vs water level and soil moisture readings

4.2.5 Hydraulic Conductivity

As discussed above, the ability to sustainably extract groundwater from the alluvial aquifer depends on the hydraulic conductivity, storage properties and recharge rates. Submissions on the EIS commented that pumping tests would be useful to estimate hydraulic properties in a wider zone around each borehole.

The EIS described the hydraulic properties of the alluvial aquifer using data collected by Douglas Partners during the baseline monitoring period. Hydraulic properties of the alluvium were assessed by undertaking rising head tests within the installed standpipe piezometers. Twenty three values for horizontal hydraulic conductivity were successfully obtained for the various lithology types making up the alluvium. Falling/rising head tests provide a useful indication of a formation's hydraulic character, but are limited to the localised area that is stressed as part of the test.

WorleyParsons (2015) carried out additional hydrogeological assessments, which included conducting constant-rate pumping tests on four pre-existing farm supply bores. The tests provide further information on the range of hydraulic conductivity values present in the alluvium. By increasing the duration and magnitude of the stress applied to the aquifer unit the results provide increased confidence in the range of hydraulic conductivity values that may be present.

Figure 13 presents the hydraulic conductivity range recorded within the alluvium as a box and whisker plot. The farm supply bores included in the pumping tests undertaken by WorleyParsons use the prefix PB (PB-1, PB-3, PB-4 and PB-6). The monitoring bores have an 'A0' prefix. The extent of the 'box' shows the 25th and 75th percentiles, with the 'whiskers' showing the minimum and maximum values. The chart uses a logarithmic axis to account for the range in values, which is characteristic of alluvium and its heterogeneous grainsize.

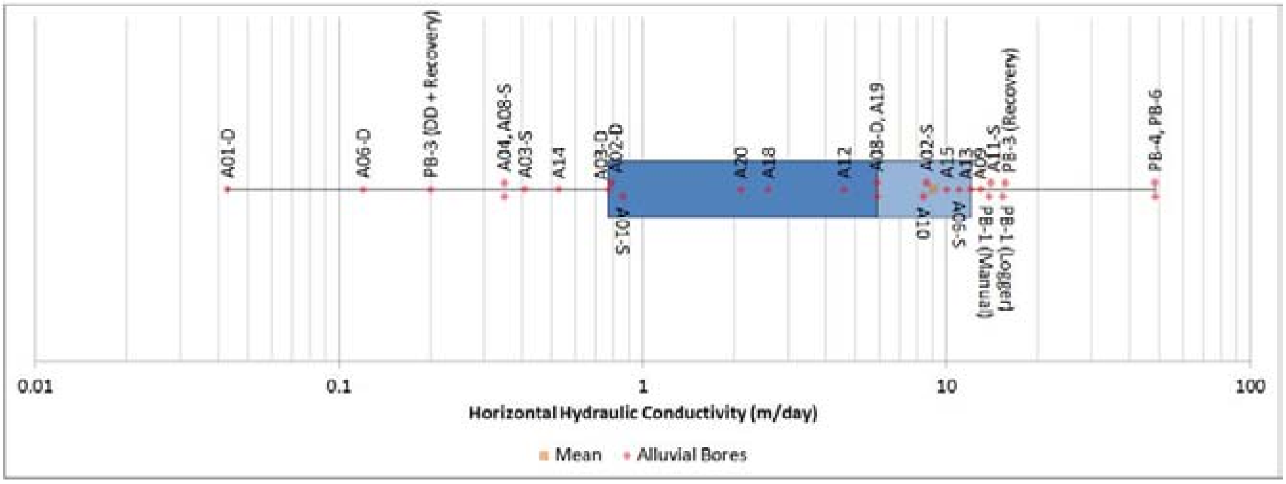


Figure 13 Box and whisker plot showing measured hydraulic conductivity range for alluvium

The figure shows a minimum hydraulic conductivity value of 0.043 m/d (A01-D) and a maximum of 48.6 m/d (PB-4 and PB-6). The chart shows the pumping test data typically return a relatively high value of hydraulic conductivity compared to the falling head tests, with all values above 10 m/d. This indicates that the falling head test results presented in the EIS, and used in the numerical model, may underestimate the permeability of the alluvium. The difference could also relate to pumping bores being located within the more transmissive zones of the alluvium that have been discovered during drilling to maximise water supply.

The flow equations used in the pumping test analyses require a value of thickness for the aquifer. In all cases WorleyParsons assumed an average alluvial aquifer thickness of 15 m, based on historic observations. However, in the report it is recognised that the saturated thickness of the alluvium is variable and that during the testing it was typically less than 5 m. This means that in deriving the horizontal hydraulic conductivity values they may have been underestimated.

A hydrogeological investigation for the now cancelled Mt Penny Project was also made available during the response to submissions period. The hydrogeological investigation conducted by RPS Aquaterra (2012) presented the results of pumping tests conducted on five farm wells within the lower Bylong River alluvium. The testing indicated yields of between 1 L/sec and 15 L/sec with transmissivity values calculated as ranging from 470 m^2/day and 960 m^2/day. Similar to the work done by WorleyParsons, RPS were not able to obtain the saturated thickness from the farm wells. However if a saturated thickness of 5 m is assumed then the hydraulic conductivity is very high ranging from 94 m/day to 192 m/day.

Section 5.4 describes additional modelling undertaken to address stakeholder concerns which makes use of the measured hydraulic conductivity range.

4.3 Tertiary basalt groundwater system

4.3.1 Water levels

A stakeholder requested further information on groundwater levels within the formations overlying the Coggan and Ulan Coal seams and justification for the conclusion that strata is not fully saturated up to the base of the perched Tertiary basalt aquifer. Information on the thickness of the saturated and unsaturated zones was also requested.

The groundwater monitoring network includes a monitoring bore (BY0091-B) that is screened within the Tertiary basalt layer that overlies the proposed underground extraction area. A monitoring bore in sandstone underlying the basalt and a vibrating wire piezometer array are also installed at site BY0091. The monitoring at this site includes:

- Monitoring bores screened in:
  - Tertiary basalt at 23 m deep (BY0091-B); and
  - State Mine Formation at 36 m deep (BY0091-S).
- Vibrating wire piezometers in:
  - State Mine Formation sandstone at 57 m deep;
  - Glen Davis Formation sandstone at 103 m deep;
  - Coggan coal seam at 172 m deep; and
  - Marrangaroo sandstone at 178 m deep.

Figure 14 shows the water level and pore pressure elevations recorded through the profile at this site.

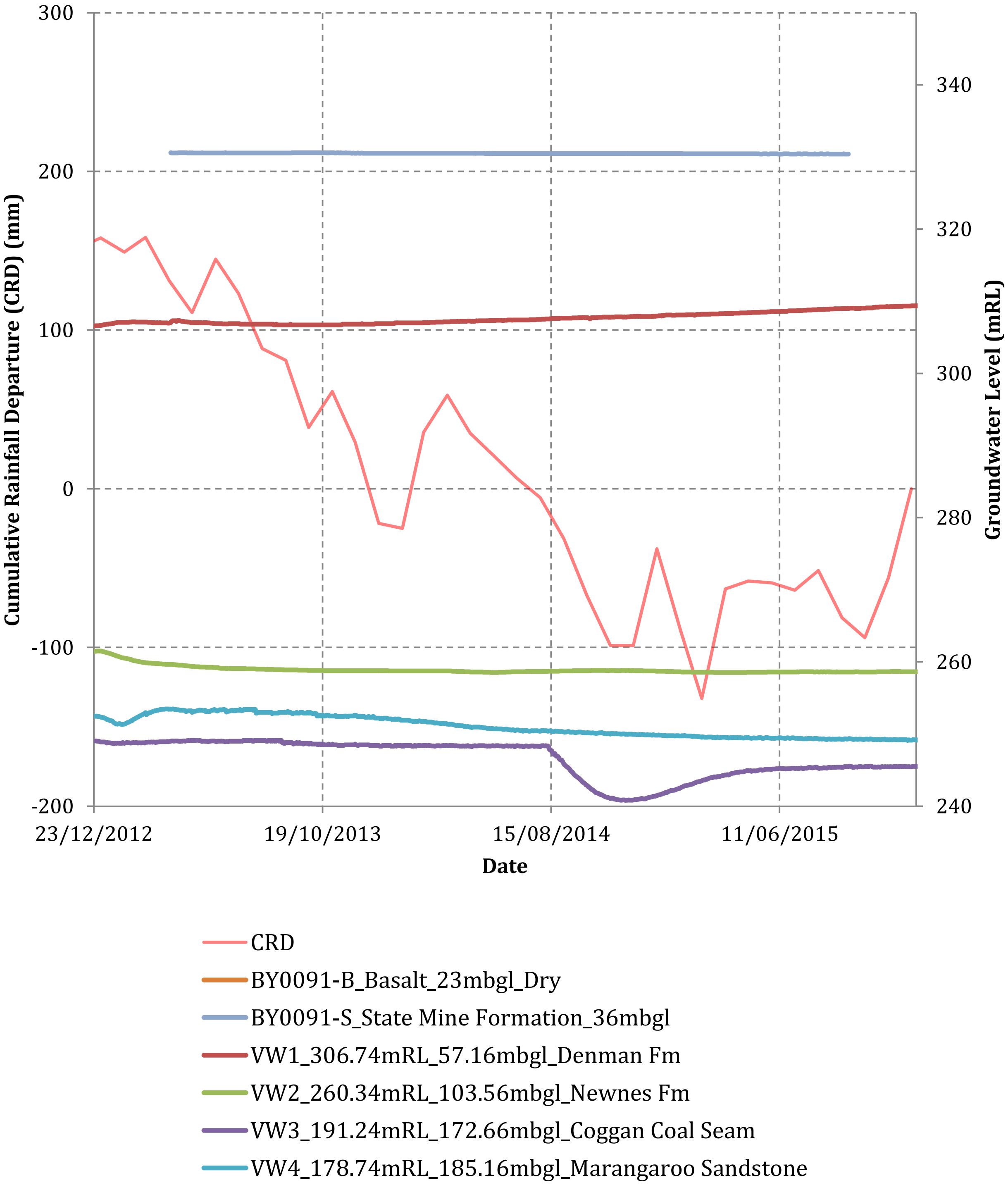


Figure 14 Pore pressure elevation recorded by vibrating wire piezometer at BY00091

The data was further examined to determine the level of saturation in Permian formations underlying the basalt. Following investigations of the basalt monitoring bore the basalt was found to be dry in this area. The deeper bore BY0091-S recorded a valid water level indicating, whilst the basalt appears dry in this area it would be saturated in areas where the base of the basalt flow is above 328 m RL. The underlying sandstone of the State Mine Formation also appears to form as perched aquifer system in this area, and may be fed from enhanced recharge and seepage through the basalt.

Figure 14 also shows the recorded pressure in the sandstone of the State Mine Formation is some 60 m higher than the VWP sensor within the Newness Formation. Examination of data from the Newness Formation VWP indicates it does not record a positive pressure and the formation therefore appears dry at this point, which is 103.7 m below ground level (260.3 mRL). The large reduction in pressure suggests the groundwater within the shallow basalt/sandstone is saturated but becomes only partially saturated below the State Mine Formation.

For this to occur, there would need to be some loss of groundwater, potentially due to sideways lateral movement and discharge, potentially as slow seeps into the weathered zone , at the side of the hills or into the shallow strata under Dry Creek. Alternatively rapid flow of groundwater to underlying formations would be required, but this is unlikely as permeability is higher horizontally than vertically within the sedimentary strata.

Stakeholders commented that due to uncertainty with the current hydrogeological conceptual model, future drilling and construction of a limited and reasonable number of monitoring bores into sandstones may be required should a data gap be recognised (Farmers Creek Formation, the Gap Sandstone, Watts Sandstone or other aquifers). It is agreed as raised within stakeholders submissions, that additional monitoring bores would be required to fully define the saturated and unsaturated units within the basalt area. These bores would target potentially deeper and thicker zones within the basalt where there is potential for groundwater to occur. The floor of the basalt appears to generally conform with the topography and therefore the highest potential for statured zones is likely to be in topographically lower lying areas. Section 7.2.5 outlines a methodology for installation of additional bores to be documented within the Water Management Plan.

4.3.2 Recharge

Recharge to the basalt occurs via seepage of rainfall through the soil profile when it is sufficiently saturated from rainfall events to allow deep drainage. As the basalt is a perched system with no other direct connectivity to other aquifers, rainfall is the only source of recharge. Recharge will vary depending on soil properties and topography.

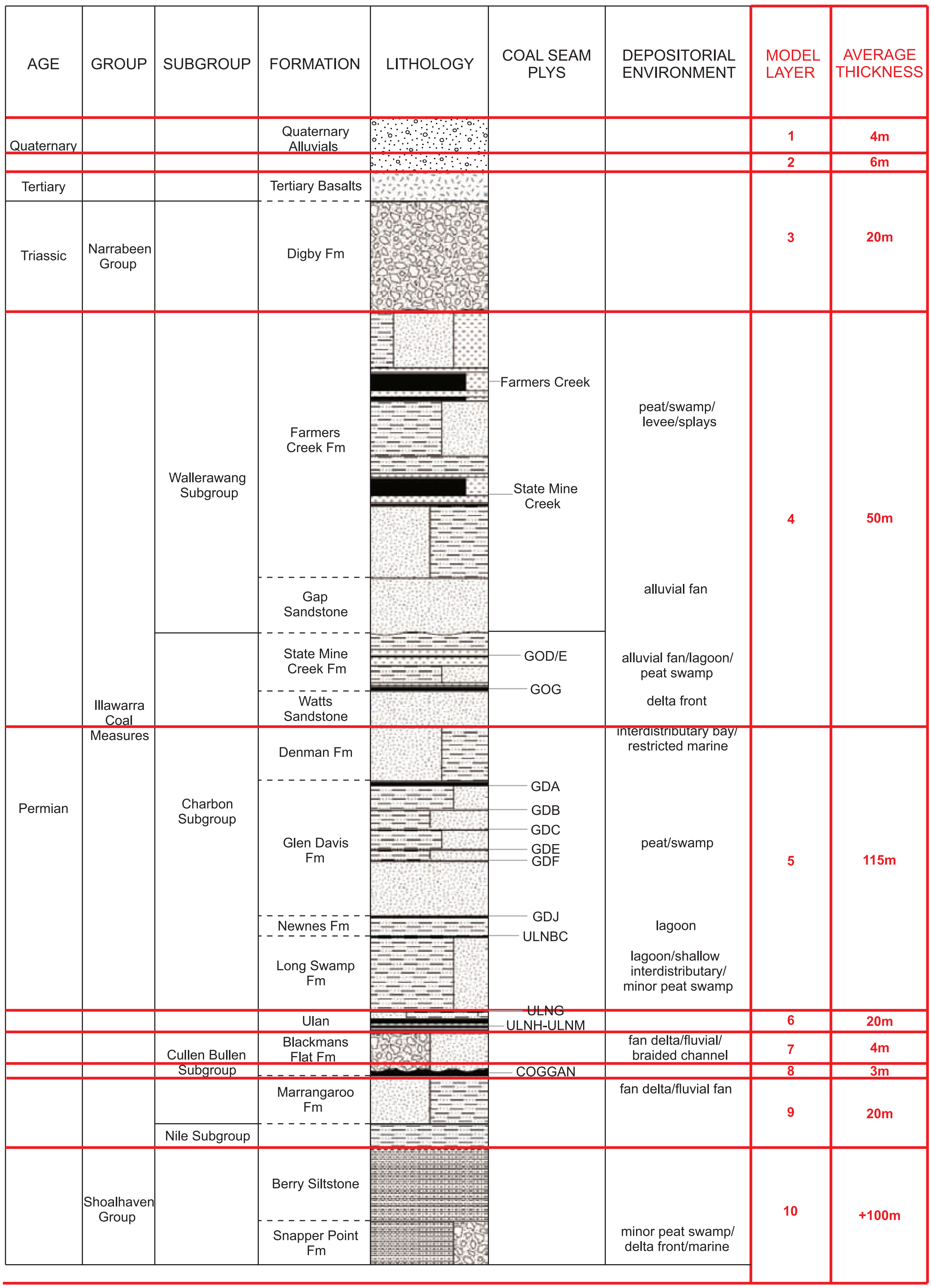
4.4 Triassic and Permian groundwater systems

Stakeholders requested additional information on groundwater systems within the Triassic and Permian bedrock units, particularly the formations overlying the coal seams. Some stakeholders also queried the ratio of hydraulic conductivity and specific storage adopted for the modelling. The sections below provide further information on the hydrostratigraphic units within the Permian, including hydraulic properties, zone of weathering, water levels, flow directions and preferential recharge zones where the coal seams contact the alluvium.

4.4.1 Hydrostratigraphic units

Figure 1 provided previously shows graphically the main stratigraphic units occurring within the Project Boundary. As described in Section 3 the Permian geology beneath the Project Boundary is subdivided into numerous groups, subgroups and formations. Groundwater investigations require a conceptual model to represent the key processes in the groundwater regime with a simplified representation of numerous geological layers into the categories of aquifers and aquitards. For the purposes of the numerical modelling in the EIS Groundwater Impact Assessment, the various geological units were lumped according to their role in the groundwater regime. Figure 15 shows the stratigraphic column and formations lumped together as layers within uniform properties within the model.

The model represented the discontinuous layers Tertiary basalts and Triassic intrusives to the east of the proposed mining area, and coal seam sills as zones within model layers, not as separate layers. Layer 10 represented all formations between the base of the Marrangaroo Formation and the top of the Carboniferous volcanic basement.



Stratigraphic column and model layers

Adapted from information provided by Anthony Leone, Worley Parsons, 2016

Figure 15

Bylong Coal Project (G1606)

As discussed above, the groundwater regime in the coal measures has been represented by combining geological units to create hydrostratigraphic units. This required lumping of the formations overlying the coal seams targeted for mining to create relatively thick layers with uniform properties. The approach was based on the results of hydraulic testing that indicated a generally lower hydraulic conductivity within the non-coal units (sandstones, siltstones, claystones and interbedded combinations) compared to the thicker coal seams proposed to be targeted for mining. Figure 16 and Figure 17 show the distribution of horizontal hydraulic conductivity measurements for the coal and non-coal units. It shows the typically wide range in hydraulic conductivity that is common for porous and fractured rocks, but a median hydraulic conductivity of some 60 to 70 times lower in the non-coal units compared with the coal. Figure 17 shows no clear trends in the hydraulic conductivity of the overlying non-coal formations.

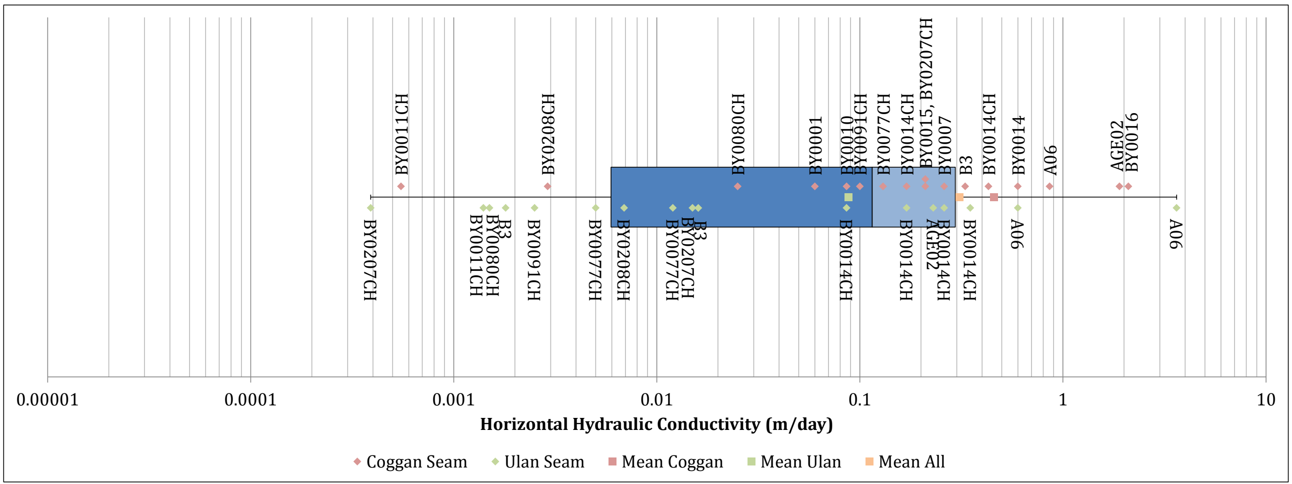


Figure 16 Horizontal hydraulic conductivity of Coggan and Ulan Coal Seams

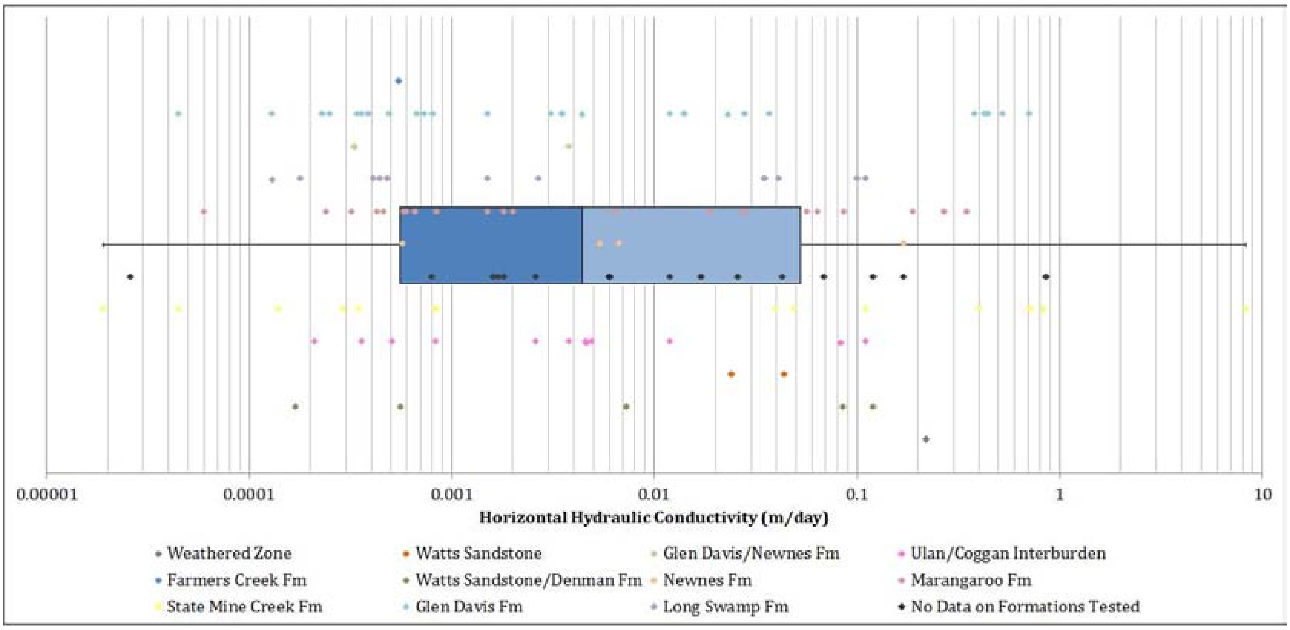


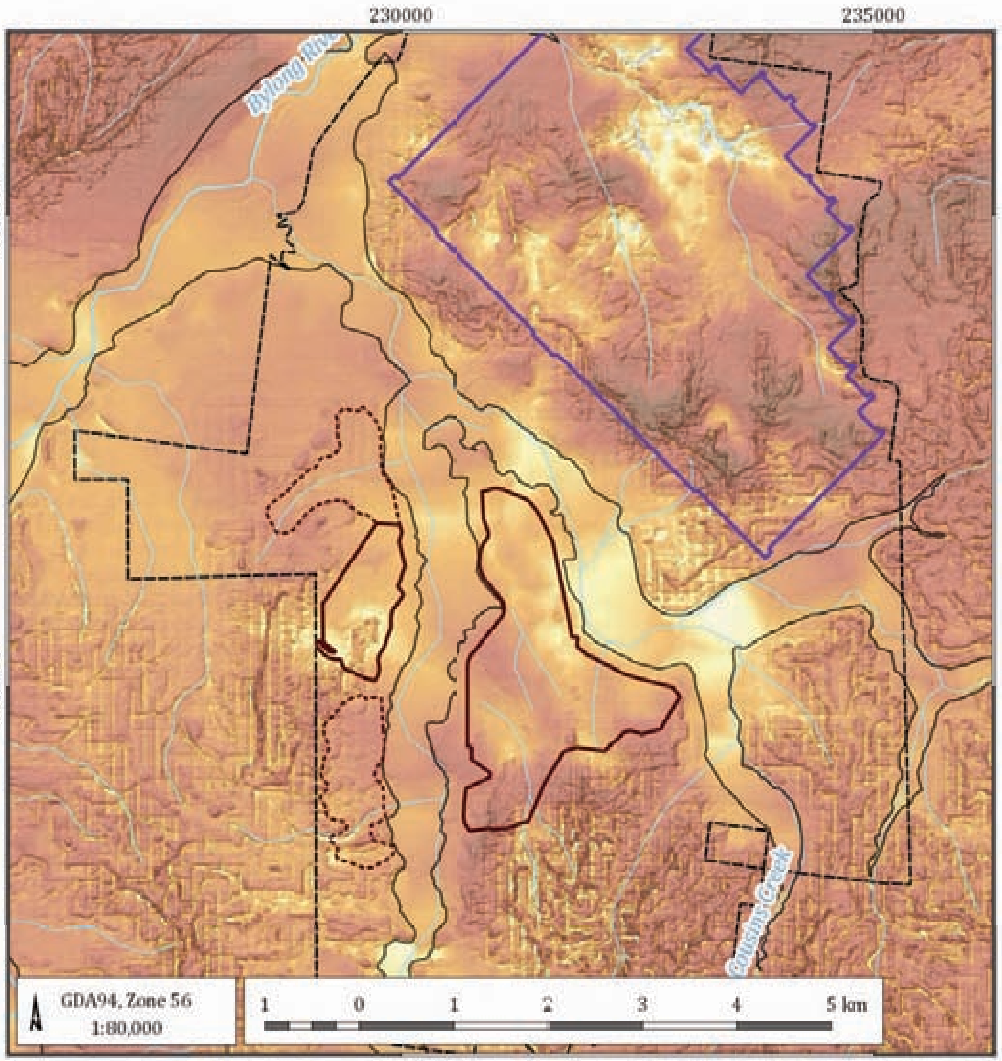
Figure 17 Horizontal hydraulic conductivity of non-coal Triassic / Permian lithological units

Stakeholders also requested more detail on the hydraulic properties of the weathered zone and a map indicating the thickness of the unit. Figure 17 above shows the hydraulic conductivity values measured within weathered rock units, indicating a wide range from between 0.0001 m/day and 1 m/day. Figure 18 shows the thickness of the weathered zone represented within the numerical model developed for the EIS. Figure 18 also shows analysis from CSIRO (2015) estimating the thickness of regolith material from remote sensing analysis. Regolith is a layer of loose, heterogeneous superficial material covering solid rock.

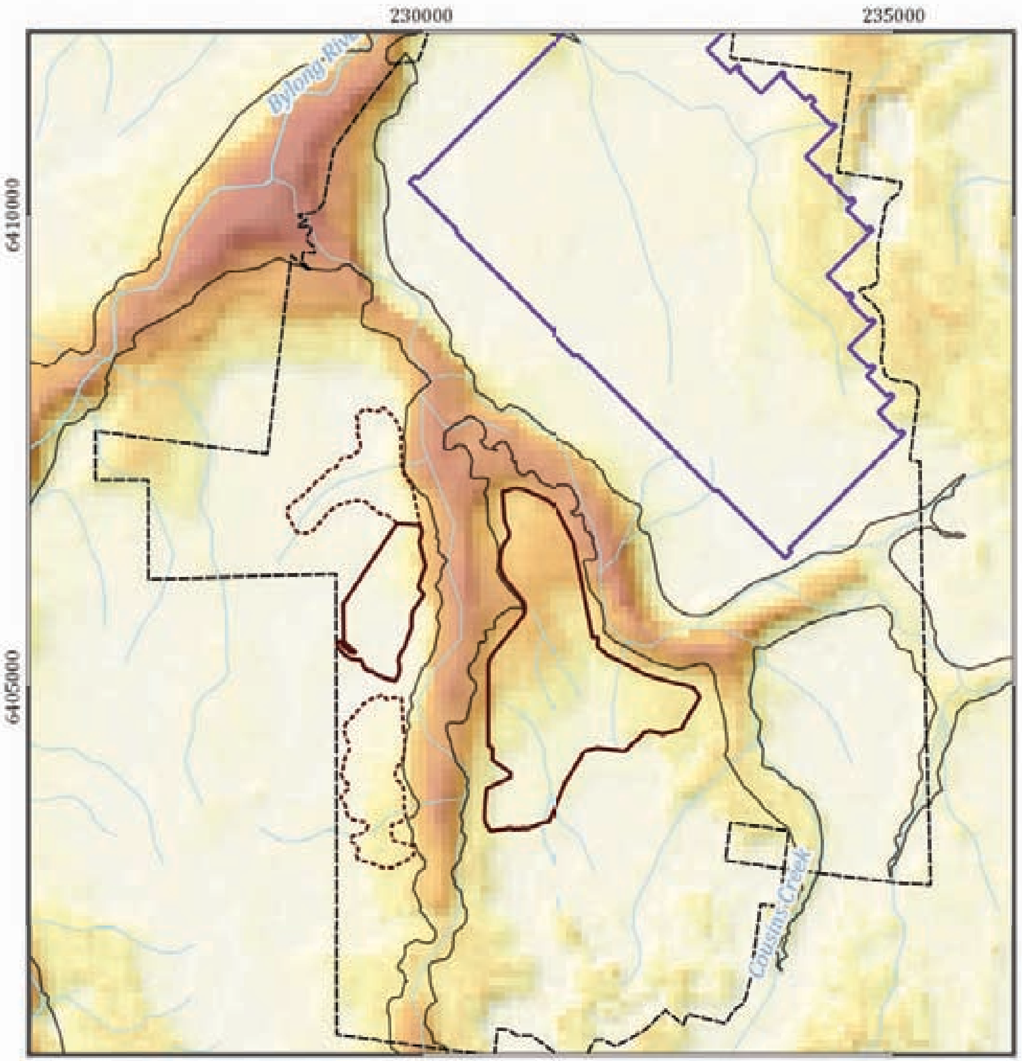
The available data indicates hydraulic properties of the weathered zone vary considerably. Given the natural variability that occurs within the weathered zone, it was important in the EIS to adopt conservative hydraulic properties that would ensure the maximum impact was identified. The weathered formations in elevated areas outside the floodplain are largely unsaturated. In contrast, in areas of the lower lying valley floors, the weathered zone rock that is adjacent to and underlies the alluvium is likely to be saturated for most periods of time. This is of particular interest in the region between the proposed open pits and the flood plain where the weathered zone may yield groundwater to the open pits during mining and act as a conduit for flow through from the alluvium. For this reason, the EIS conservatively adopted a horizontal hydraulic conductivity value for the weathered material of 0.2 m/day, at the extreme of the available data to ensure the impacts of connecting the mining and the alluvium through the weathered zone were represented.

The potential for the weathered zone to enhance connectivity with the underground mining areas only occurs in the low lying flood plain areas, as available data from VWPs indicates the thin weathered zone is unsaturated in the elevated areas.

Numerical model weathered zone thickness



CSIRO regolith thickness



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Project Boundary
- Quaternary alluvium
- Major drainage
- Minor drainage

Thickness (m)

- 0
- 5
- 10
- 20
- 50

Bylong Coal Project (G1606E)

Weathered zone thickness

DATE
1/3/2016

FIGURE No:
18

4.4.2 Specific storage

A submission to the EIS suggested the ratio of hydraulic conductivity to specific storage values, referred to as the diffusivity was inappropriate for some of the model layers. They considered diffusivity values should be 2 to 3 orders of magnitude higher in selected layers within the model in order to be consistent with known bulk modulus[1] values of the geology.

To further investigate this comment, the specific storage for each layer in the model was plotted against Youngs Modulus, which was estimated from the Bulk Modulus and Poisson's Ratio. Figure 19 shows the relationship between specific storage and Young's Modulus from the numerical model, and values for alluvium, interburden or coal identified in the literature. The upper and lower bounds of each formation type were calculated by varying Poisson's Ratio (lower bound 0.15 to upper bound 0.3) depicted by the shaded area.

Figure 19 indicates not all values are outside the ranges suggested by literature, however Layer 8 (Coggan coal seam) is slightly above the upper extreme and Layer 3 (colluvium) is lower than the literature range. Adjusting these values by a factor of ten results in the values falling within the typical ranges depicted in Figure 19.

The EIS recognised the uncertainty in geological properties and assessed the sensitivity of the model predictions to changes in the hydraulic conductivity and specific storage values. The specific storage of the alluvium, weathered material and tertiary basalt was adjusted by ± 5 times, with the all other layers changed by ± 1 order of magnitude over the base case. Whilst an order of magnitude reduction in the Coggan coal seam specific storage was assessed during the EIS, the results were influenced by reductions applied to other layers at the same time. Further sensitivity analysis was conducted to determine the influence of reducing the specific storage in the Coggan coal seam, and increasing the specific storage in the colluvium with the results presented in Section 5.4.

[1] Bulk modulus represents the change in volume under hydrostatic pressure

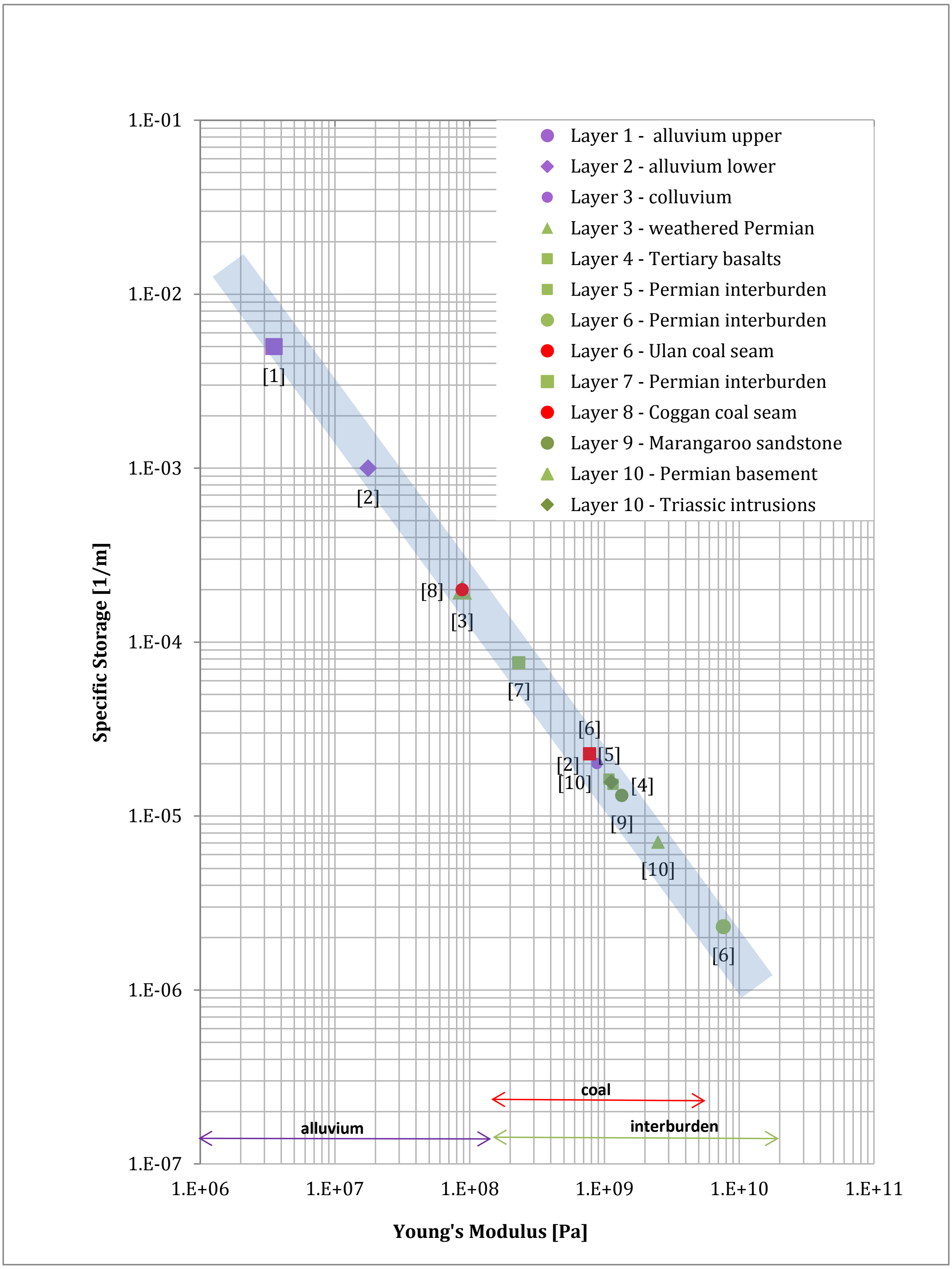


Figure 19 **Specific storage vs. Young's Modulus - Literature ranges and model values**

4.4.3 Water levels

The inferred potentiometric surfaces for each hydrostratigraphic unit are presented in Figure 20 to Figure 25. It should be noted that negative water level measurements indicate artesian pressures within the aquifers, which can occur in the northern part of the Project area within the Marangaroo Formation. Most of the plots show a northerly component to their respective inferred flow regimes. This is consistent with the conceptual understanding of regional groundwater flow presented within the EIS. All plots should be considered as indicative only. This is because where the measuring points are sparse or in clusters, linear interpolation of water levels changes between these points becomes less accurate as distance increases.

The data for the shallowest formation being the Wallerawang Subgroup (Figure 20) shows an apparent groundwater mound associated with the topographic high in the area of proposed underground extraction. The deeper units have a broadly similar groundwater flow system. Water elevations are comparable when considered in light of the bore and VWP constructions. For example, the 270 mRL contour occurs in a similar location for each unit.

The contours suggest some connectivity between the Ulan coal seam, Coggan Coal seam and the Marrangaroo Formation. Observed differences may be artefacts of the available data set and/or due to differences in hydraulic properties and local recharge affecting flows.

Figure 22 to Figure 24 show the outcrop or sub-crop of the respective coal seams. It shows were the coal seams are buried under the Quaternary which is potentially a preferential recharge zone for the coal seam aquifer. Elsewhere the seams are expected to outcrop above the water table where recharge would be from direct rainfall infiltration. Areas where the coal seam outcrop coincides with the break of slope are likely to be areas where runoff accumulates and enhanced recharge can occur to the coal seams.

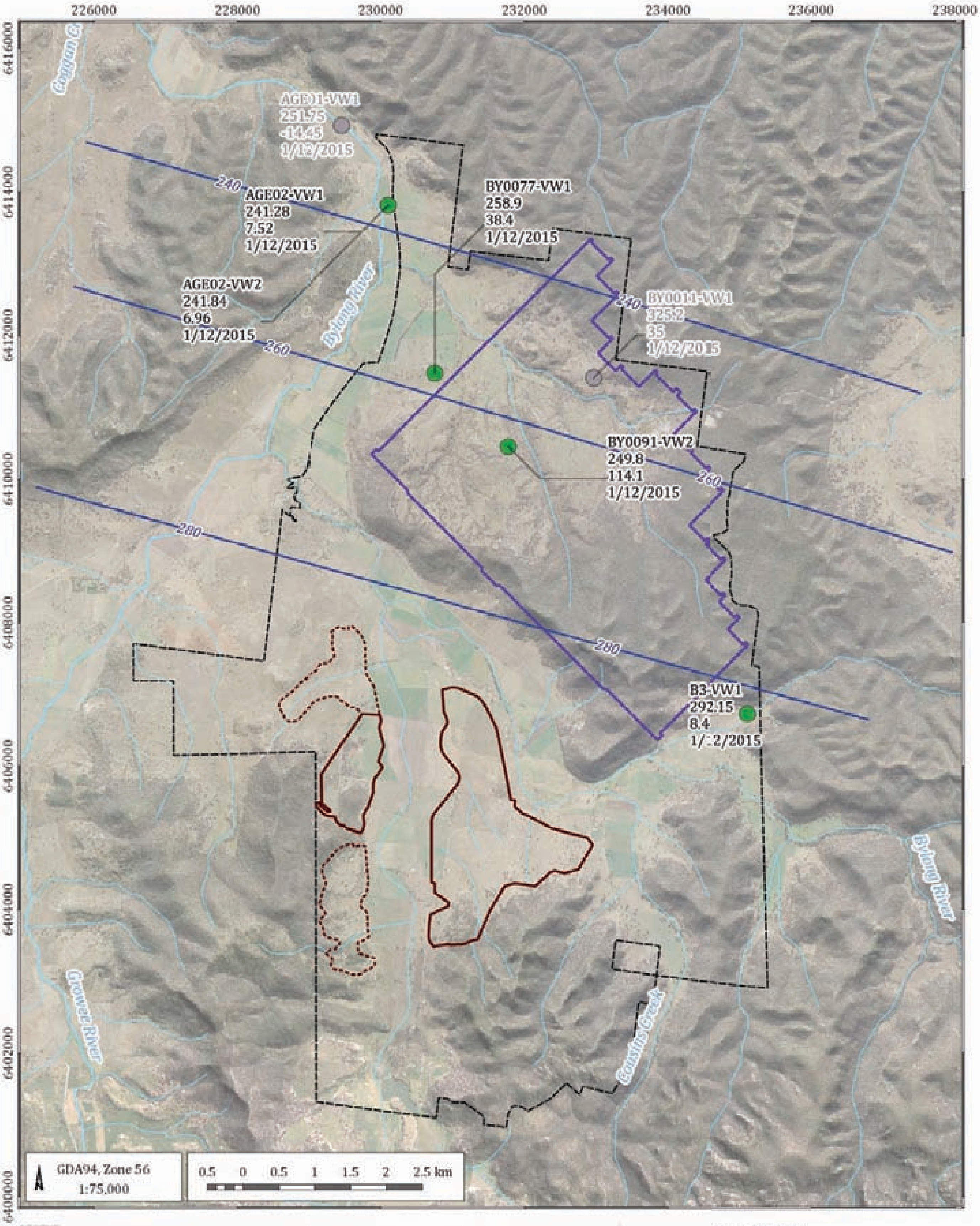
4.4.3 Water levels

The inferred potentiometric surfaces for each hydrostratigraphic unit are presented in Figure 20 to Figure 25. It should be noted that negative water level measurements indicate artesian pressures within the aquifers, which can occur in the northern part of the Project area within the Marrangaroo Formation. Most of the plots show a northerly component to their respective inferred flow regimes. This is consistent with the conceptual understanding of regional groundwater flow presented within the EIS. All plots should be considered as indicative only. This is because where the measuring points are sparse or in clusters, linear interpolation of water levels changes between these points becomes less accurate as distance increases.

The data for the shallowest formation being the Wallerawang Subgroup (Figure 20) shows an apparent groundwater mound associated with the topographic high in the area of proposed underground extraction. The deeper units have a broadly similar groundwater flow system. Water elevations are comparable when considered in light of the bore and VWP constructions. For example, the 270 mRL contour occurs in a similar location for each unit.

The contours suggest some connectivity between the Ulan coal seam, Coggan Coal seam and the Marrangaroo Formation. Observed differences may be artefacts of the available data set and/or due to differences in hydraulic properties and local recharge affecting flows.

Figure 22 to Figure 24 show the outcrop or sub-crop of the respective coal seams. It shows were the coal seams are buried under the Quaternary which is potentially a preferential recharge zone for the coal seam aquifer. Elsewhere the seams are expected to outcrop above the water table where recharge would be from direct rainfall infiltration. Areas where the coal seam outcrop coincides with the break of slope are likely to be areas where runoff accumulates and enhanced recharge can occur to the coal seams.



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Groundwater level contour (mRL)
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Date of measurement

ND = no data

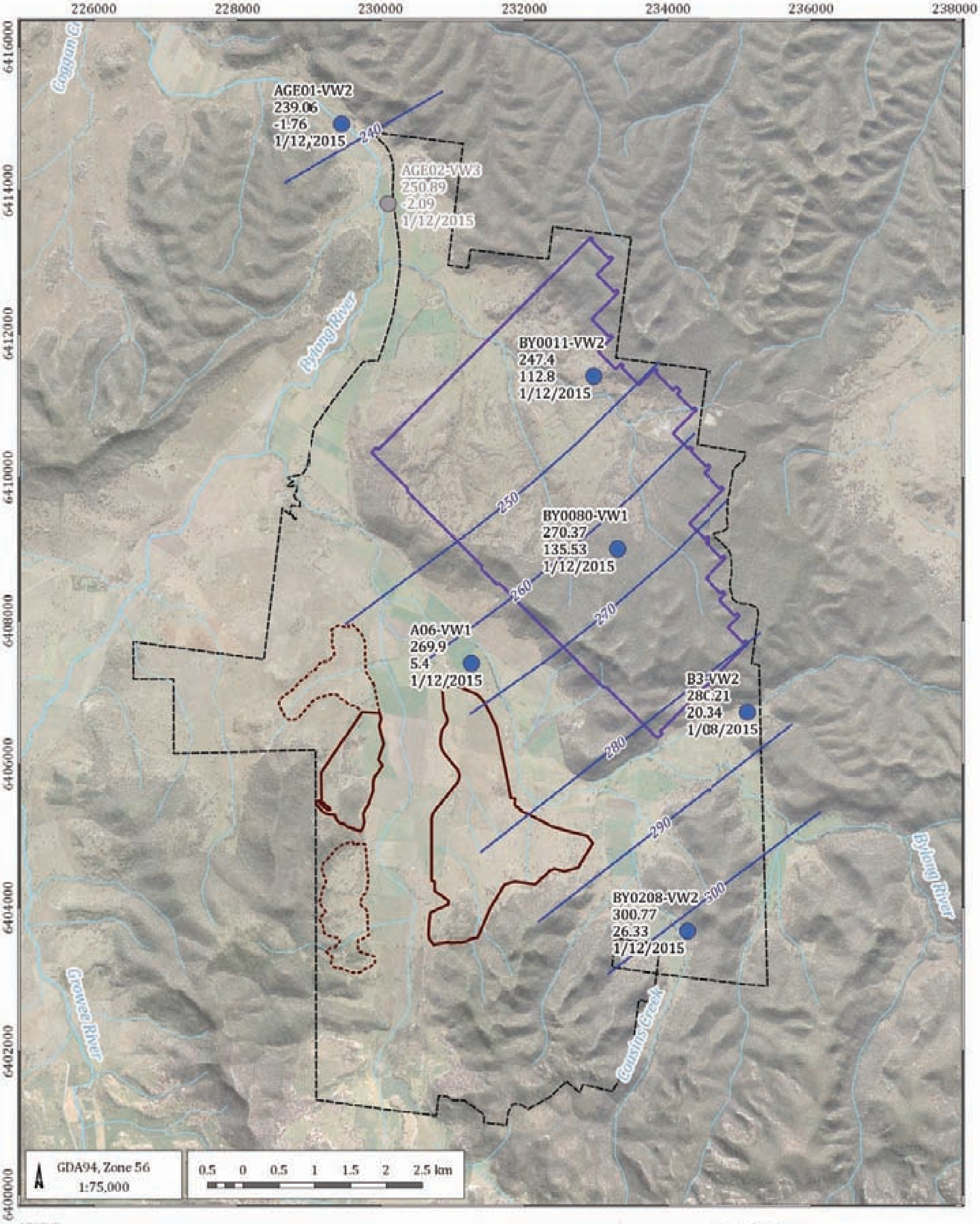
Bylong Coal Project (G1606E)

Wallerawang Subgroup potentiometric surface - December 2015

AGE GROUNDWATER & ENVIRONMENTAL

DATE 1/3/2016

FIGURE No: 20



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Groundwater level contour (mRL)
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Date of measurement

ND = no data

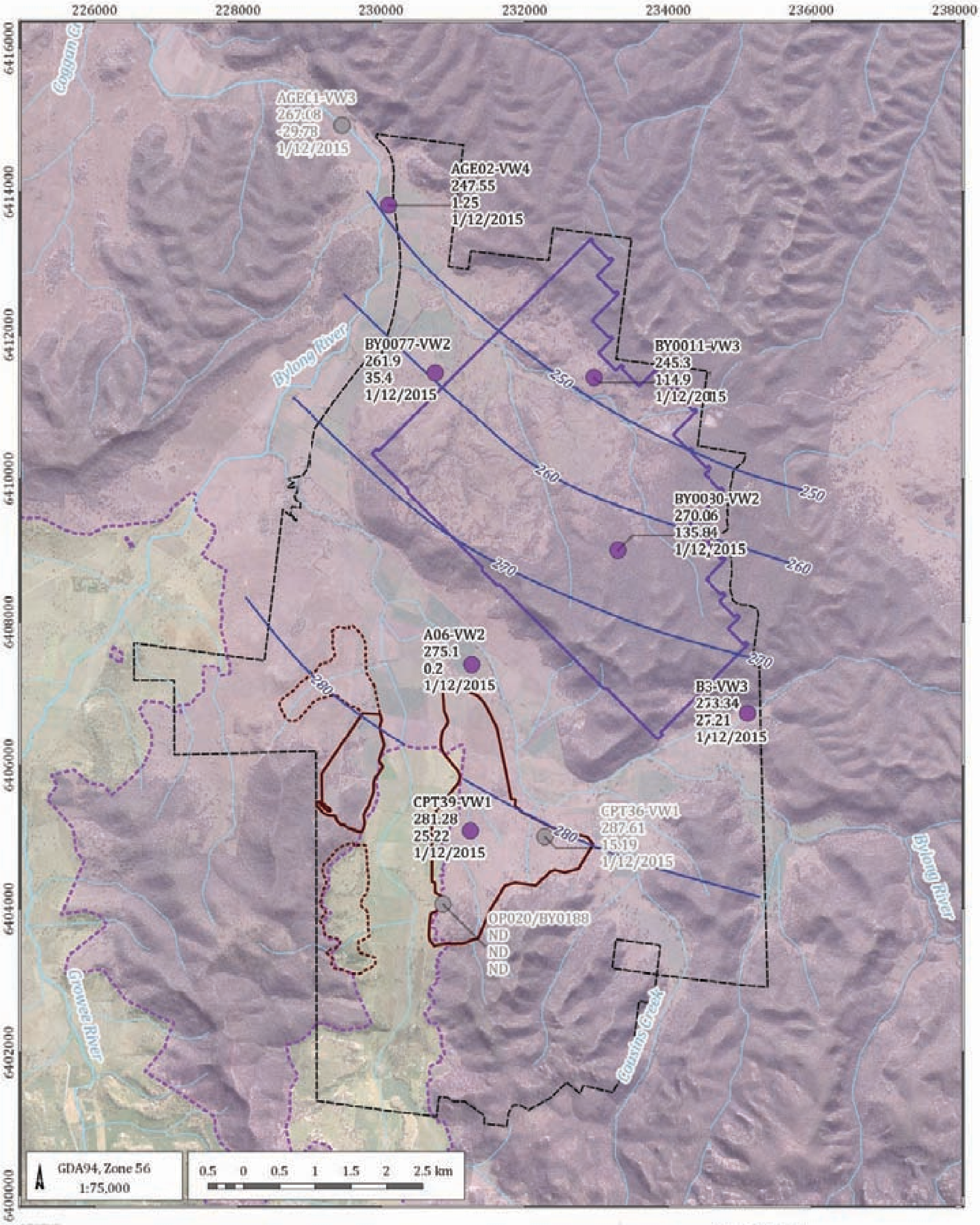
Bylong Coal Project (G1606E)

Charbon Subgroup potentiometric surface - December 2015

AGE

DATE 1/3/2016

FIGURE No: 21



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Groundwater level contour (mRL)
- Ulan coal seam presence and subcrop / outcrop
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Date of measurement

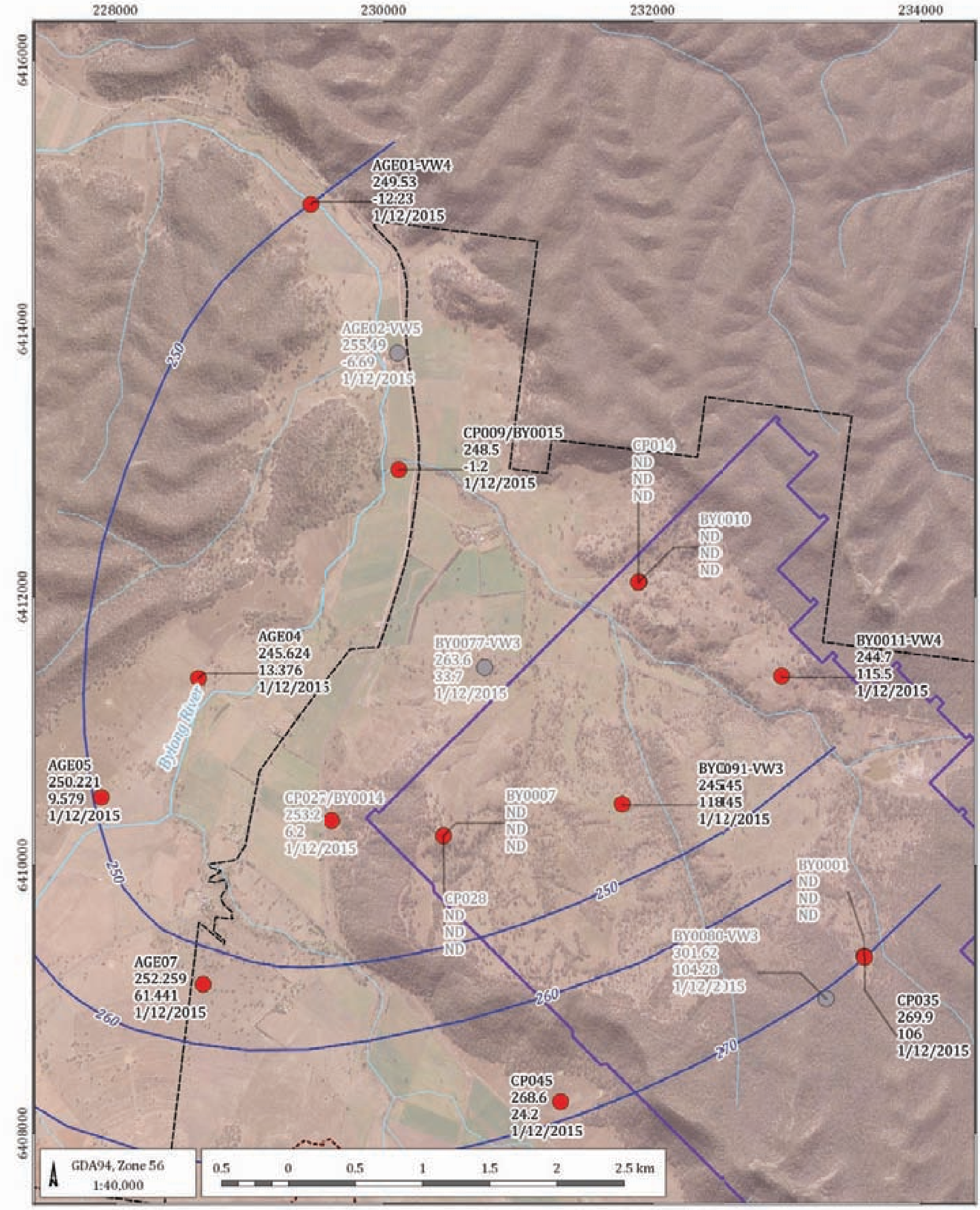
ND = no data

Bylong Coal Project (G1606E)

Ulan coal seam potentiometric surface and sub-crop recharge zones - December 2015

DATE 1/3/2016

FIGURE No: 22



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Coggan coal seam sub-crop
- Groundwater level contour (mRL)
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Date of measurement

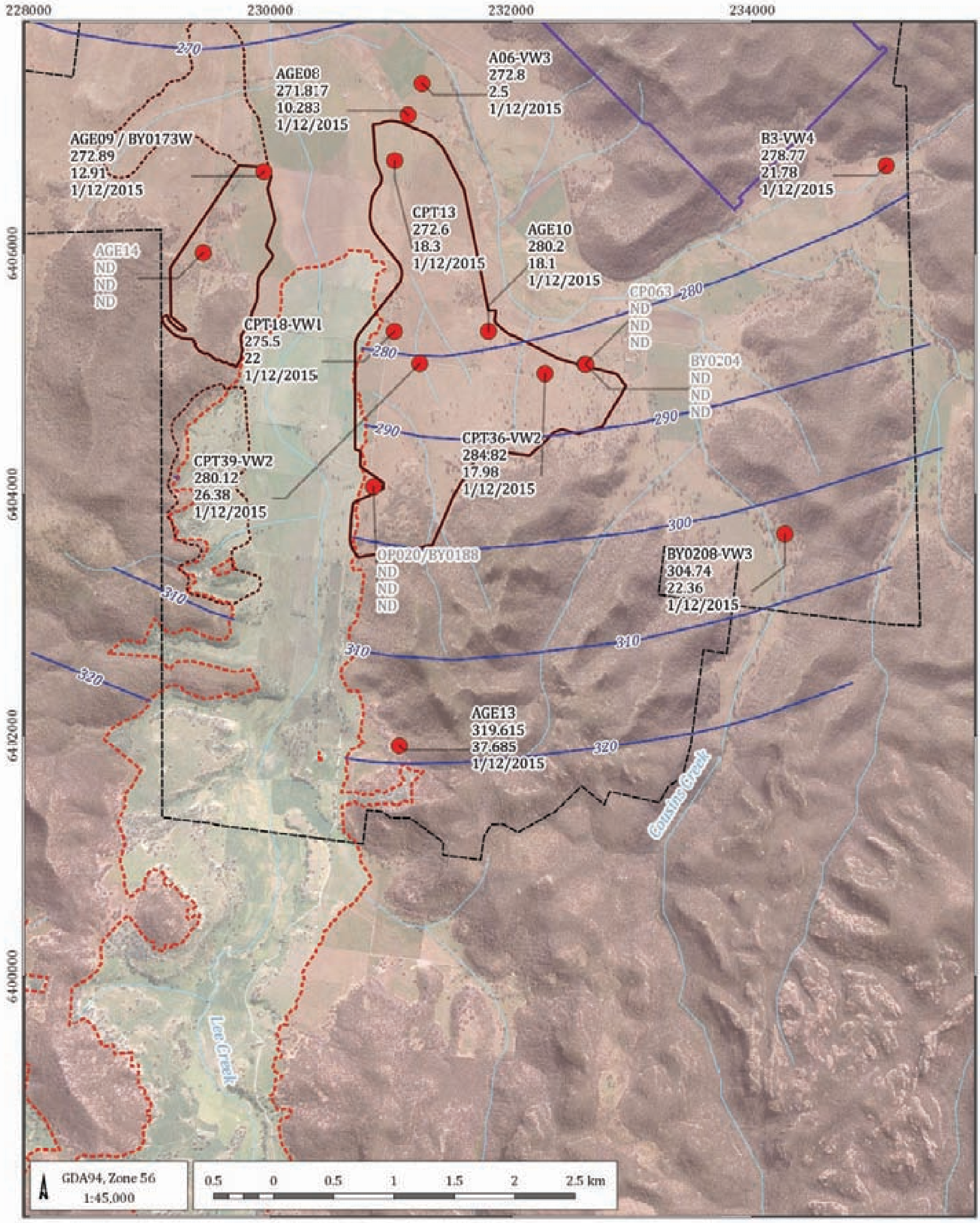
ND = no data

Bylong Coal Project (G1606E)

Coggan coal seam - north - potentiometric surface and sub-crop recharge zones - December 2015

DATE 1/3/2016

FIGURE No: 23



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Coggan coal seam presence and subcrop / outcrop
- Groundwater level contour (mRL)
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Date of measurement

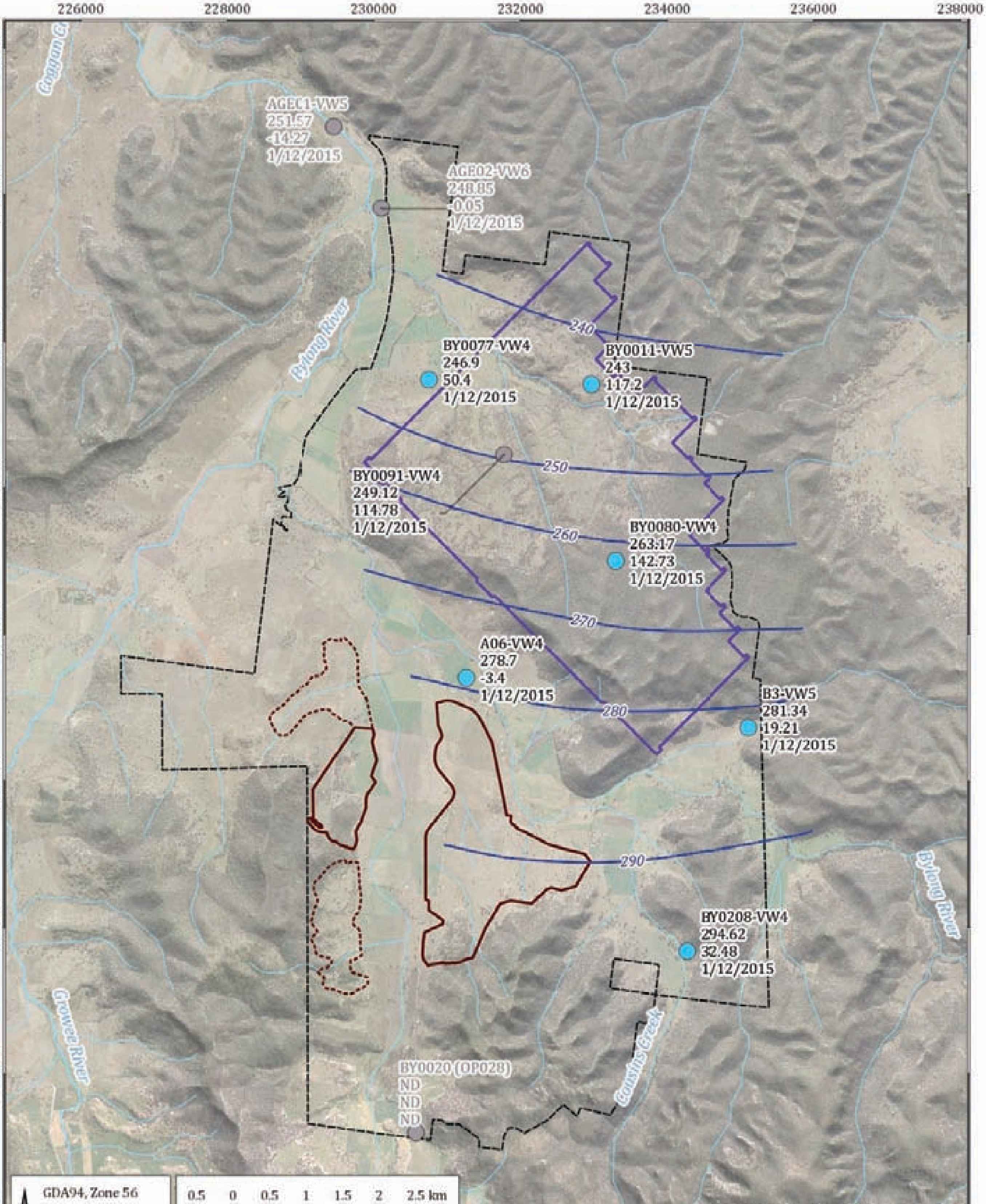
ND = no data

Bylong Coal Project (G1606E)

Coggan coal seam - south - potentiometric surface and sub-crop recharge zones - December 2015

DATE 1/3/2016

FIGURE No: **24**



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Groundwater level contour (mRL)
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Date of measurement

ND = no data

Bylong Coal Project (G1606E)

Marrangaroo Formation potentiometric surface - December 2015

AGE GROUNDWATER & ENVIRONMENTAL

DATE 14/3/2016

FIGURE No: 25

5 Numerical modelling

As outlined previously, some stakeholders raised a number of questions regarding 'fitness for purpose' of the groundwater model presented in the EIS. These issues included:

- representation of the unsaturated zone;
- parameter and boundary condition values;
- sensitivity of assumptions;
- representation of streamflow;
- water balance for each aquifer; and
- design, operation and impact of a borefield .

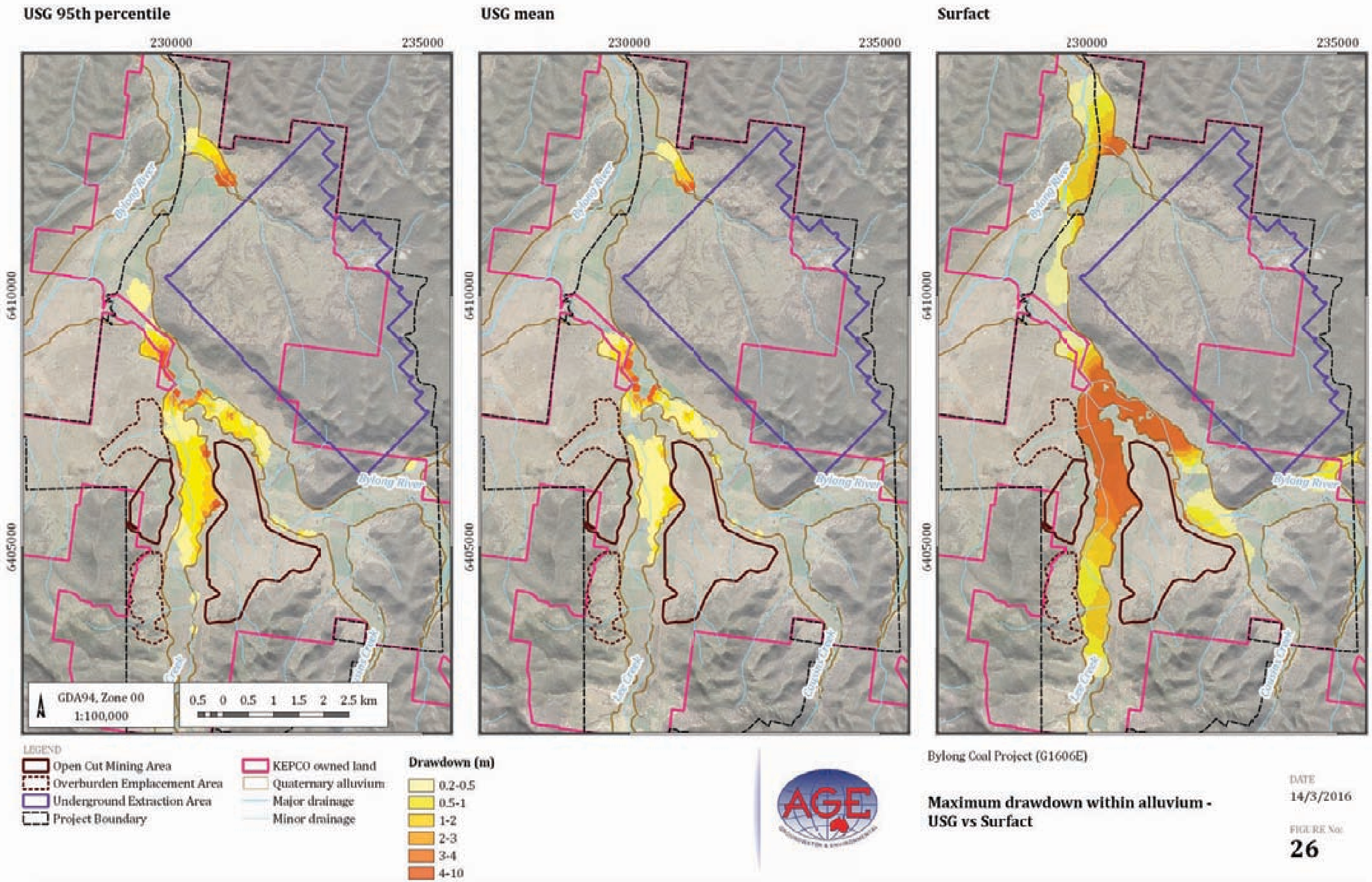
To address these queries further sensitivity analysis was undertaken using the numerical model. The model was firstly updated using the most recent groundwater level measurements recorded in the monitoring network and the appropriateness of the model parameters considered. The sections below outline the updates to the model and the results of sensitivity analysis and additional model runs.

5.1 Modelling code and unsaturated zone

The EIS utilised the MODFLOW SURFACT code to simulate groundwater flow. This code has the option to simulate groundwater flow within both the saturated zone, and the unsaturated zone using the van Genuchten equations, or only the saturated zone using the pseudo soil function. The option of modelling flow within both the saturated zone and unsaturated zone was adopted for the EIS.

During the EIS, attempts were made to utilise the pseudo-soil function to test the sensitivity of the model predictions to the presence of unsaturated zone flow. However, the pseudo soil function failed to converge. This was likely due to the large number of unsaturated cells in the upper layers of the groundwater model, coupled with the relatively low recharge rates assigned to the model cells in areas of high relief creating a high matric suction.

The MODFLOW USG (USG beta version) code was therefore used to assess the sensitivity of removing unsaturated flow, by utilising the upstream weighting method that is similar to the pseudo-soil function. A stakeholder requested a direct comparison of the drawdown impacts predicted using both methods. Figure 26 below shows the drawdown predicted within the Quaternary alluvium by both the MODFLOW USG and MODFLOW SUFACT models. Two drawdown scenarios are presented for the USG model, being the mean and 95th percentile drawdown predicted by the uncertainty analysis. Figure 26 shows the MODFLOW USG model predicts significantly less drawdown within the alluvium than the MODFLOW SURFACT model. When interpreting this result, it is important to note there are some differences between the models, particularly the rate of landholder pumping which is explained within the EIS. However, despite these differences, Figure 26 shows MODFLOW SURFACT predicts significantly more drawdown vertically and laterally within the alluvium, and therefore was a conservative approach to assessing impacts for the EIS.



Bylong Coal Project (G1606E)

Maximum drawdown within alluvium - USG vs Surfact

DATE
14/3/2016

FIGURE No:
26

5.2 Updates to model

5.2.1 Model code

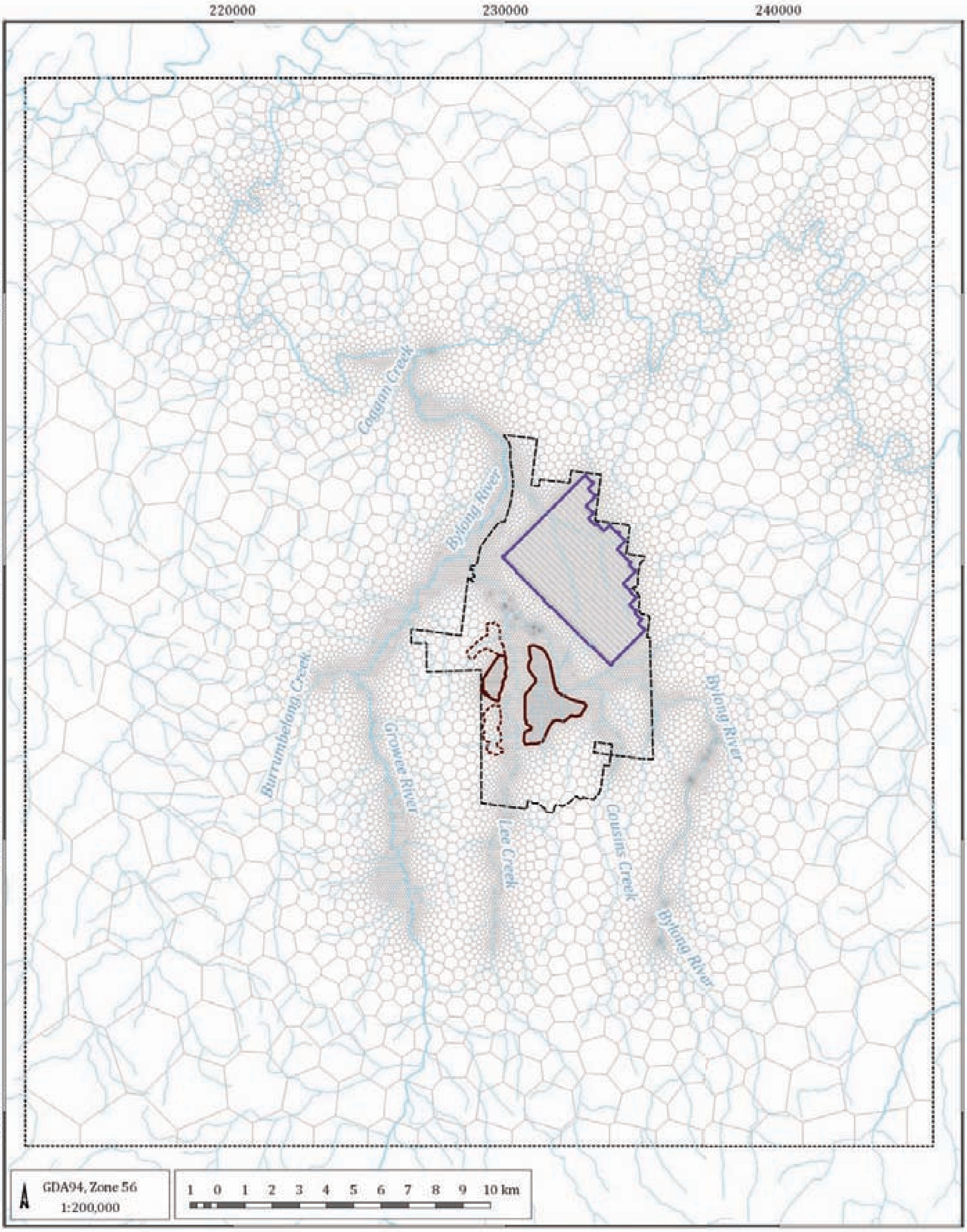
A stakeholder commented that the potential presence of layered semi-confined aquifers separated by aquitards and the potential for several distinct, largely unrelated shallow water tables to be present within the modelling domain suggests that other model codes could be better suited to the Project.

MODFLOW USG was used to undertake the additional supplementary modelling to address the submissions. A MODFLOW USG version of the model was developed during the EIS to assess the sensitivity of the predictions to the representation of flow within the unsaturated zone. This model was considered the most appropriate to use for the supplementary modelling because the MODFLOW USG code:

- allows variably saturated conditions and can therefore represent perched groundwater systems that are expected to occur within the hills of the Project Boundary;
- is numerically stable and converges reliably when solving using the pseudo-soil function;
- does not require parameters to represent the unsaturated zone that are difficult to measure in fractured rock;
- allows for better refinement of cells along geological features such as the alluvium and around the borefield;
- allows for an unstructured grid which reduces the number of cells within the model, reducing run times; and
- is a public domain code and can therefore be utilised on multiple cloud severs without licensing issues.

It is important to note that whilst MODFLOW USG is considered an appropriate model code to quantify the impacts of the Project, any future revisions of the model will consider the most appropriate code for the task at that time. Section 7.2.3 provides recommendations for future updates to the groundwater model to be incorporated into the Water Management Plan for the Project, which will consider the most appropriate modelling code at this time.

Figure 27 shows the mesh for the MODFLOW USG version of the model that was developed for the EIS. The MODFLOW USG mesh is shown here as it was not presented within the EIS groundwater report.



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Model extent
- Model mesh
- Project Boundary
- Major drainage
- Minor drainage

Bylong Coal Project (G1606E)

MODFLOW USG model mesh from EIS

DATE 14/3/2016

FIGURE No: 27

5.2.2 Stream- aquifer interaction

Section 4.2.3 discusses the connectivity between surface water and groundwater in the Project Boundary. As previously outlined, the stream systems only receive baseflow during periods of above average rainfall when the alluvial water table rises above the bed of the streams. During dryer times flow of water is expected to be in the reverse direction, i.e. from the streams into the underlying aquifers.

The groundwater model presented within the EIS represented the flow of baseflow with the MODFLOW river package. This modelling package set the level of water within the stream above the stream bed and assumed a constant presence of water within the Bylong River and Lee Creek during the calibration and prediction periods. A stakeholder commented that it would be more appropriate to use a modelling package that also represented measured stream flow volumetrically. This was considered, but determined not to be appropriate given the water table was falling below the bed of the streams during periods of low rainfall.

The constant head of water within the streams was removed from the river package to allow the water table to fall below the river bed. The river package therefore allowed water to enter the streams when the water table was relatively elevated, and fall below the bed of the river when rainfall recharge was low.

5.2.3 Connectivity with alluvial aquifers

Stakeholders raised concerns that the numerical model developed for the EIS may under estimate the inflow take of water from the alluvium into the mine working where the coal sub-crops below the alluvium. It is agreed that as shown on Figure 22 to Figure 24 above, that the sub-crop of the respective coal seams where they are buried under the Quaternary alluvium may provide a pathway for alluvial groundwater to enter the open cut mine workings. The magnitude of the connectivity will depend on the impact of weathering on the coal seam and the presence of any clays within the base of the alluvial channel. The numerical model represented the sub-cropping coal seams, and the overlying alluvium, however the need to maintain continuous layers within MODFLOW SURFACT meant that these units were separated by two layers of interburden within the model (layers 4 and 5). The MODFLOW USG model does not have 'physical layers' where they are not present and therefore connects layers directly where they are connected in reality. The MODFLOW USG version of the model therefore does not retard the connection of the coal with the alluvium.

5.3 Verification and recalibration

5.3.1 Baseline period verification

The model was updated using estimates of rainfall recharge from the baseline monitoring period and rerun to verify the updated model replicated recent measured groundwater water fluctuations. Appendix D contains hydrographs showing the measured groundwater levels predicted by the updated model. The hydrographs contained with Appendix D, showed a common trend with groundwater levels within the alluvium not declining the magnitude observed within the observation bores. Section 5.3.2 below describes manual adjustments made to the model to improve the level of fit between the observations and predictions.

5.3.2 Baseline period recalibration

A stakeholder commented that the model was over predicting water levels within the alluvium, and this combined with a low vertical hydraulic conductivity within the Permian stratum underlying the alluvium may dampen the magnitude of drawdown during mining. A number of potential factors resulting in heightened water levels, and the limited decline within the alluvium over the baseline period within the model were examined including the potential for:

- irrigation returns (drainage from irrigated areas to the water table) were lower than the 35% assumed within the EIS model;
- the adopted recharge rates were too high within the EIS model;
- the rate of landholder pumping was higher than represented within the EIS model due to the below average rainfall and increased need to irrigate due to low soil moisture;
- the river stage height within the EIS model was providing additional water to the alluvium; and
- hydraulic conductivity and storage values within the EIS model were inappropriate.

As discussed above, a series of adjustments were made to the model to improve the level of fit between the observations and predictions. Adjustments to the model included:

- reducing the irrigation returns to the water table to 5% of the irrigated volume;
- removing the ability of the rivers to leak water back into the aquifers by removing the seasonal constant head stage height assigned within the river package;
- reducing the effective recharge rates (daily rainfall and evaporation data from SILO was used to estimate the rainfall recharge periods); and
- allowing private water supply bores with allocations to extract the full allocation nominated for each bore.

Appendix D contains the updated hydrographs comparing the measured and model predicted groundwater levels. Whilst it is acknowledged each model predicted hydrograph does not perfectly match the measured groundwater levels, the model shows an improved match overall and importantly groundwater levels decline at most locations of the baseline period due to the below average rainfall conditions. Table 2 below presents the changes made to the hydraulic properties in the recalibrated model.

Table 2 Calibrated aquifer parameters

Unit	Horizontal hydraulic conductivity (m/day)		Vertical hydraulic conductivity (m/day)			Specific yield (%)		Specific storage (m^{-1})	
	EIS	Updated model	EIS	Updated model	Kh/Kv	EIS	Up-dated model	EIS	Updated model
Alluvium upper	2.7	4.2	1.06	1.65	2.6	10	3	5E-3	1E-3
Alluvium lower	4.72	10.1	1.66	3.55	2.8	9	6	1E-3	5E-3
Colluvium	4.6E-1	4.6E-1	8.62E-4	4.6E-2	10	8	2	2E-5	1E-3
Weathered Permian	2.41E-1	2.41E-1	1.21E-1	1.21E-1	2	10	10	2E-4	2E-4
Tertiary basalts	1.10	1.10	1.92E-2	1.92E-2	59	5	5	1.52E-5	1.52E-5
Wallerawang Subgroup	1.5E-3	1.5E-3	1.5E-4	1.5E-4	10	2	2	1.63E-5	1.63E-5
Charbon Subgroup	3.64E-4	3.64E-4	4.32E-7	4.32E-7	1000	3	3	2.31E-6	2.31E-6
Ulan Coal Seam	1E-5 to 0.05	1E-5 to 0.05	1E-6 to 0.03	1E-6 to 0.03	2	2	2	2.28E-5	2.28E-5
Interburden	1.5E-3	1.5E-3	1.5E-4	1.5E-4	10	1	1	7.6E-5	7.6E-5
Coggan Coal Seam	1E-5 to 0.13	1E-5-0.13	0.03 to 1E-6	0.03 to 1E-6	9	2	2	2E-4	2E-5
Marrangaroo Formation	1.63E-3	1.63E-3	3.15E-6	3.15E-6	500	1	1	1.31E-5	1.31E-5
Shoalhaven Group	1.87E-4	1.87E-4	1.87E-5	1.87E-5	10	1	1	7.06E-6	7.06E-6
Triassic intrusions	1.49E-3	1.49E-3	7.47E-4	7.47E-4	2	1	1	1.57E-5	1.57E-5

The changes made to the hydraulic properties included:

- small adjustments to the specific storage within the alluvial layers;
- increasing specific storage within the colluvium and reducing it in Coggan Coal Seam by an order of magnitude to address comments by stakeholders;
- a slight increase in the horizontal and vertical hydraulic conductivity of the alluvium; and
- a significant increase within the vertical hydraulic conductivity of the colluvium to reduce the contrast with the value adopted for the horizontal hydraulic conductivity.

Table 2 also shows the ratio of the horizontal hydraulic conductivity to the vertical hydraulic conductivity. It shows horizontal hydraulic conductivity is generally 10 times or less the value adopted for the vertical hydraulic conductivity. The exceptions were the Tertiary basalts, the Charbon Subgroup and the Marrangaroo Formation which calibrated to factors of 59, 1000 and 500 times respectively for the vertical and horizontal hydraulic conductivity, suggesting the model needed to reduce these factors to produce head differentials between layers.

Table 3 below summaries the water balance from the updated numerical model.

Table 3 Water balance - average for calibration period

Parameter	EIS		Updated model	
	Input (ML/day)	Output (ML/day)	Input (ML/day)	Output (ML/day)
Rainfall recharge	14.9		11.5	-
River leakage	34.7		58	-
River baseflow		43.3	-	3.1
Evapotranspiration		21.5	-	64.9
General head		0.1	0.0	0.0
Wells		6.2	0.0	6.5
Storage	36.4	15.2	18	13
Total	**86**	**86.3**	**87.5**	**87.5**

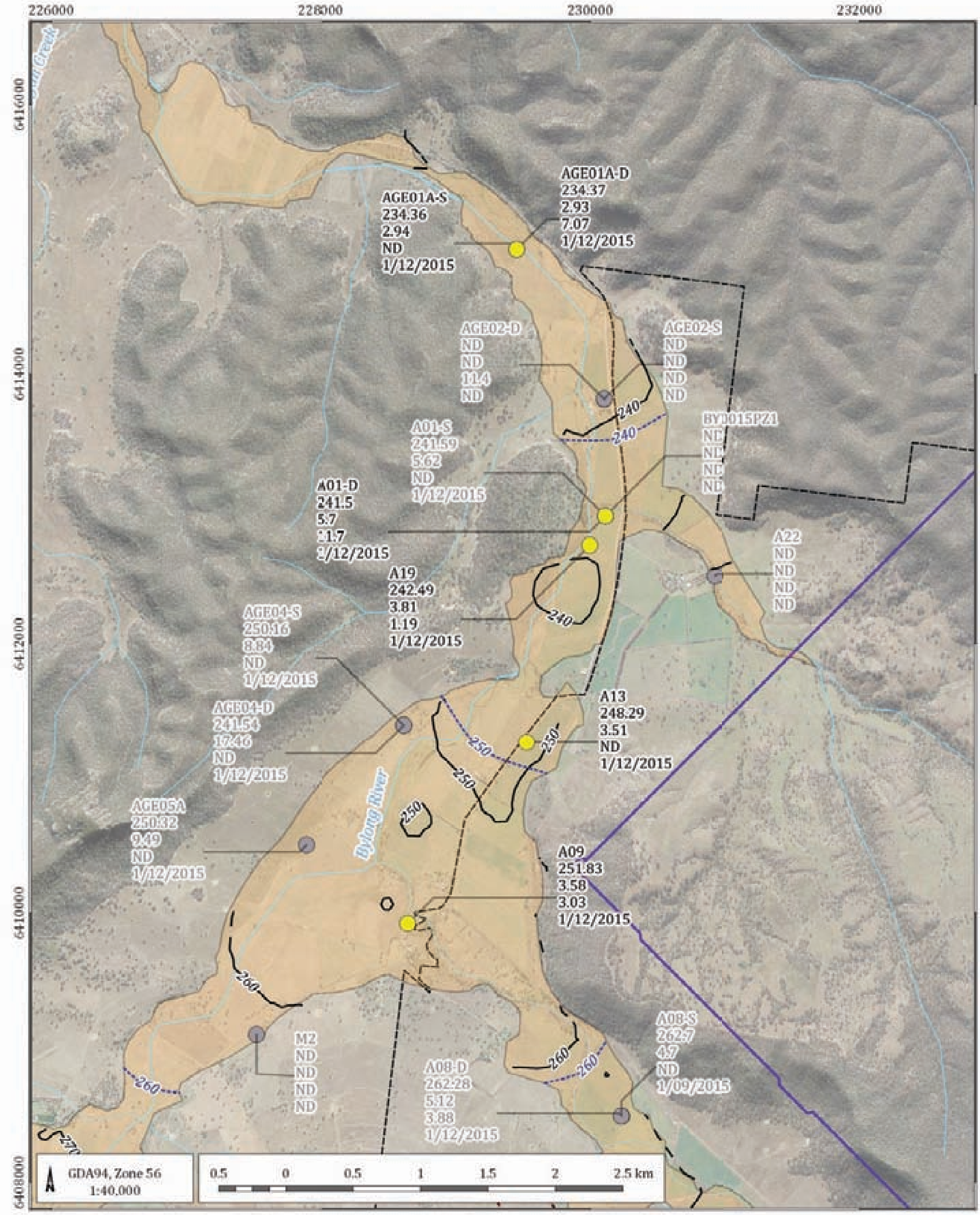
Table 3 shows a net increase in recharge, during the baseline calibration period. However it is important to note that firstly this table compares the MODFLOW SURFACT model with the MODFLOW USG version, that have different cell dimensions. On a net basis the diffuse recharge to the alluvium and bedrock hills as well as the river recharge to the alluvium is reduced in the updated model. There is an increase in river leakage, but as leakage is not active in the Project Boundary this leakage only occurs within the Goulburn River area where large unrefined cells are present within the MODFLOW USG version of the model. There is also a reduced rate of discharge from the aquifers to the streams due to lower groundwater levels, but this is offset by an increase in evapotranspiration.

Stakeholders requested groundwater level outputs from the model for layers between the alluvium and Coggan Coal Seams, to allow comparison with the conceptual contour maps (contained within Section 4) generated from the raw data. Figure 28 to Figure 37 display the measured and simulated groundwater levels for December 2015 for the key layers within the model as follows:

- Layer 2 – alluvium;
- Layer 3 - Tertiary basalt;
- Layer 4 - Wallerang Subgroup;
- Layer 5 - Charbon Subgroup;
- Layer 6 - Ulan Coal Seam;
- Layer 8 - Coggan Coal Seam; and
- Layer 9 - Marrangaroo Formation.

When using MODFLOW USG the water level contours for each layer only show groundwater levels in the areas where each of the geological units represented by the model layer are present. The predicted groundwater levels correlate well with the measured groundwater levels within layer 2, which represents the alluvium. The water levels within layers 3 to 9 show the groundwater model represents an elevated head within the hills overlying the proposed underground mining area, and a general decline in head in the deeper layers towards the coal seam.

The model approximates the potentiometric surface measured within the Coggan coal seam and the underlying Marrangaroo Formation. However, there is a systematic over prediction of groundwater levels, particularly in the southern areas of the Project, and in the bedrock hills. The match between observed and predicted is more closely correlated in bores installed under the alluvial flood plain, presumably due to the boundary condition effect of this feature on underlying strata. Figure 31 which represents the Wallerawang Subgroup does not show a good match between the location of the formation and the location of the monitoring bores and indicates further interpretation on the geological formations in these areas is required. Section 7.2.5 describes further geological modelling to be undertaken during development of the Water Management Plan to better define the geological surfaces, and the formations within which new and existing bores are installed.



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Groundwater level contour (mRL)
- Simulated groundwater level contour (mRL)
- Project Boundary
- Underground Extraction Area
- Quaternary alluvium
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Saturated thickness
5. Date of measurement

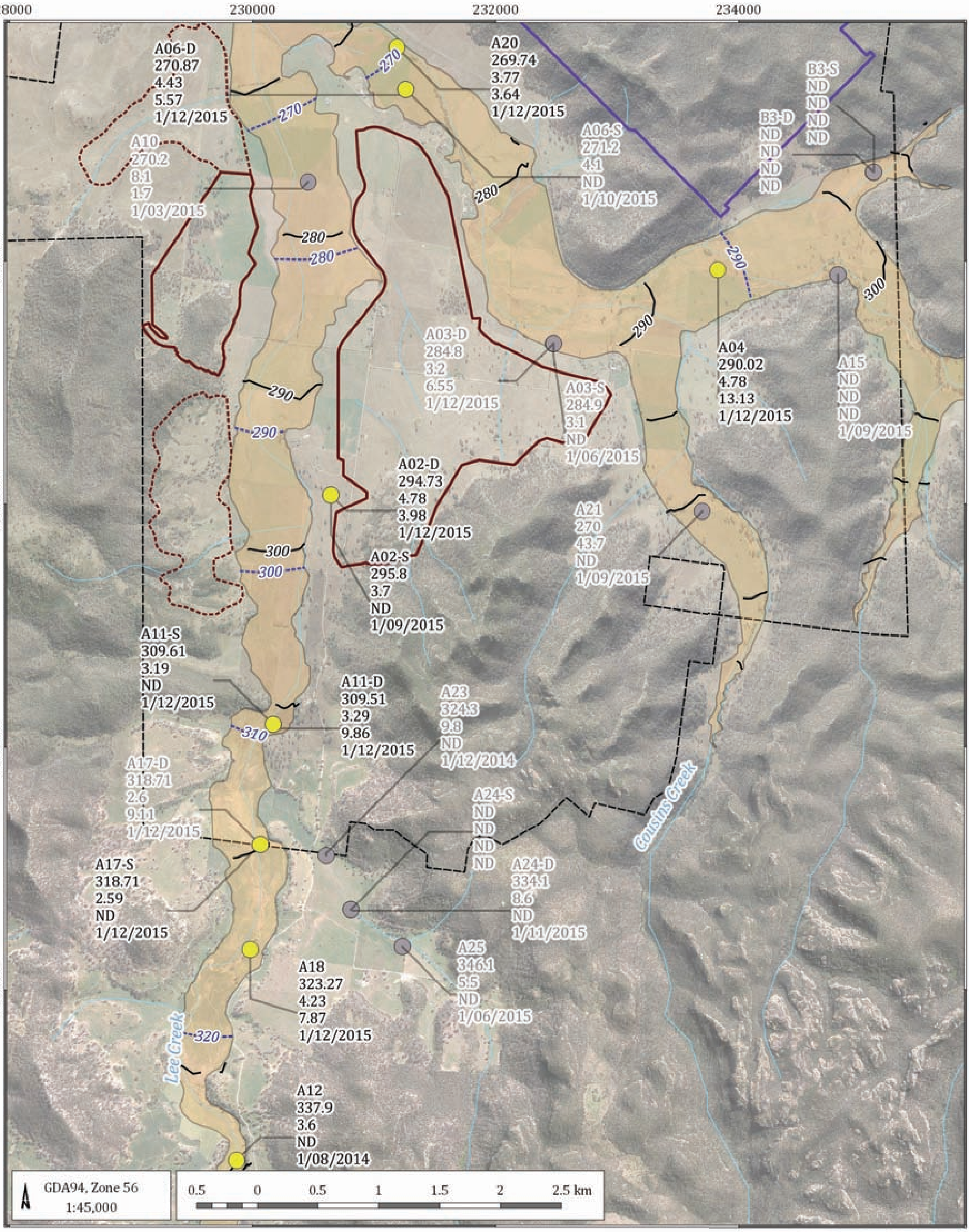
ND = no data

Bylong Coal Project (G1606E)

Simulated and observed groundwater levels north - alluvium (layer 2) - December 2015

DATE 14/3/2016

FIGURE No: 28



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Groundwater level contour (mRL)
- Simulated groundwater level contour (mRL)
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Quaternary alluvium
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Saturated thickness
5. Date of measurement

ND = no data

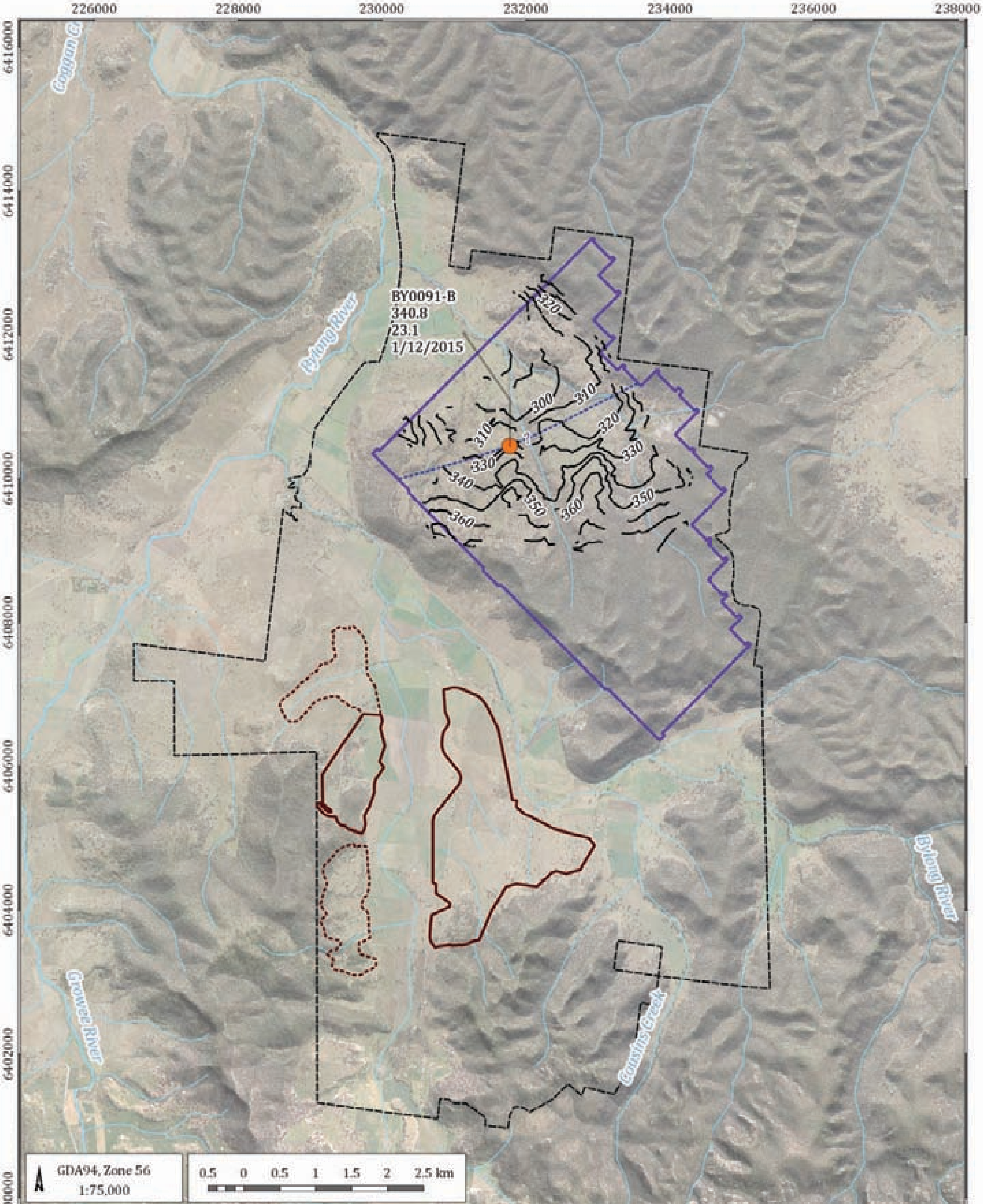
Bylong Coal Project (G1606E)

Simulated and observed groundwater levels south - alluvium (layer 2) - December 2015

AGE GROUNDWATER & ENVIRONMENTAL

DATE 14/3/2016

FIGURE No: 29



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Groundwater level contour (mRL)
- Simulated groundwater level contour (mRL)
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Saturated thickness
5. Date of measurement

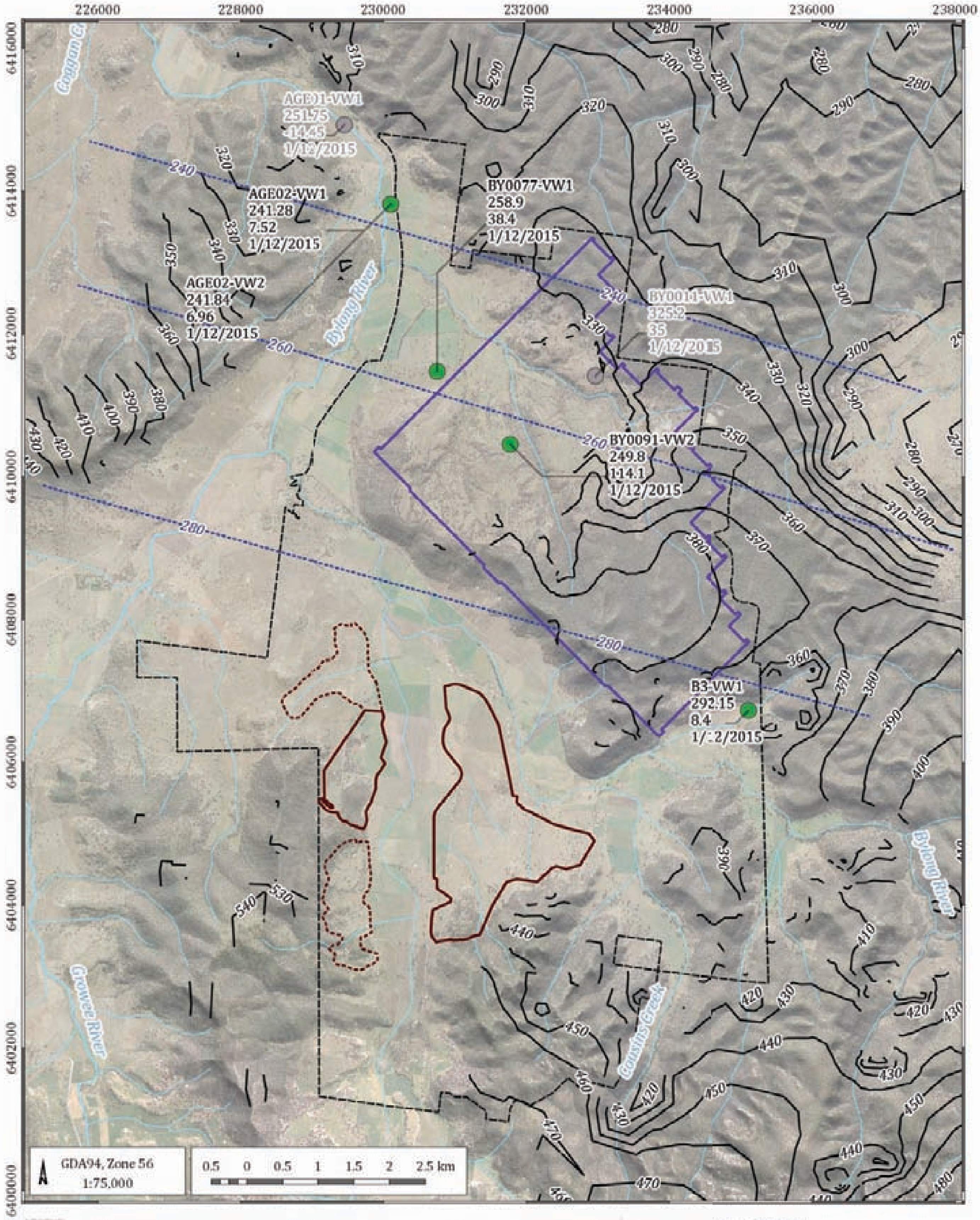
ND = no data

Bylong Coal Project (G1606E)

Simulated and observed groundwater levels - Tertiary basalt (layer 3) - December 2015

DATE 14/3/2016

FIGURE No: 30



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Groundwater level contour (mRL)
- Simulated groundwater level contour (mRL)
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Date of measurement

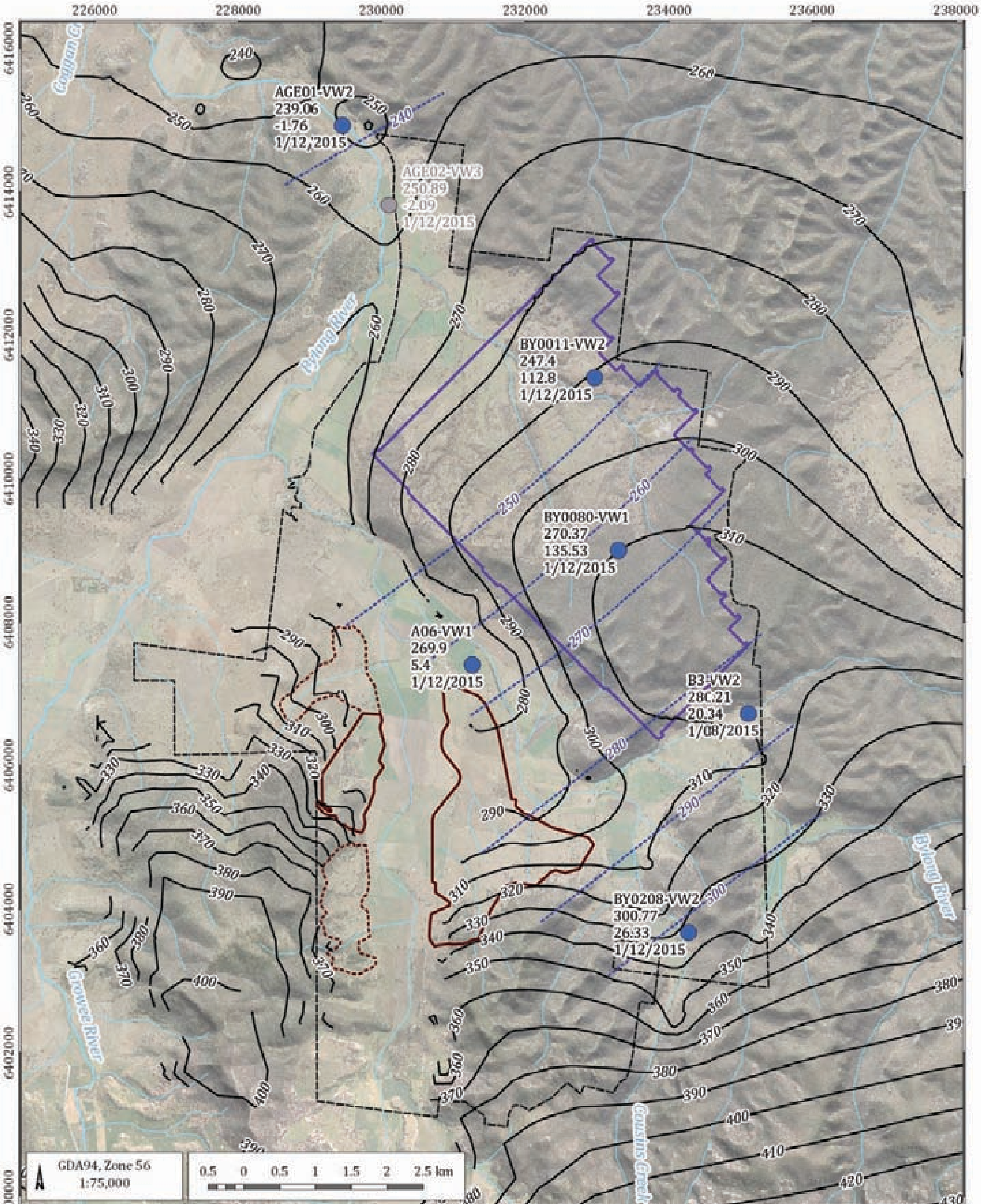
ND = no data

Bylong Coal Project (G1606E)

Simulated and observed groundwater levels - Wallerawang Subgroup (layer 4) - December 2015

DATE 14/3/2016

FIGURE No: **31**



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Groundwater level contour (mRL)
- Simulated groundwater level contour (mRL)
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Date of measurement

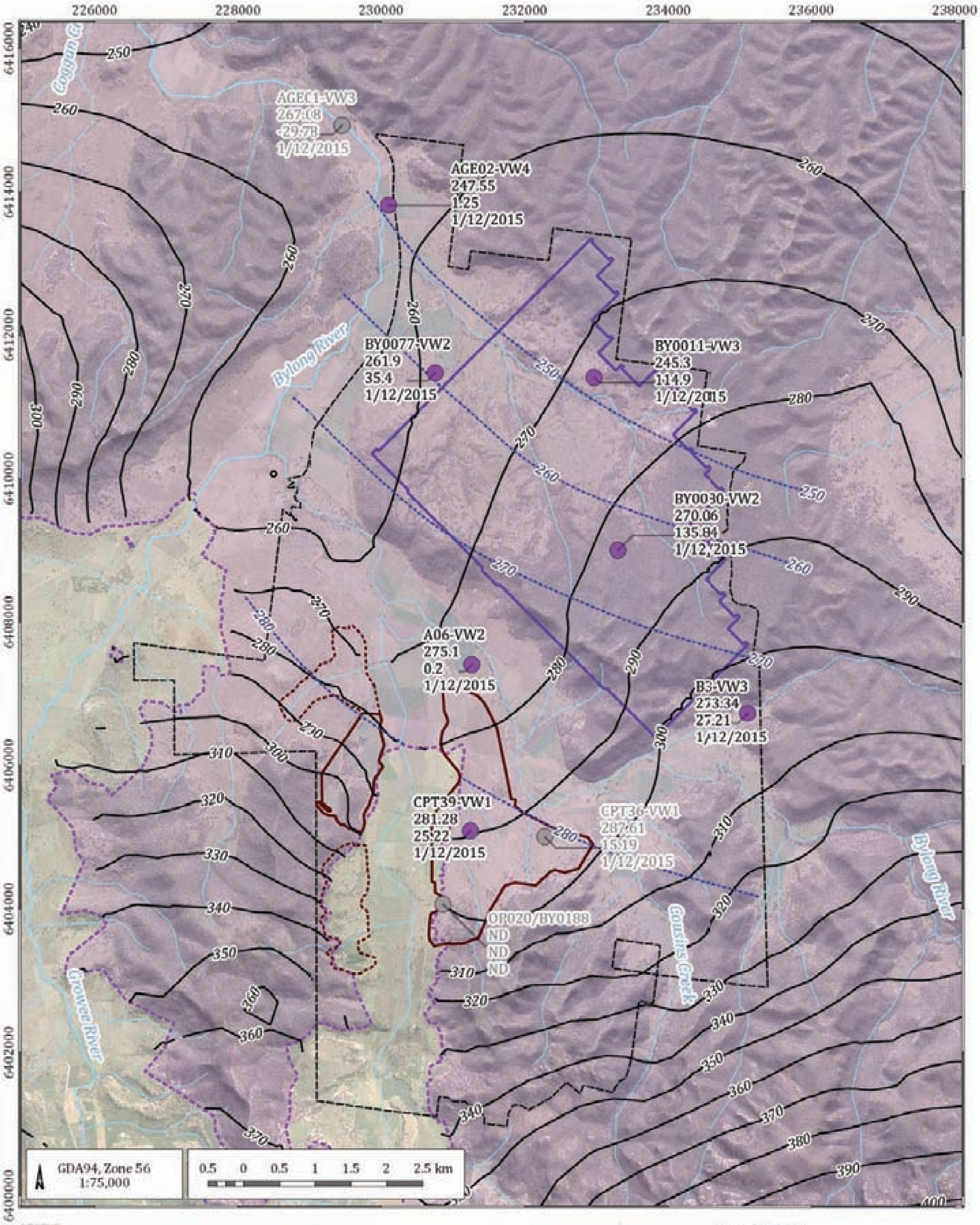
ND = no data

Bylong Coal Project (G1606E)

Simulated and observed groundwater levels - Charbon Subgroup (layer 5) - December 2015

DATE 14/3/2016

FIGURE No: **32**



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Groundwater level contour (mRL)
- Simulated groundwater level contour (mRL)
- Ulan coal seam presence and subcrop / outcrop
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Date of measurement

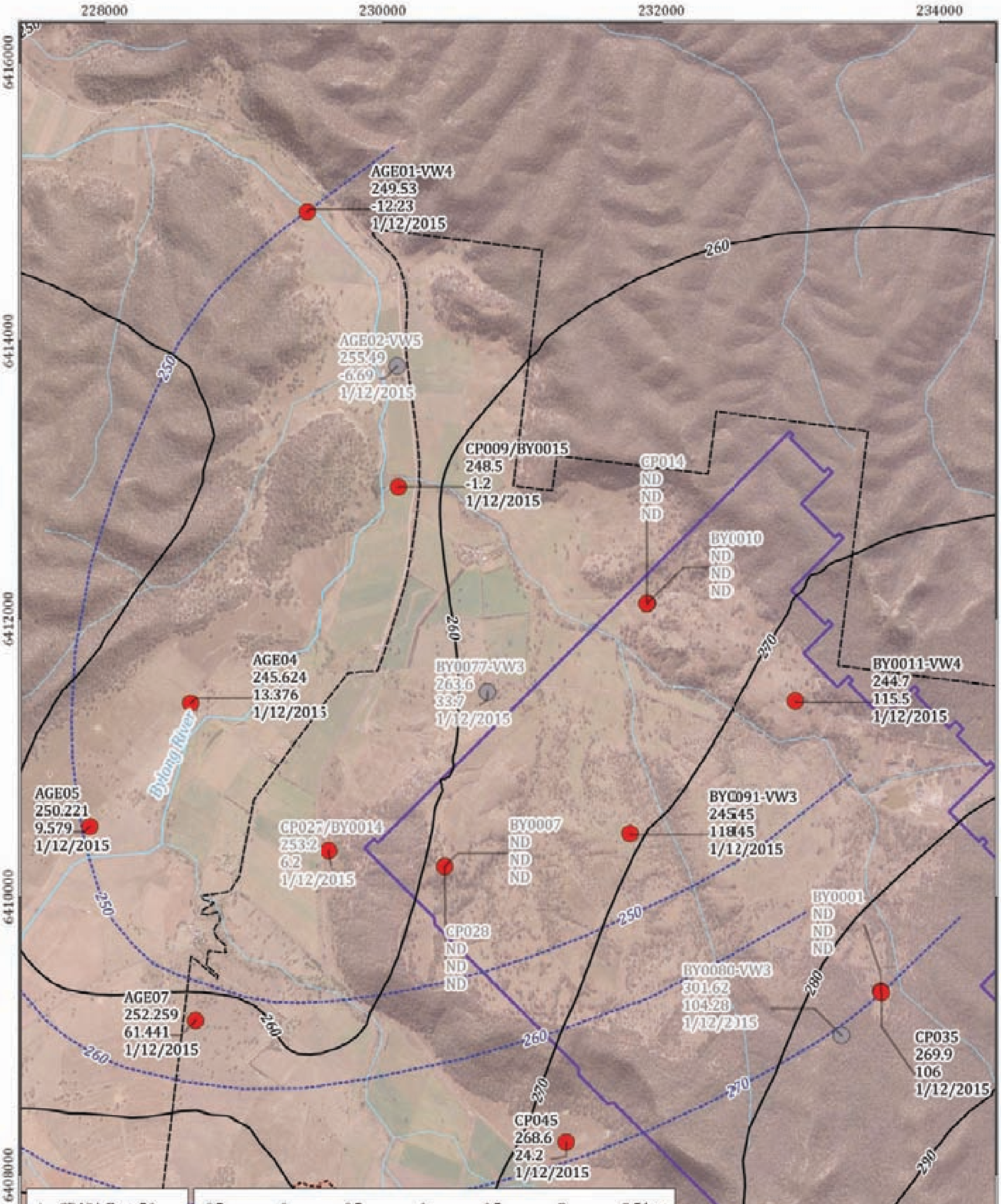
ND = no data

Bylong Coal Project (G1606E)

Simulated and observed groundwater levels - Ulan Seam (layer 6) - December 2015

DATE 14/3/2016

FIGURE No: **33**



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Coggan coal seam sub-crop
- Groundwater level contour (mRL)
- Simulated groundwater level contour (mRL)
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Date of measurement

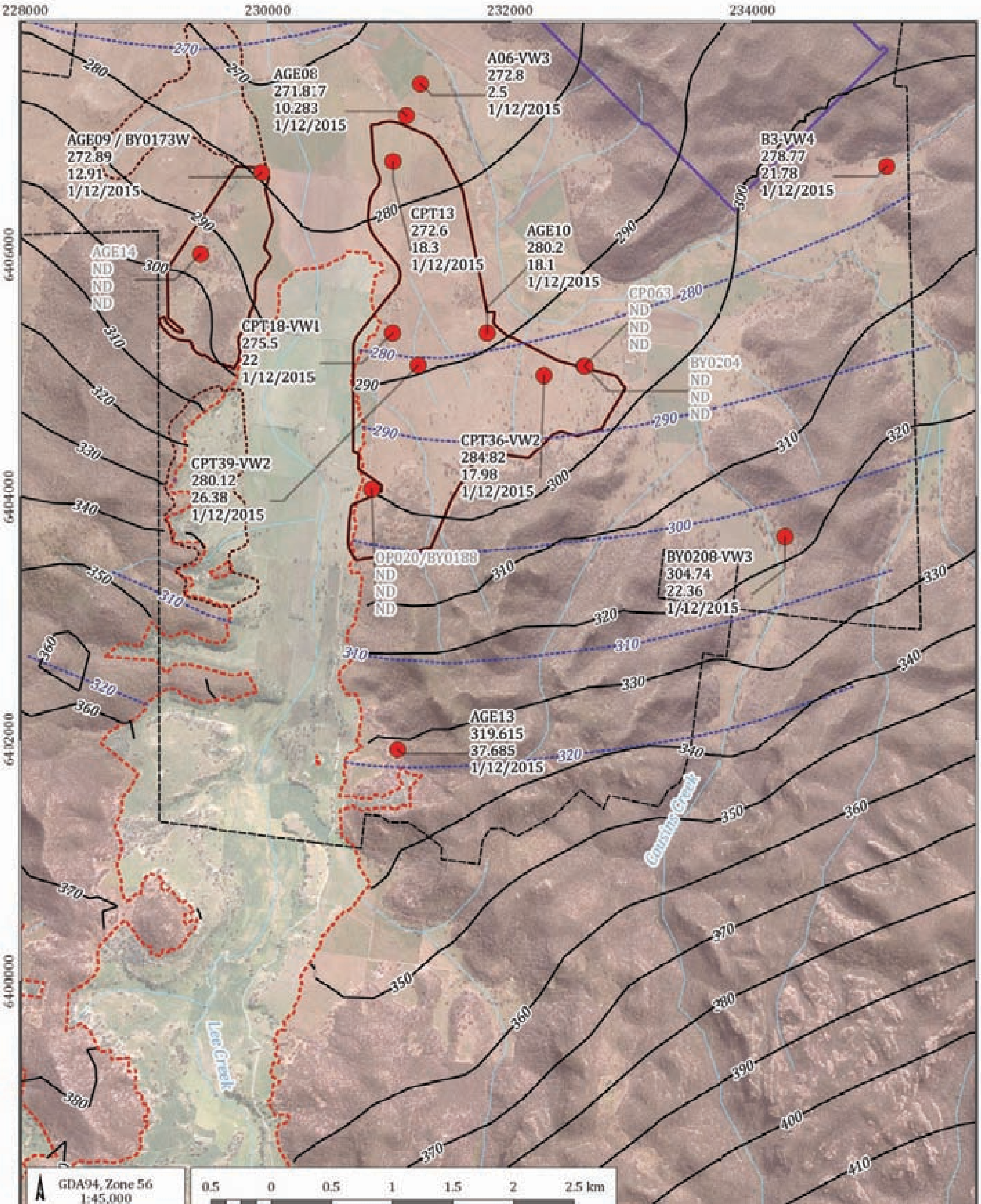
ND = no data

Bylong Coal Project (G1606E)

Simulated and observed groundwater levels north (layer 8) - Coggan Seam - December 2015

DATE 14/3/2016

FIGURE No: **34**



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Coggan coal seam presence and subcrop / outcrop
- Groundwater level contour (mRL)
- Simulated groundwater level contour (mRL)
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Date of measurement

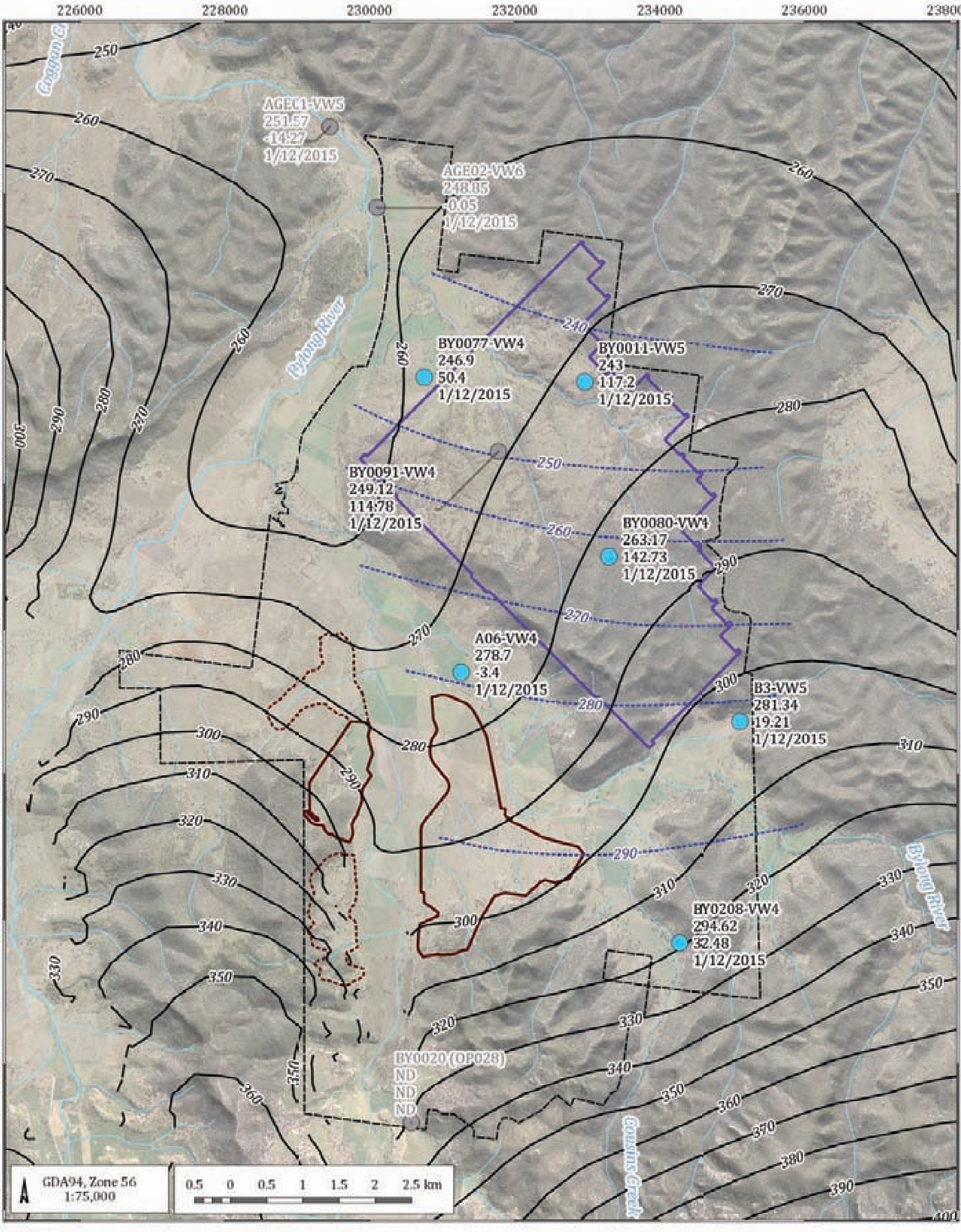
ND = no data

Bylong Coal Project (G1606E)

Simulated and observed groundwater levels south - Coggan Seam (layer 8) - December 2015

DATE 14/3/2016

FIGURE No: 35



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Groundwater level contour (mRL)
- Simulated groundwater level contour (mRL)
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Date of measurement

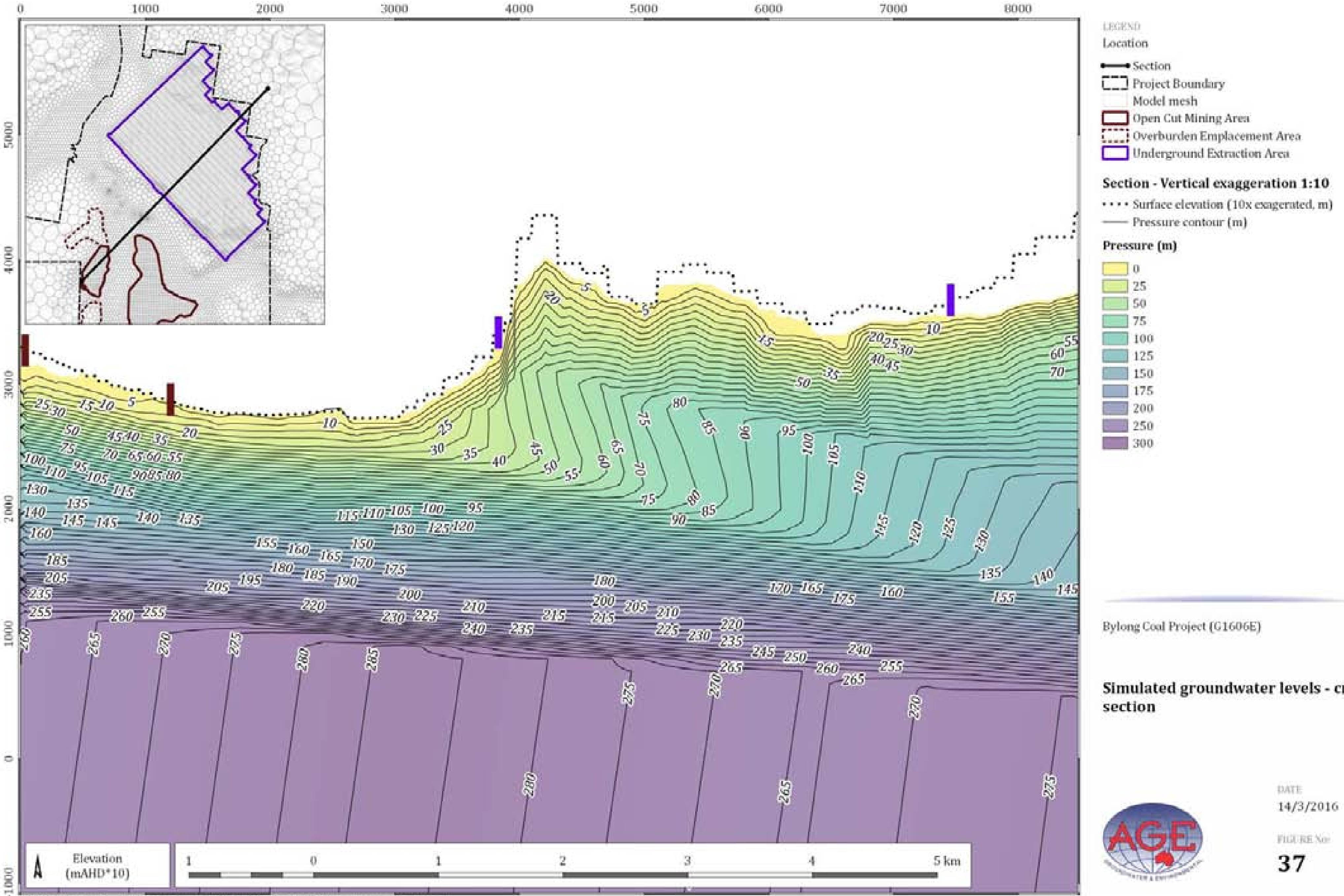
ND = no data

Bylong Coal Project (G1606E)

Simulated and observed groundwater levels - Marrangaroo Formation (layer 9) - December 2015

DATE 14/3/2016

FIGURE No: **36**



Bylong Coal Project (G1606E)

Simulated groundwater levels - cross section

DATE
14/3/2016

FIGURE No:
37

5.4 Sensitivity and uncertainty analysis

The recalibrated model was used to undertake additional sensitivity analyses to address questions raised by stakeholders on the borefield sustainability and hydraulic properties within the model. The sections below outline additional modelling undertaken to assess the yields from a borefield, and the impacts of changing the hydraulic properties of the Permian units on model predictions.

5.4.1 Supplementary water take

Various stakeholders requested additional information on the ability of the 'make up water' borefield to supply the mining operations if there is a short fall of surface water, particularly during a drought period. Ultimately, the ability of a borefield to supplement the surface water supplies depends on climatic conditions (which control rates of diffuse rainfall recharge and stream bed recharge), as well as the hydraulic properties of the alluvial aquifer.

Whilst the hydraulic properties are not definitively known, the available testing data (falling/rising head tests and pumping tests described in Section 4.2.5) does provide a range of hydraulic properties within which the alluvium within the Project Boundary will ultimately hold. Similarly, the future climate cannot be predicted with confidence, however historical climate records which date back to 1901 at Wollar indicates how rainfall may vary during times of drought, and the rainfall conditions when droughts break.

To quantify the uncertainty in the predicted borefield yield, a linear uncertainty analysis was undertaken according to the methods described by Dr John Doherty (Watermark Numerical Computing, 2015). The process involves assessing the statistical uncertainty around model predictions, and projecting these linearly to estimate the likely range in borefield yield due to uncertainty in model parameters.

This type of analysis tests parameter wide changes to the model within possible ranges, rather than exploring spatial variability within the calibrated solution. One advantage of this type of analysis compared to the Monte Carlo method is the ability to quantify model parameters and observations that contribute to the uncertainty (or variance) of a certain impact from occurring. The linear analysis will reveal the 'data worth' of the measured set of observations, and reveal which bores are providing the most information to the predictive model.

A borefield was set up in the model using the MODFLOW WEL package. The pumping bores were located according to the Water Sharing Plan rules as follows:

- 400 m from access license bores on private property;
- 200 m from basic landholder rights bores;
- 50 m from a boundary with an adjacent landholder; and
- 400 m from departmental monitoring bores.

This differed slightly from the EIS that presented a total of 15 bores, located with proximity to the source of the water demand being the coal handling and preparation plant. The adjusted borefield comprised of 16 bores, located along the alluvial aquifer at 700 m spacing within the Project Boundary. The locations of the bores were adjusted from those presented within the EIS to reduce the interference between bores, comply with the Water Sharing Plan rules Pumping from private bores including bores on land owned by KEPCO remained active within the model to represent ongoing agricultural enterprises. Figure 38 shows the locations of each bore within the borefield. Table 4 summarises the parameter ranges adopted for the linear uncertainty analysis.

Groundwater recharge was calculated for the predictive model by using rainfall records from the most recent historical period of drought on the east coast of Australia, which was the 'Millennium drought' that occurred between 1995 and 2009. Daily rainfall records from 2000 to 2012 generated by SILO for the Project Boundary were used to estimate recharge rates using the soil moisture spreadsheet. This period encompassed a period of low rainfall from 2000 to 2008 and above average rainfall from 2009 to 2012. This cycle of recharge was then repeated for the proposed 23 years of the Project.

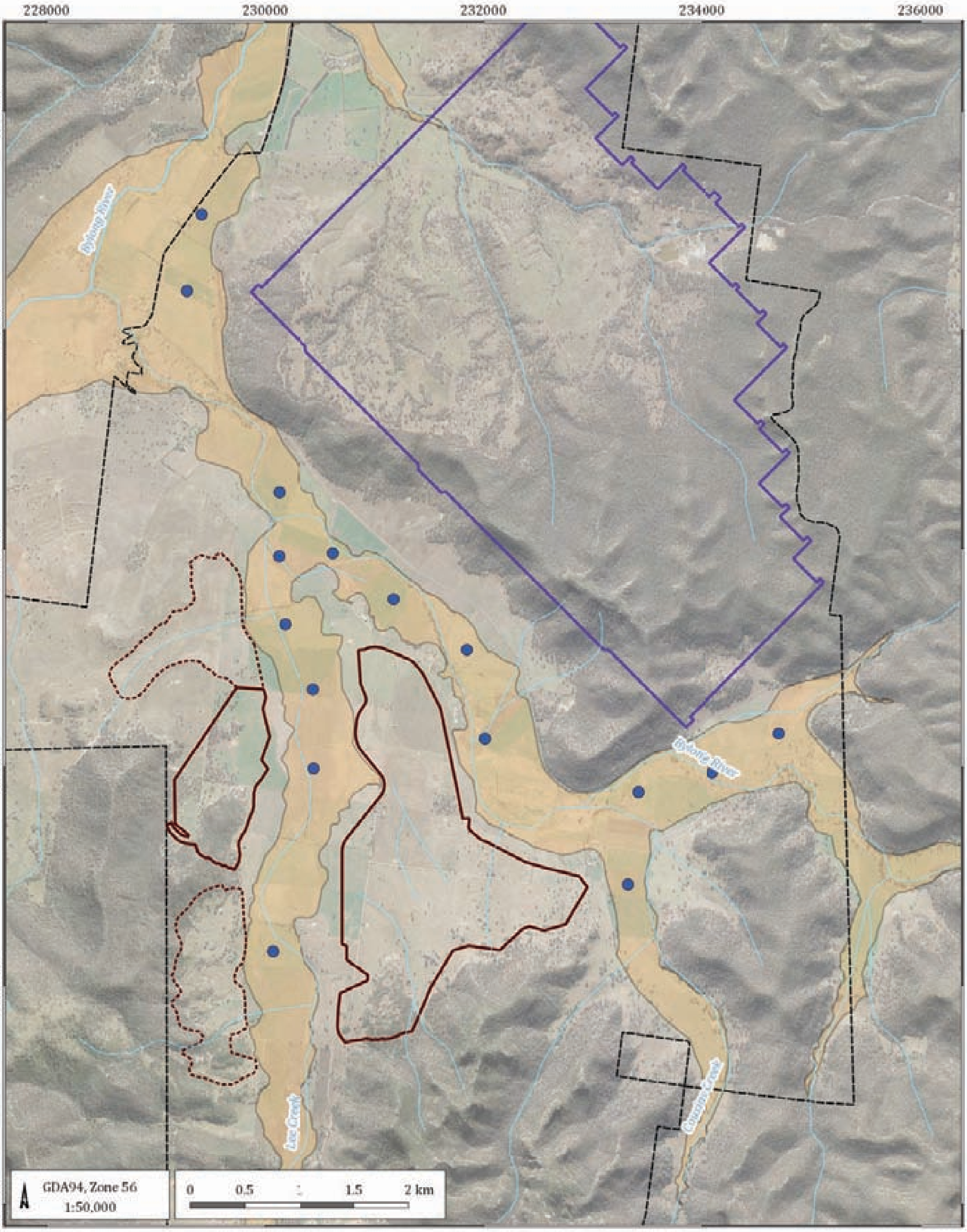
The analysis works by running many different versions of the model with slightly altered parameters to assess the relationship and implications to an observation data point, and/or a predictive impact occurring. For the purposes of this assessment, the hydraulic parameters of the alluvium, colluvium, weathered Permian, and contact between the Permian to the Alluvium was explored.

The range of parameters explored in the linear uncertainty analysis were based on the 95th confidence interval of expected upper and lower bounds. These ranges were based on field testing data, where available, and range presented in literature where data is sparse. Table 4 summaries the bounds on the linear uncertainty analysis.

Table 4 Linear uncertainty analysis parameter ranges

Parameter	Parameter number	Description	Lower bound	Mean	Upper bound
Horizontal hydraulic conductivity (m/day)	hc01	Upper Alluvium parameters	0.152	4.2	17.7
	hc02	Lower Alluvium parameters	0.152	10.1	35.4
	hc03	Colluvium parameters	0.046	0.46	4.6
	hc04	Weathered parameters	0.02412084	0.2412084	2.412084
hydraulic conductivity (m/day)	vhc01	Upper Alluvium parameters	0.001	0.392	0.7
	vhc02	Lower Alluvium parameters	0.001	0.351	0.5
	vhc03	Colluvium parameters	0.001	0.1	0.5
	vhc04	Weathered parameters	0.001	0.5	0.5
	vhc06	Interburden (layer 4) parameters	0.001	0.1	0.5
Specific yield (m^{-1})	sy01	Upper Alluvium parameters	0.01	0.03	0.1
	sy02	Lower Alluvium parameters	0.01	0.06	0.15
	sy03	Colluvium parameters	0.002	0.02	0.2
	sy04	Weathered parameters	0.01	0.1	0.1
Specific storage (m^{-1})	ss01	Upper Alluvium parameters	0.001	0.001	0.0125
	ss02	Lower Alluvium parameters	0.005	0.005	0.01875
	ss03	Colluvium parameters	0.0001	0.001	0.01
	ss04	Weathered parameters	0.00002	0.0002	0.002

Parameter	Parameter number	Description	Lower bound	Mean	Upper bound
Rainfall recharge (proportion of recharge rate estimated from soil moisture spreadsheet)	rch01	% of rainfall on alluvium	1	14	18
	rch02	% of rainfall on colluvium	0.5	2.794147	10
	rch04	% of rainfall on regolith	0.001	0.1	1
	rch01tr	% of rainfall on alluvium	30	100	150
	rch02tr	% of rainfall on colluvium	0.5	50	10
	rch04tr	% of rainfall on regolith	0.001	1	1
Irrigation return (proportion of volume of water pumped by irrigators)	irrig	% of rainfall from irrigation	0.01	0.05	0.1



LEGEND

- Modelled Bore Locations
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Project Boundary
- Quaternary alluvium
- Major drainage
- Minor drainage

Bylong Coal Project (G1606E)

Borefielc layout simulated

DATE 14/3/2016

FIGURE No: **38**

Figure 39 shows the uncertainty in the borefield yield determined from the linear uncertainty analysis. The graph shows how the total yield from the 16 bores varies as the parameters are adjusted to account for uncertainty in the hydraulic properties and recharge rates. Also shown on Figure 39 is the estimated make up water requirement from the borefield presented within the EIS, and a further sensitivity analysis conducted for the response to submissions. This allows the borefield yield and makeup water requirements to be compared. The additional sensitivity analysis for 'make up' water demand assumes that groundwater seepage to the underground mine cannot supply water to the mine water circuit and therefore increases the water demand on the borefield. The supplementary report prepared for surface water outlines this additional sensitivity analysis undertaken for the makeup water supply in more detail. It is however important to note that the estimated volume of 'make up' water required from the borefield is based on the 99th percentile conditions within the water balance, and is therefore an extreme.

The graph uses different colours to represent 1, 2 and 3 standard deviations from the mean borefield pumping rate which in a normal distribution are equivalent to the 84.1st, 97.7th and 99.9th percentiles. The assumption of linearity generated some negative values of pumping that were removed to generate the figure.

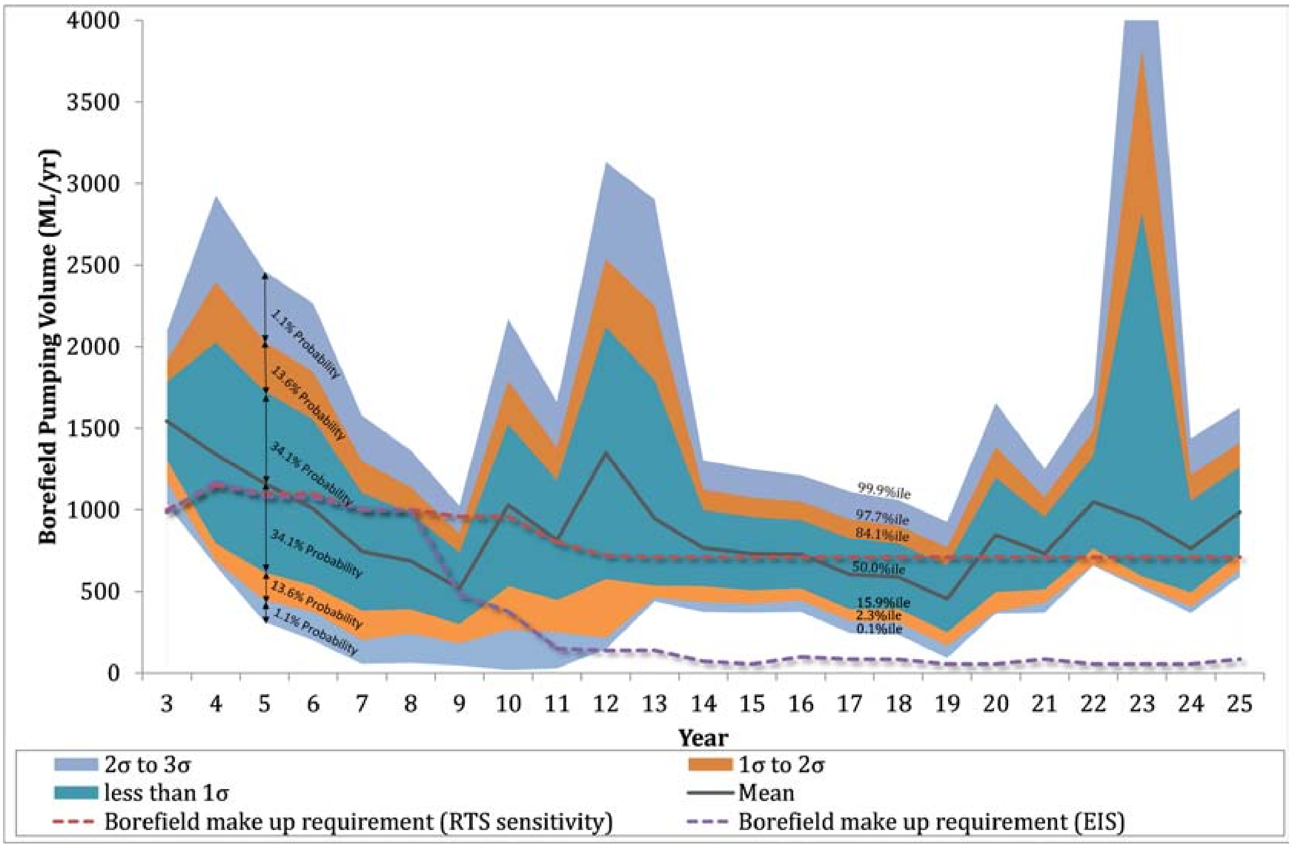


Figure 39 Uncertainty in borefield yield

Figure 39 shows a cyclical trend, with the yield from the borefield falling in response to drought represented in the recharge data, following by an increase in the yield when the drought breaks. This cycle occurs twice during the Project life as shown by the peaks in the figure. It indicates, that as one would expect, as a drought continues the probability that the borefield can supply the Projects 99th percentile 'make up' water demands reduces, as water levels within the aquifer falls. The graphs show in the last two to three years towards the end of the drought the probability that the borefield can supply the available water decreases. The average yield from the borefield is generally similar to the makeup water demands except for these periods towards the end of a drought.

Figure 39 highlights the yield from the borefield will depend on climate conditions during mining. There may be a need to expand the borefield outside the Project Boundary towards the end of a drought, reduce the rate of mining to reduce water demand or source water makeup water from an alternative source. Again, it should be noted this outcome is based on the extremes in both the groundwater and surface water models and should be considered a conservative outcome.

As noted within the EIS, KEPCO have secured a large landholding which means there is only one private property with active pumping bores that is in close proximity to the proposed borefield.

The uncertainty analysis process provides information on how influential the hydraulic parameters are to the calibrated solution. The results show the information in the alluvial observation dataset is highly influential to hydraulic conductivity in layer 2 and transient diffuse rainfall recharge to the alluvium. This is because the short rainfall events represent a small weighting to the calibration.

The code GENLINPRED provides information on the contribution of a parameter to the variance of a prediction. In this instance, the prediction is the mean borefield yield. Variance is equal to the square of the standard deviation; however, the standard deviation is not additive, so the sum of the variance presented is equal to the total standard deviation of dewatering.

Figure 40 presents the mean predictive variance of daily borefield supply rates over the 25 year model simulation period for the prior and posterior solutions (Table 4 identifies the codes used on the x-axis). The results show that recharge to the alluvium and the hydraulic conductivity of layers 1 and 2 are the highest contributors to the uncertainty of the dewatering volume. The storage parameters and recharge rates to the weathered Permian formation are also high contributors. The results also suggest that the information in the calibration dataset does little to reduce the uncertainty of the sustainable yield, and the value of the planned pumping tests within the alluvium.

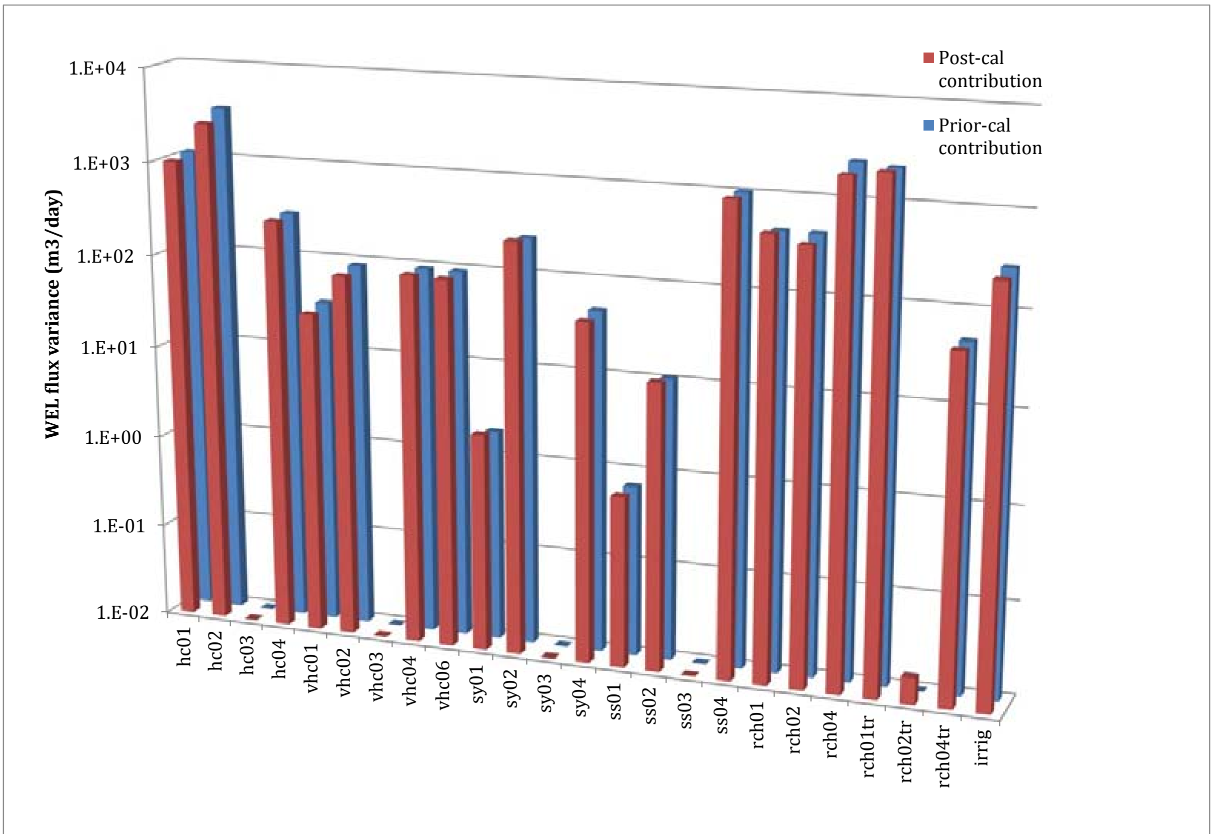


Figure 40 Parameter contribution to uncertainty in borefield yield

5.4.2 *Groundwater drawdown*

Figure 41 shows the range in maximum drawdown predicted at the private water supply bores on the 'Tinka Tong' property, and other bores outside of KEPCO land by the linear uncertainty analysis.

The results show that the majority of landholder bores experience drawdown less than 2 m. Based on the modelling, in 40% of the model runs the bores GW022518 and GW047394 experience groundwater drawdowns of greater than 2 m. The locations of the bores in the figure below are shown on Figure 43 to Figure 45.

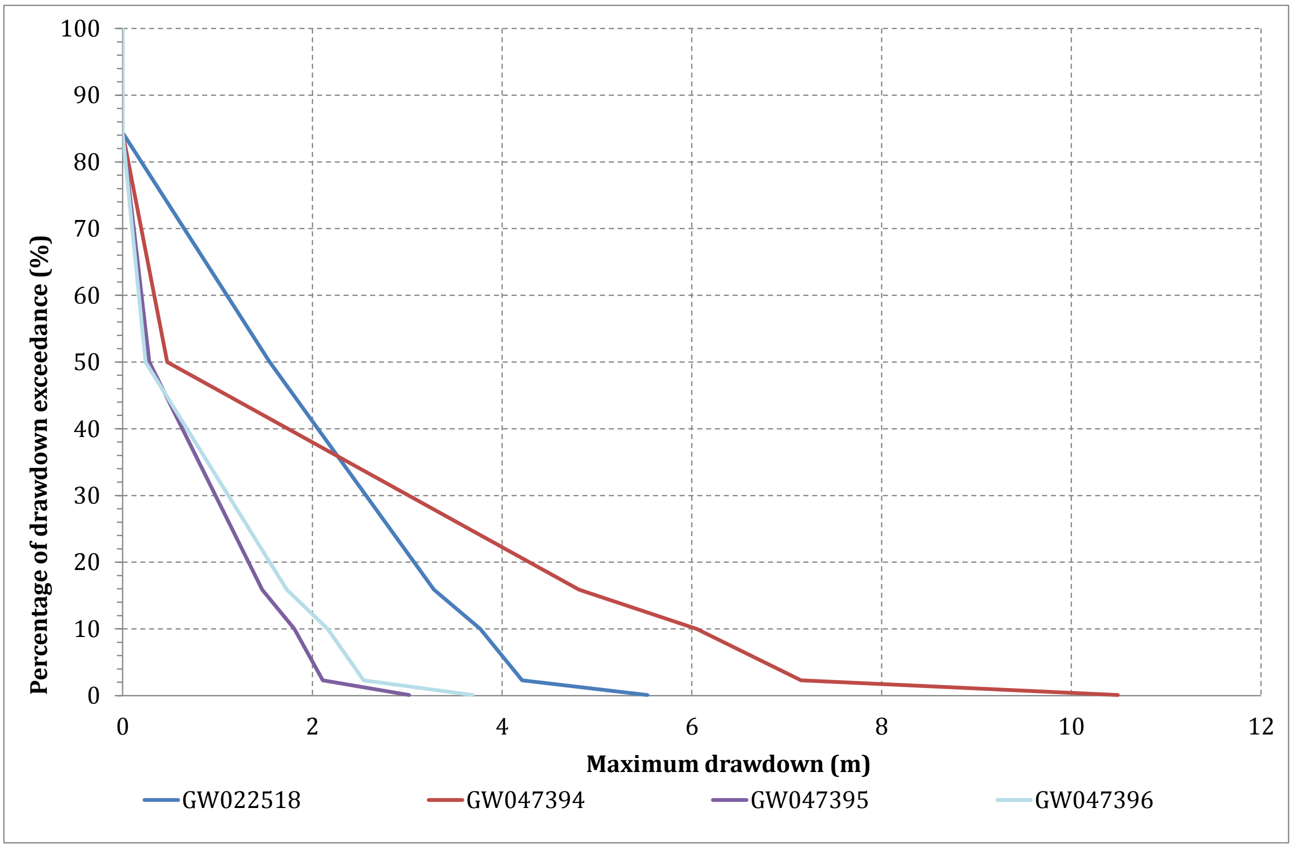


Figure 41 Private water supply bores - drawdown exeedence curves

Figure 42 presents the mean predictive variance of maximum drawdown at the bores on the Tinka Tong property (GW022518 and GW047394). The results show that similar to borefield volume, the parameters associated with the layer 2 alluviums are highly influential.

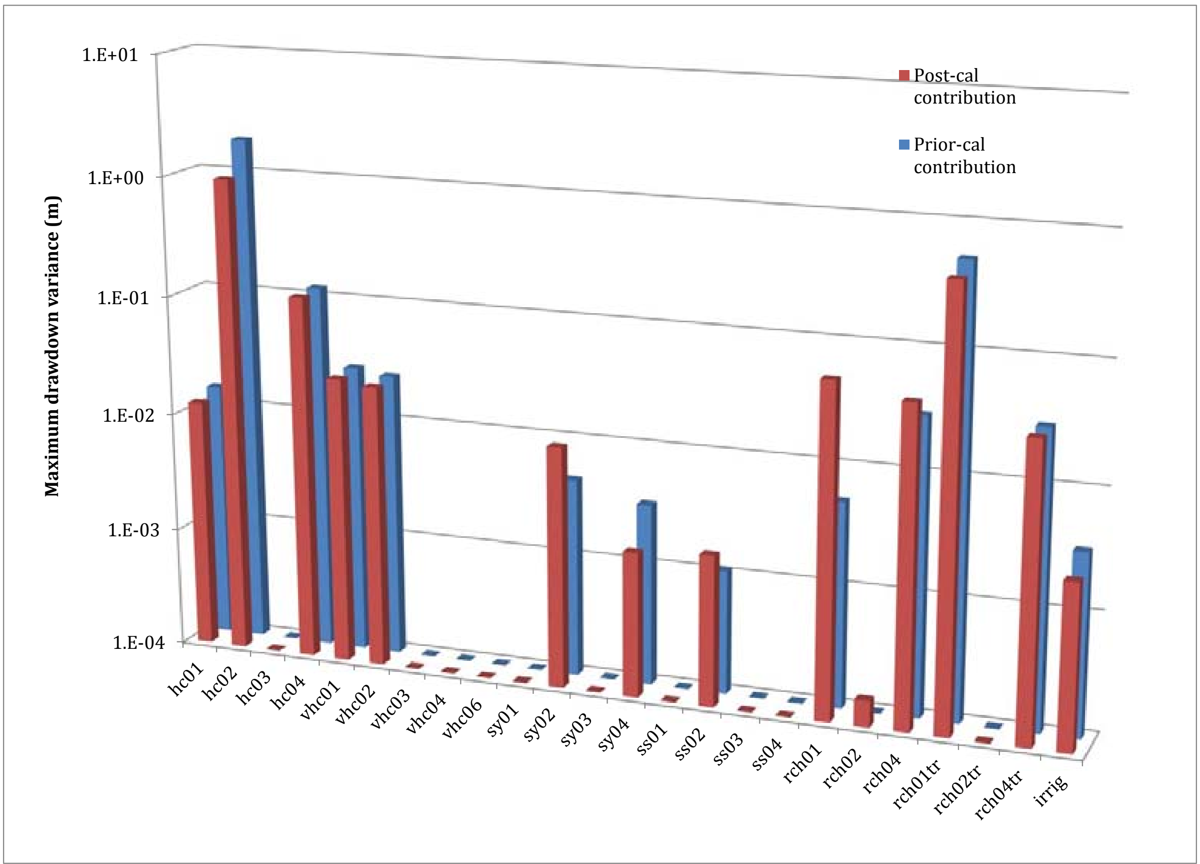
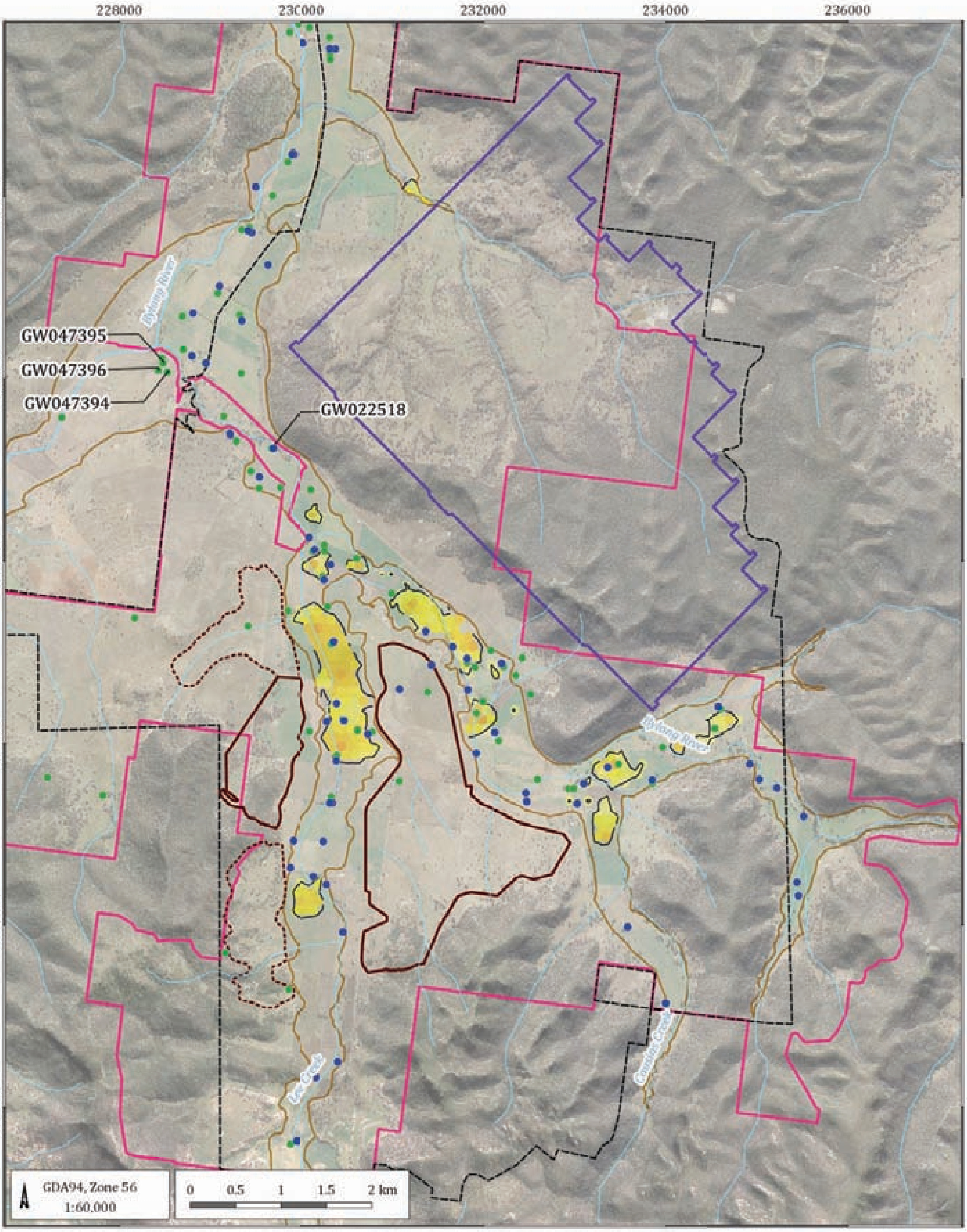


Figure 42 Parameter contribution to uncertainty in drawdown

A number of stakeholders commented the hydraulic properties used to represent the Permian strata and requested modelling with alternative combinations of parameters. The following additional sensitivity analyses were undertaken:

- reducing the specific storage in the Coggan coal seam to 2 x 10^{-5} m^{-1};
- increasing the specific storage in the colluvium to 0.001;
- reducing the contrast between the vertical and horizontal hydraulic conductivity of the Triassic and Permian rock units to a minimum of two orders of magnitude; and
- increasing the contrast between the vertical and horizontal hydraulic conductivity of the Triassic and Permian rock units to one order of magnitude.

Figure 43 to Figure 45 shows the maximum drawdown predicted by the model within layer 2 (alluvium) for the above scenarios. The figures illustrate the mean, and three standard deviations from the mean (0.1st and 99.9th percentiles) which are essentially the upper and lower boundary of impacts. Figure 46 shows the changes to drawdown that occurred in the model when changing the vertical hydraulic conductivity.



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Project Boundary
- KEPCO owned land
- Quaternary alluvium
- Monitoring bore
- Registered bore (Pinneena)
- Major drainage
- Minor drainage

2m drawdown contour (m)

Drawdown (m)

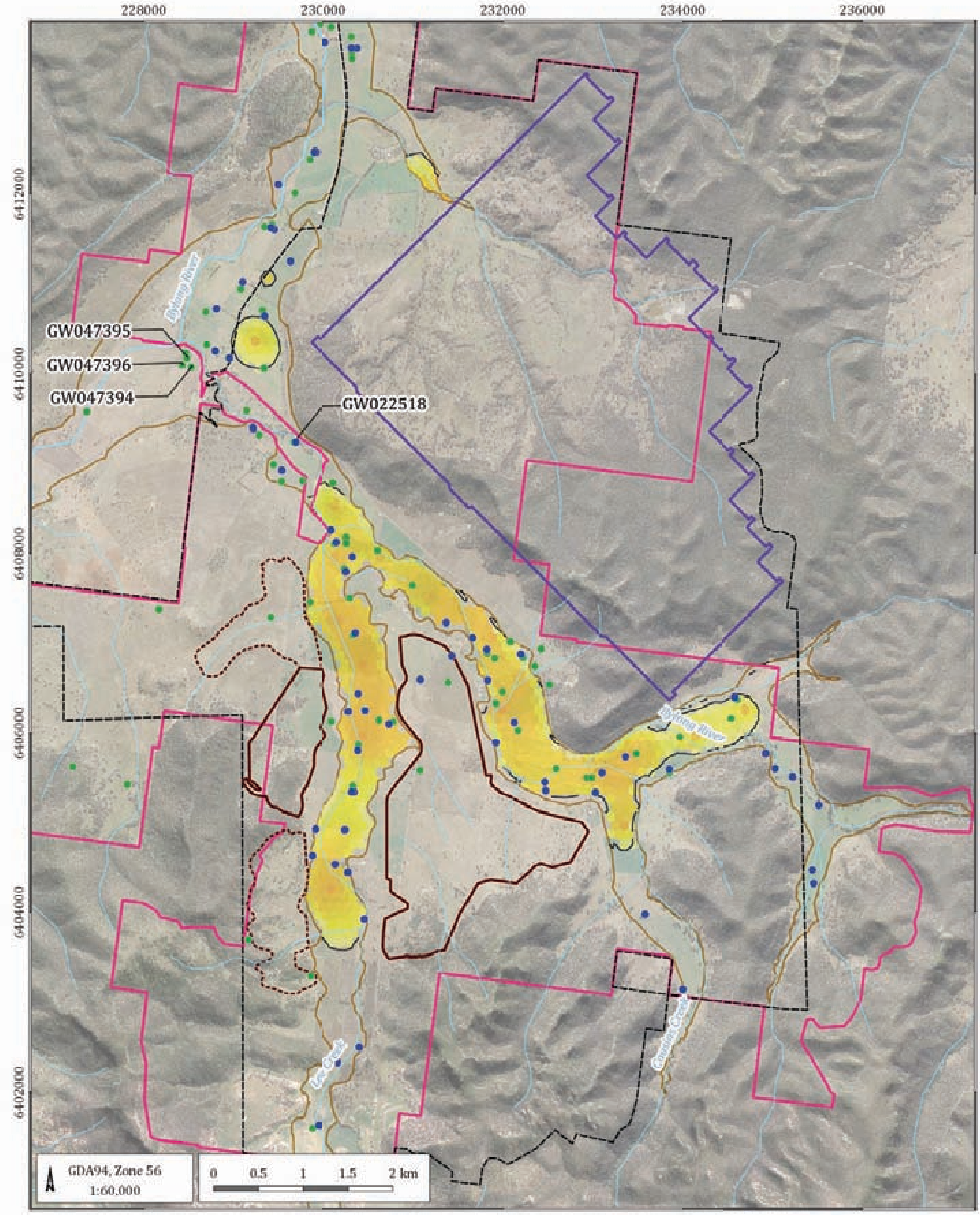
- 2
- 3
- 5
- 10

Bylong Coal Project (G1606E)

Uncertainty of drawdown to aquifer parameters - alluvium (layer 2) - 0.1th percentile

DATE 14/3/2016

FIGURE No: **43**



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Project Boundary
- KEPCO owned land
- Quaternary alluvium
- Monitoring bore
- Registered bore (Pinneena)
- Major drainage
- Minor drainage

— 2m drawdown contour (m)

Drawdown (m)

- 2
- 3
- 5
- 10

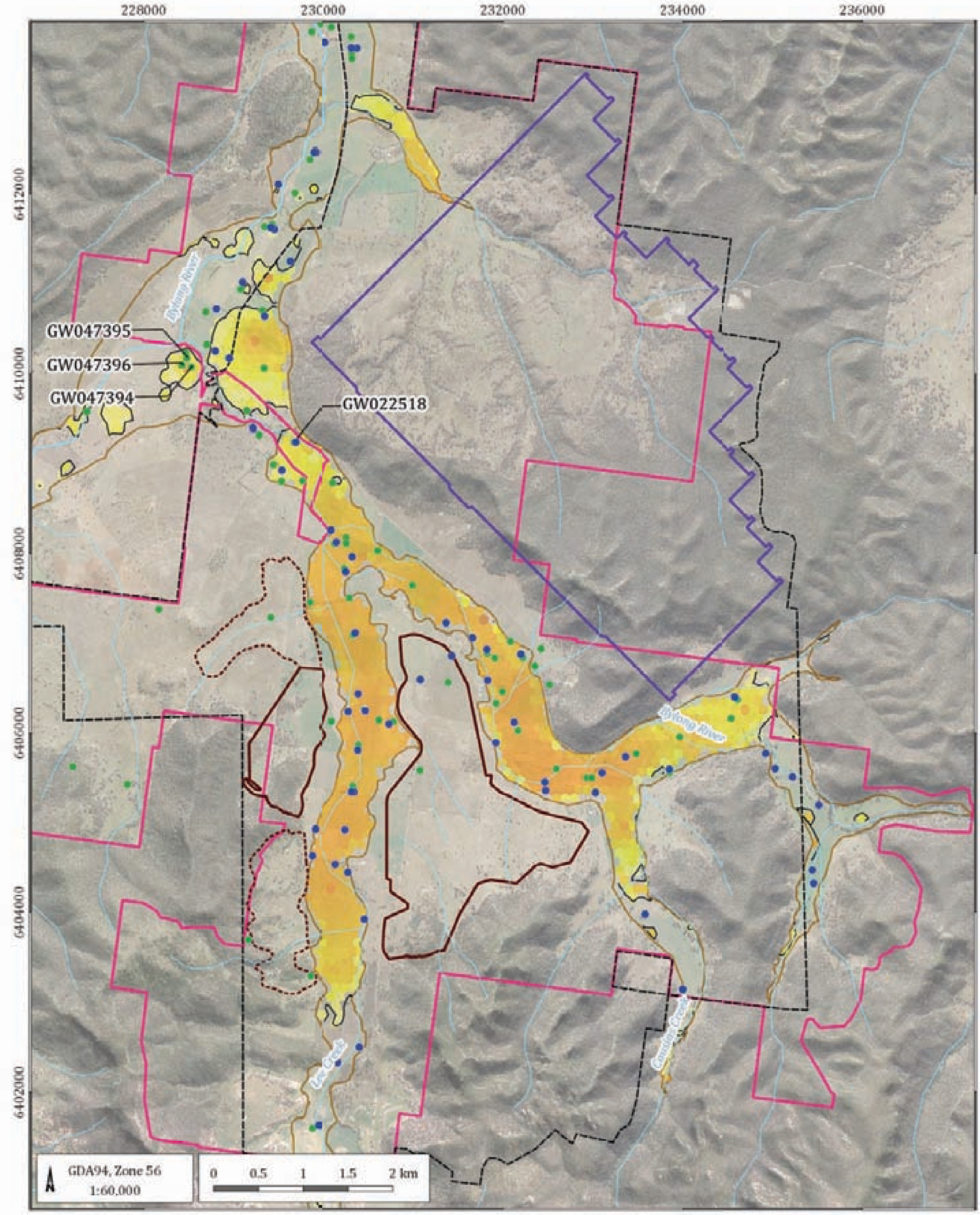
Bylong Coal Project (G1606E)

Uncertainty of drawdown to aquifer parameters - alluvium (layer 2) - mean

AGE GROUNDWATER & ENVIRONMENTAL

DATE 14/3/2016

FIGURE No: **44**



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Project Boundary
- KEPCO owned land
- Quaternary alluvium
- Monitoring bore
- Registered bore (Pinneena)
- Major drainage
- Minor drainage

— 2m drawdown contour (m)

Drawdown (m)

- 2
- 3
- 5
- 10

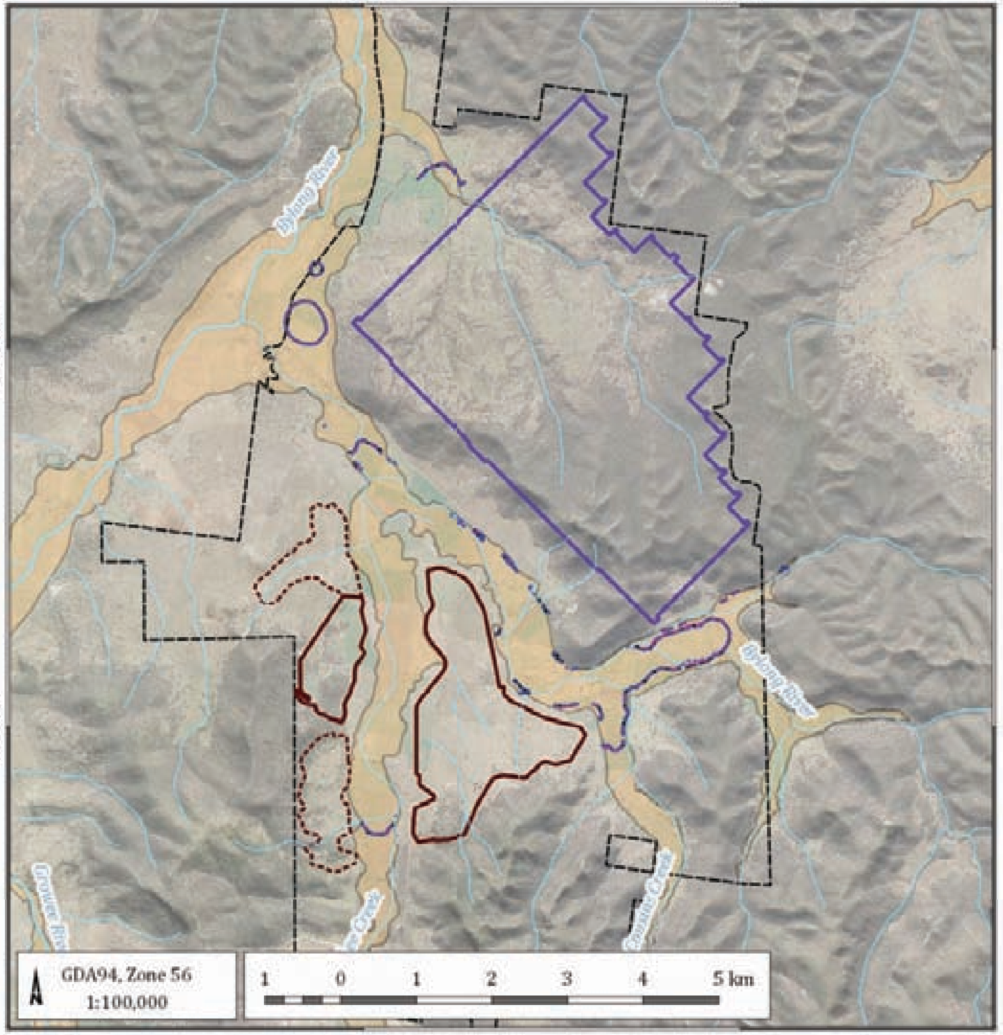
Bylong Coal Project (G1606E)

Uncertainty of drawdown to aquifer parameters - alluvium (layer 2) – 99.9th percentile

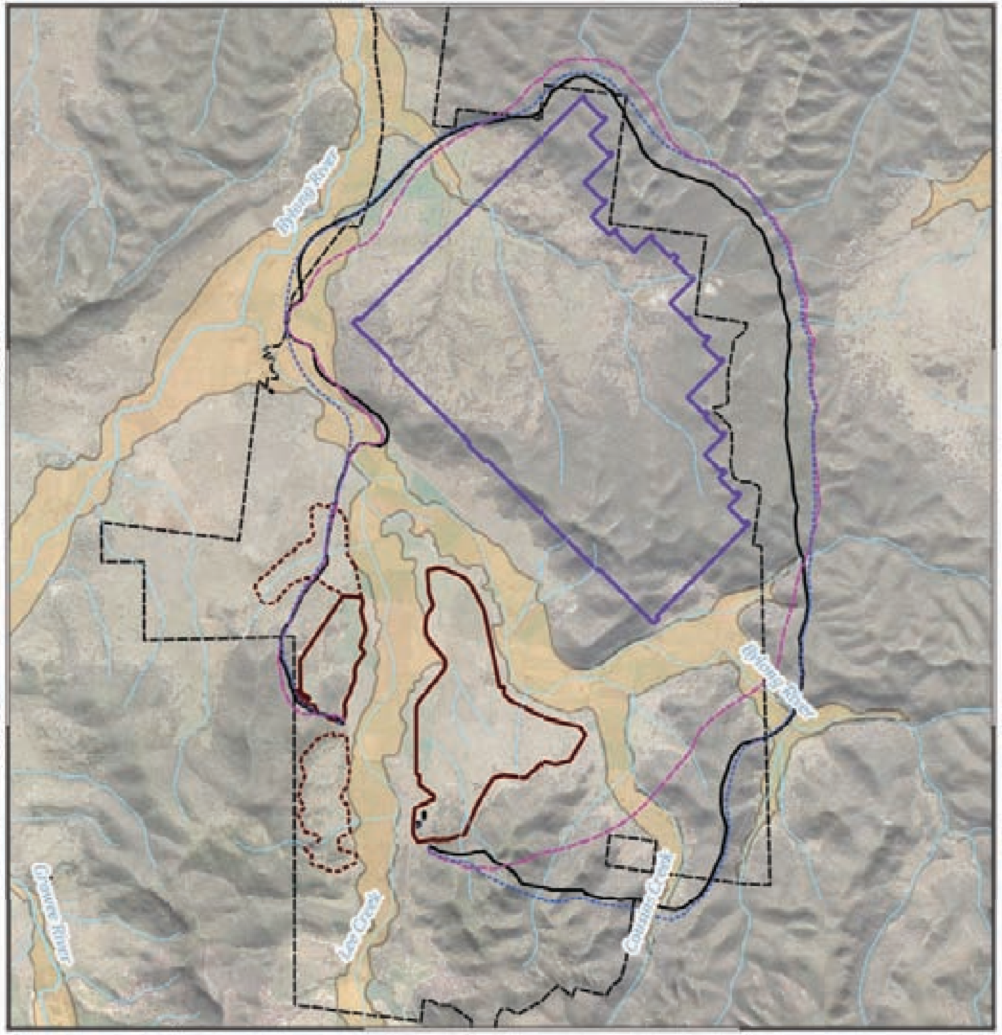
DATE 14/3/2016

FIGURE No: **45**

Alluvium (layer 2)



Coggan Seam (layer 8)



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Project Boundary
- Quaternary alluvium
- Major drainage
- Minor drainage

2m drawdown contour sensitivity

- vk-
- vk+
- base

Bylong Coal Project (G1606E)

Sensitivity of drawdown to aquifer parameters - alluvium (layer 2) and Coggan Seam (layer 8)

DATE
14/3/2016

FIGURE No:
46

6 Discussion and conclusions

6.1 Conceptual understanding of geology and groundwater regime

The conceptual understanding of the geology within the Project Boundary has been augmented and refined since publication of the EIS. Assessment of borehole data and the additional monitoring rounds has developed the geological characterisation in terms of stratigraphy and lithological controls on groundwater flow. A revised stratigraphic column is presented in Section 3 as Figure 1.

The inferred groundwater head maps presented in Section 4 provide a further indication of the hydraulic characteristics of the geology in terms of hydrostratigraphic groupings. It should be noted that the formations assessed as part of this study are typically heterogeneous in terms of grain size variations. The bore logs often indicate a spectrum of clay/silt to sand grade material is present depending on the lateral and vertical location of a bore within a particular formation.

The lithological heterogeneity is also evidenced by the large range in hydraulic properties measured in the area. This is shown graphically in the box and whisker plot of hydraulic conductivity for coal and non-coal units presented in Figure 16 and Figure 17 respectively. The depositional environments interpreted for the sedimentary units are typically ones of fluctuating energy within a fluvial and coastal margin system. These environments lead to mixed silt (low energy) and sand (higher energy) deposits. This in turn leads to a strong scale-dependence of measured hydraulic properties. Testing small volumes, such as with slug tests and packer tests, leads to high ranges in observed values.

Similar to the geology the conceptual understanding of the groundwater regime at the Project has been enhanced through the revised numerical model and the increased groundwater monitoring data that has been collected since the EIS.

The groundwater flow regime is broadly considered one of relatively high recharge through the alluvium and more limited recharge where the Permian and Triassic bedrocks form steep and undulating hills. Available data shows a typical conceptual model of groundwater moving from the elevated areas such as in the proposed longwall mining area towards the low-lying flood plain. This involves groundwater in higher areas moving both horizontally along lower permeability strata and downwards through the strata due to lower pressures in underlying layers. Within the flood plain, the system transitions from downward flow in the hills to upward flow and slow seepage of groundwater into the alluvium and creek systems. This conceptualisation is supported by the vertical hydraulic gradient data obtained from the VWPs and monitoring bores.

Within this conceptualisation, there is some uncertainty at a local level due to groundwater flow being controlled to varying extents by observed intra- and inter-formational heterogeneity in the rock units. Dipping beds, faulting and igneous intrusions all influence groundwater levels and hydraulic gradients.

6.2 Water security and borefield design

Section 5.4.1 outlined the modelled borefield yield and the potential uncertainty range in this estimate due to the foreseen uncertainty within the model parameters. This modelling was based on a borefield within the alluvium of the Project Boundary comprising 16 separate bores spaced at 700 m apart. This allowed the borefield yield and makeup water requirements to be compared. The additional sensitivity analysis for 'make up' water was highly conservative assuming there was no groundwater available from the underground mine to supply the mine water circuit which further increases the water demand on the borefield. On top of this unlikely outcome the estimated volume of 'make up' water required from the borefield is based on the 99th percentile dry conditions in the surface water balance and is therefore an extreme.

The uncertainty in the estimate of the borefield yield is due to uncertainties in future rainfall recharge as well as hydraulic properties. Whilst some initial test pumping has been undertaken on existing farm bores (WorleyParsons [2015]), additional testing in new bores with adjacent monitoring bores would serve to reduce the uncertainty further. Section 13.6 of the Groundwater Impact Assessment prepared for the EIS made this recommendation, and KEPCO had commenced this work at the time of writing.

Whilst stakeholders requested locations for any additional bores required to maintain yields from the alluvial borefield during drought, at this stage it is not appropriate to provide locations of additional bores. The locations of additional bores will depend on the results of test pumping commencing in mid-March 2016, as well as climatic conditions at the time of mining. KEPCO owns a large landholding within and adjacent to the Project Boundary and this area remains a potential location for additional water supply bores if expanding the Projects borefield is necessary to maintain make up water volumes during drought. Ultimately if the borefield cannot sustainably supply the required make up water during drought then KEPCO will implement measures described within the Water Management Plan. This may include purchasing additional entitlements on the water market if available, the redundancy of KEPCO agriculture activities that extract water from bores to progressive reduction in the mining activities that consume water.

Section 7.2.2 outlines how the Water Management Plan will address the management of this potential issue.

6.3 Water licensing

The EIS estimated the peak take of water from the Permian groundwater systems at approximately 2109 ML. Stakeholders commented that KEPCO does not currently hold a licence under Part 5 of the Water Act to account for the take of water from the Triassic and Permian groundwater system (sometimes referred to as the hard rock). Since submission of the EIS KEPCO have lodged an application for a Water licence under Part 5 of the Water Act and DPI-Water are currently considering this application. It is also relevant to note that since submission of the application for a water licence, DPI Water have changed the approach to water management in the Hunter valley in preparation for commencement of the 'Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources. This water sharing plan which is planned to commence in July 2016 will replace provisions under the Water Act 1912, and bring the management of all remaining groundwater to the North of Sydney under the Water Management Act 2000. This legislation separates water and land rights and allows trading of water via the market. In the interim period until the new water sharing plan commences in July 2016, the DPI-Water will allow trading of groundwater entitlements on a market basis, rather than seeking a new licence from the Government. An embargo for new licences has been issued in these areas, meaning that new licences will no longer be issued by the Government, however it is understood existing applications will be granted under the Water Act 1912.

KEPCO will acquire sufficient water licenses to account for the predicted water take, prior to that water take occurring. KEPCO welcome the changes to water management and implementation of trading, as it will allow the Project to acquire licenses in preparation for periods when water take is forecast to be high, and to also sell licences when demand is lower or adjust licensing when updates to the groundwater model provide more accurate forecasts. The key benefit of this approach is that KEPCO will not need to acquire the full entitlement for periods when it is not using this entitlement. This means water is not unnecessarily removed from water market by 'over licensing' which prevents water being available to other water users who could benefit from its availability.

Stakeholders also noted, that whilst KEPCO currently hold sufficient entitlement to account for take of surface and alluvial waters, the seasonal availability of water within the alluvial aquifer may mean the full entitlement may not be obtainable during dry periods. If seasonal water assignments (announced allocations) reduce the volume of water that can be accounted for with KEPCOs entitlements then, KEPCO will implement measures described within the Water Management Plan. This may include the purchasing water on the water market, redundancy of KEPCO agriculture activities that extract water from bores to progressive reduction in the mining activities that consume water. Section 7.2.2 outlines how the Water Management Plan will address this issue.

A stakeholder commented that information on volumes of 'water take' did not present the take of water from the basalts, or break down the take from other units. The 'water take' estimates provided within the EIS were based on the requirements to breakdown water take according to each water sharing plan and the Aquifer Interference Policy at the time the EIS was prepared. The inflow to the underground and open cut mines therefore represents the 'water take' from the bedrock units lumped together, whilst a separate 'water take' from the alluvial aquifer was provided which is under a separate water sharing plan.

6.4 Setback distance

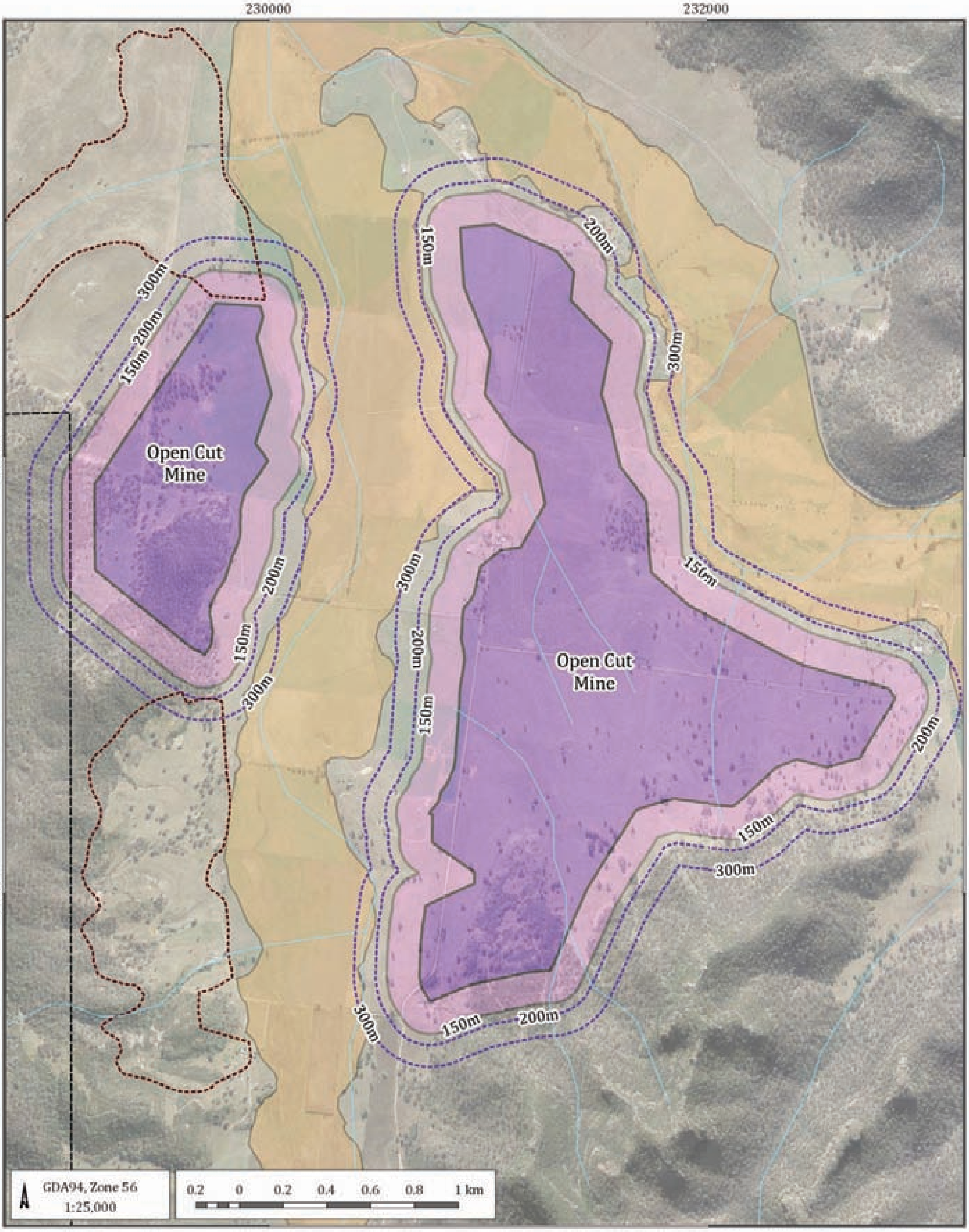
A stakeholder commented that the setback distances from the alluvium were determined from the alluvium as depicted on broad scale mapping, and that there is potential for this mapping to be inaccurate. The stakeholder recommended the alluvial boundary be verified by field work using the mine plans to ensure the alluvium setbacks are maintained in the field.

During the EIS process it was recognised that the publically available mapping of the extent of the alluvium would not be of sufficient detail and accuracy for the purposes of the Project. As part of developing the EIS, KEPCO commissioned Douglas Partners to refine the mapping of the alluviual boundary. Douglas Partners used multiple datasets to locate the boundary between the unconsolidated alluvial sediment and the consolidated bedrock outcrop including:

- aerial photography viewed through stereoscope;
- fine scale 0.25 m contours from LIDAR datasets;
- lithological data from bores; and
- lithology inferred from cone penetration tests.

The aerial photography and the LIDAR contours identified the break of slope and flood plain where alluvial sediments accumulate. The inferred boundary was then verfied by reviewing lithological logs from drilling and cone penetration tests. Figure 47 and Figure 48 shows the outcome of the mapping identifying the extent of the alluvial and colluvial sediments adjacent to the proposed open cut and underground mining areas respectively.

Douglas Partners seperated the unconsolidated material into 'valley alluvium' referring to coarser grained sediments occuring along the floor of the main valleys, and 'gully colluvium' comprising finer sediments occuring outside the main valleys in areas elevated above the main valley floor. The mine plan as assessed in the EIS was designed to remain at least 150m back from the identified extent of alluvial sediments.



LEGEND

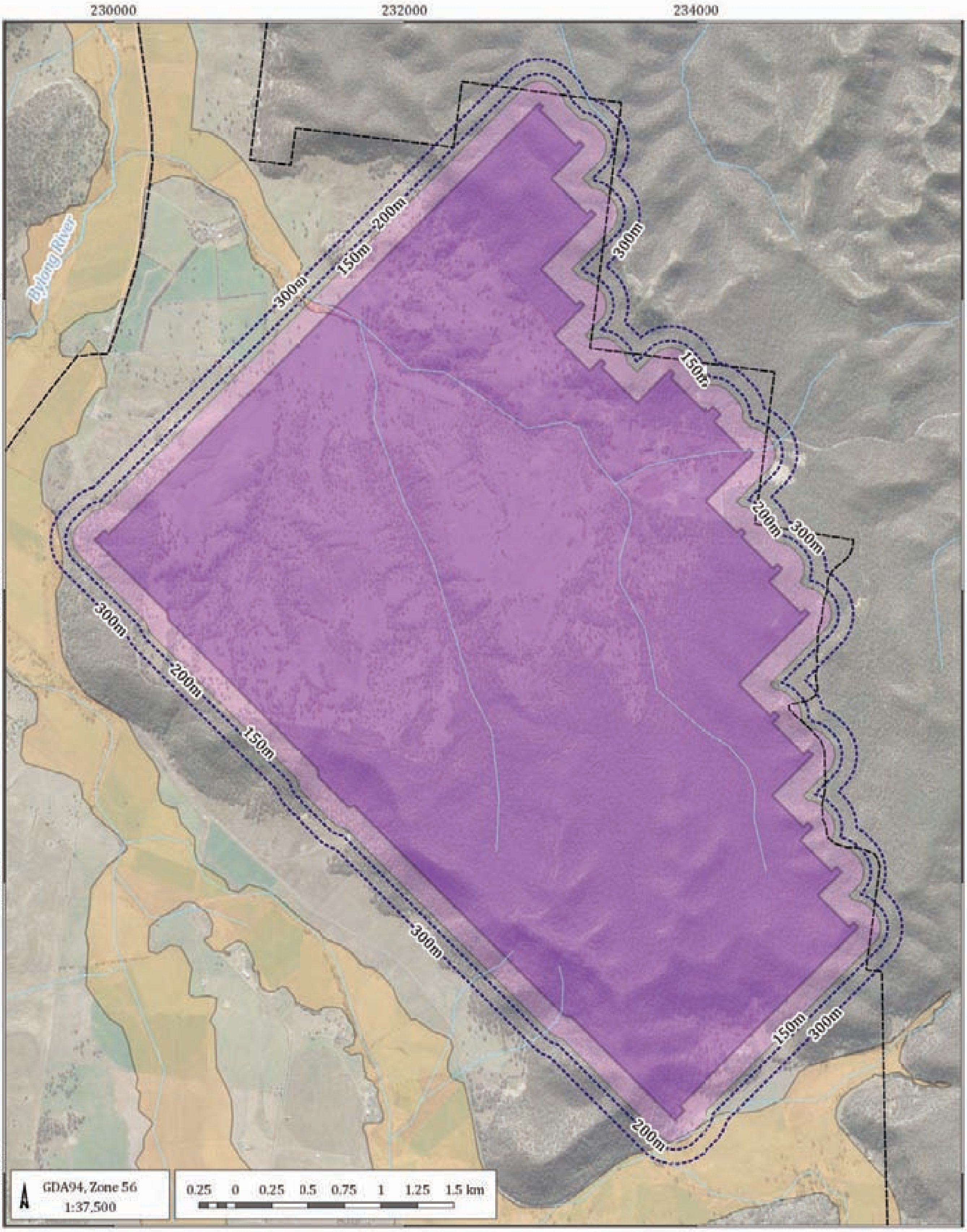
- Overburden Emplacement Area
- Project Boundary
- Open cut footprint
- Open Cut footprint 150m buffer
- Open Cut footprint 200m & 300m buffer
- Quaternary alluvium
- Major drainage
- Minor drainage

Bylong Coal Project (G1606E)

Buffer zone and set back of open cut pits from alluvial aquifer

DATE 14/3/2016

FIGURE No: 47



LEGEND

- Underground Extraction Area
- Underground extraction area 150m buffer
- Underground extraction area 200m & 300m buffer
- Project Boundary
- Quaternary alluvium
- Major drainage
- Minor drainage

Bylong Coal Project (G1606E)

Buffer zone and set back of underground mine from alluvial aquifer

DATE 14/3/2016

FIGURE No: **48**

6.5 Water quality impacts

The EIS considered the impact of the proposal to emplace coarse and fine reject materials into the overburden emplacement areas and Western and Eastern Open Cut Mining Areas during the years of open cut mining operations, as well the disposal of reject materials generated during the underground mining operations within a compartment within the Eastern Open Cut Mining Areas after mining is completed.

The EIS utilised a simple salt balance to estimate the changes in salt load from the mining areas to the adjacent alluvial aquifer and streams using information from the geochemistry, groundwater and surface water studies. The salt balance concluded salinity within the alluvial groundwater could increase by some 12%, but this increase would not change the beneficial use of the water, which would remain fresh.

Stakeholders commented a more rigorous method to assess the potential for changes in salinity would be to utilise a contaminant transport model coupled with the numerical groundwater flow model developed for the EIS.

It is agreed with the comment in the submission that a contaminant transport model can better represent the formation of any plumes emanating from the buried rejects materials, however it is considered that contaminant transport modelling is not warranted at this stage of the Project. This is because the EIS which used conservative assumptions on salinity released from the rejects materials indicated a low risk to water quality. As the risk was identified to be low, more sophisticated methods were not considered to be warranted at this stage. Section 7.2.8 discusses measures to be documented within the Water Management Plan for ongoing monitoring of waters that come in contact with the rejects materials and a post closure monitoring program.

7 Groundwater management

7.1 Water sharing plan rules

A stakeholder commented that the proposed activities, particularly the borefield may influence triggers to establish at the DPI - Water reference sites that are installed as part of developing ‘cease to pump’ triggers.

The Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources commenced on 1 August 2009. It requires a groundwater trigger for the ‘cease to pump’ rule to be determined by Year 10 of the Water Sharing Plan for the Bylong River water source. Year 10 of the Water Sharing Plan will commence on 1 August 2018. If approved, the Project is expected to commence open cut mining in Year 3, which will not be before 1 August 2018. Therefore, the potential to develop the cease to pump trigger is not expected to be affected by the Project.

It could be argued that a cease to pump rule to protect surface water flow is of limited value in the Bylong River catchment as there is only limited surface water extraction, with the majority of extraction from more reliable groundwater sources. Monitoring shows the Bylong River is not perennial, and dries out to a chain of ponds, during periods of low rainfall periods naturally. Limiting groundwater extraction is of limited value when downstream users are relying on groundwater, not surface water baseflow derived from groundwater.

Should a cease to pump rule be developed, KEPCO will ensure that if the cease to pump rule applies only to bores within 40 m of surface water sources that pumping bores are located beyond this buffer zone.

7.2 Water management plan

KEPCO will develop a Water Management Plan for the Project. It will contain sections on the appropriate management of mine water and address other operational matters. It will also address how the following groundwater issues raised by various stakeholders will be managed:

- Make good agreements;
- Security of water supply;
- Setback from alluvial boundary;
- Ongoing groundwater modelling;
- Measurement of groundwater extraction;
- Monitoring bore networks;
- Measurement of stream aquifer connectivity;
- Monitoring of groundwater dependent ecosystems; and
- Post closure monitoring.

The sections below outline further how these issues will be addressed within the Water Management Plan.

7.2.1 Make good agreements

Stakeholders commented the model predictions should be used with caution due to model limitations and "Make Good provisions" should be implemented at the immediate onset of mining to ensure remaining landowners within the vicinity of the Project endure no adverse impacts to their agricultural operations.

It is usual practice for the regulator to mandate conditions for a proponent to provide a compensatory water supply to any landowner of privately-owned land whose water supply is adversely and directly impacted as a result of the development (other than an impact that is predicted in the EIS to below the minimal impact considerations outlined within the Aquifer Interference Policy).

Compensatory water supply measures will provide an alternative supply of water that is equivalent to the loss attributable to the mine development. Equivalent water supply will be provided as soon as practicable from the loss being identified as a result of the Project, unless otherwise agreed with the landowner. The Water Management Plan will set out the process by which potential impairment of landholder bores will be assessed and compensatory arrangements in the form of make good agreements.

A make good agreement is a legal agreement entered into by KEPCO and a landholder about a water bore. In the Water Management Plan KEPCO will commit to undertaking baseline assessments of water bores that are considered to potentially be impacted by the Project, or are not predicted to be impacted but remain within relatively close proximity. The baseline data will serve as the reference point for subsequent assessment of impaired capacity related to mine operations. The Water Management Plan will include trigger levels for investigating potentially adverse impacts on water supplies.

During the preparation of the response to submissions, KEPCO has consulted with land owners from properties surrounding the Project. During this consultation, KEPCO has agreed to install electronic data loggers to record groundwater levels at several surrounding properties including 'Budden', 'Murrumbo', 'Wigelmar' and 'Rothesay' to gather baseline data.

The make good agreement will be a legally binding agreement between KEPCO and the bore owner. The agreement will include make good measures arrived at by negotiation between KEPCO and the landholder. These measures may include rehabilitating or deepening existing bores, drilling new deeper bores, piping water from other sources or financial compensation. KEPCO will compensate the bore owner for any reasonable accounting, legal or valuation costs incurred during the negotiation process, other than the costs of a person facilitating alternative dispute resolution if requested by the bore owner.

7.2.2 Security of water supply

The EIS groundwater modelling and supplementary modelling completed for the Response to Submissions indicates that whilst the alluvial aquifer can be used as a source of 'make up water' for the Project, during extended drought it may fail to supply the Project's needs. In this case KEPCO will implement measures described within the Water Management Plan. This may include the purchasing water on the water market, redundancy of KEPCO agriculture activities that extract water from bores to progressive reduction in the mining activities that consume water.

7.2.3 Ongoing groundwater modelling

The Water Management Plan will describe a program to validate the water balance, salt balance, surface water model and groundwater model for the development every three years, and compare against monitoring results with modelled predictions. This will include considering the most appropriate code for the groundwater model at this time.

7.2.4 Measurement of groundwater extraction

Stakeholders commented that KEPCO should record water use from mining and agricultural enterprises within the Project Boundary by fitting an appropriate measurement device to all extraction points and any relevant transfer or pump locations on the mine site.

The Water Management Plan will outline the process of recording groundwater usage in accordance with the relevant regulatory requirements. All pumping bores for mine water use installed within the Project Boundary will be fitted with flow meters to recording the volume and rate of water extraction. Pressure transducers will also be installed within all pumping bores to measure the influence of pumping on groundwater levels. The Water Management Plan will outline the process of recording the data, data storage and protocols for reporting and transfer of data to regulatory authorities as required.

This commitment will provide robust data on water extraction, which can be used to update the groundwater model every three years and promote sustainable use of groundwater during the life of the mining Project.

7.2.5 Monitoring bore networks

A stakeholder commented that due to uncertainty with the current hydrogeological conceptual model, future drilling and construction of a limited and reasonable number of monitoring bores into basalts and sandstones (Farmers Creek Formation, the Gap Sandstone, Watts Sandstone or other aquifers) may be required should a data gap be recognised. Prior to installing monitoring bores within the Tertiary basalt it will be necessary to define the base of the unit and determine if and where low points exist that could hold groundwater. As the Tertiary basalt will be within an offset area, there will be limited potential to disturb this area within the future, so it will be important to minimise the number of bore sites by selecting optimal locations. This process will also be required for the shallow Triassic and Permian strata and is best undertaken by developing surfaces for these units within the geological model.

The Water Management Plan to be developed in consultation with DPI-Water will outline where additional bores are necessary to augment the monitoring bore network and where data will be required on baseline conditions in the future prior to mining reaching these areas.

Any monitoring bore removed during the mining process will be replaced. The five yearly reviews of the model as committed to in Section 13.7 of the Groundwater Impact Assessment prepared for the EIS will consider the adequacy of the monitoring network to detect impacts to the groundwater regime.

The Water Management Plan will also provide a commitment by KEPCO to maintain access to the government monitoring bores that occur with the Project Boundary or on KEPCO owned land outside Project Boundary.

The Water Management Plan will also outline further hydrological analysis of the mine spoils during mining to ensure that there are no outbreaks of saline groundwater around the edge of the backfilled mining area. This will include monitoring of infiltration through the spoils and permeability of backfilled materials.

7.2.6 Measurement of Stream Aquifer Connectivity

A stakeholder requested a seepage meter be installed further downstream to gauge whether the river is losing or gaining here and see if there is a correlation with water use by other users in the area. The Water Management Plan to be developed in consultation with DPI Water will outline the installation of additional seepage meters and measure the movement of water between the streams and the aquifers.

7.2.7 Monitoring Groundwater Dependent Ecosystems

A stakeholder commented that the level of accuracy for many of the model calibration targets approximates the AIP threshold, and therefore monitoring the impacts at groundwater dependent ecosystems is a preferred action.

The Water Management Plan, to be developed in consultation with DPI-Water will include a commitment to install additional bores around the potential groundwater dependent ecosystems.

7.2.8 Post closure monitoring

A stakeholder commented that the risk for salinity increase and contaminated inflows has been recognised and management measures be implemented with additional appropriate groundwater and spoil seepage monitoring.

The Water Management Plan, to be developed in consultation with DPI-Water will include a commitment to monitor the quality of water in contact with the rejects emplacements.

8 References

Australasian Groundwater and Environmental Consultants Pty Ltd (2013), "*Bylong Coal Project Gateway Groundwater Study*", prepared for Hansen Bailey Pty Ltd, Project No. G1606/A, December 2013.

Australasian Groundwater and Environmental Consultants Pty Ltd (2015), "*Bylong Coal Project Groundwater Impact Assessment*", prepared for Hansen Bailey Pty Ltd, Project No. G1606 June 2015.

CSIRO (2015) Soil and Landscape Grid National Soil Attribute Maps - Depth of Regolith (3" resolution) - Release 2

Doherty, John. (2015) "*Watermark Numerical Computing, Calibration and Uncertainty Analysis for Complex Environmental Models".*

Fetter. C.W. 1994. Applied Hydrogeology 3rd ed. Prentice-Hall Inc.

Healy, R., Cook, P. (2002). "*Using groundwater levels to estimate recharge*". Hydrogeology Journal 10, pp91-109.

RPS Aquaterra (2012). "*Mt Penny Coal Project, Groundwater Impact Assessment",* 17 July 2012

WorleyParsons (2015). "*Preliminary Hydrogeological Assessment Report, Bylong Coal Project".* (Ref. 201015-00276-KEPBYL-640-SS-REP-6019)

Yoo et al (2001) "*A compilation of the Geology of the Western Coalfield"*