Appendix E

Groundwater Impact Assessment

Bylong Coal Project

**Gateway Certificate Application
Supporting Document**

Australasian Groundwater & Environmental Consultants Pty Ltd

REPORT on

BYLONG COAL PROJECT

GATEWAY GROUNDWATER STUDY

prepared for
HANSEN BAILEY PTY LTD

Project No. G1606/A
December 2013

Australasian Groundwater & Environmental Consultants Pty Ltd

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REPORT ON

BYLONG COAL PROJECT

GATEWAY GROUNDWATER STUDY

1 INTRODUCTION

KEPCO Bylong Australia (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). Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) have been engaged by Hansen Bailey Pty Ltd (Hansen Bailey) to undertake the groundwater impact assessment for the Project on behalf of their client Cockatoo Coal Limited (Cockatoo Coal), who has been appointed as managers for the Project. The groundwater impact assessment will be a component of the Environmental Impact Statement (EIS) for the Project.

The NSW Government has announced new safeguards under the Strategic Regional Land Use Policy (the SRLU Policy). This report addresses the requirements of the NSW Gateway process (Gateway process) which is effective from the 4 October 2013 for new State significant mining and CSG proposals DPI (2013).

Conceptualisation and numerical modelling of groundwater flows within the catchment will be completed to assess changes to the groundwater regime associated with the proposed open cut and underground mine. This document outlines the work completed to date in conceptualising the groundwater system, developing a numerical groundwater model, and using the model to predict effects from the Project.

Two stages of modelling will be undertaken. The first stage includes the development of a simple model to meet the requirements for the NSW Gateway process. As more site-specific data becomes available, the second stage will be used for impact predictions for the Environmental Impact Statement (EIS).

2 PROJECT DESCRIPTION

2.1 Overview

The Project is located wholly within Authorisation (A) 287 and A342 in the western coalfield of NSW. The closest regional town centre is Mudgee, located approximately 55 km south west of the Project. The small settlement of Bylong Village is within the central portion of the Project Boundary. Figure 2.1 shows the location of the Project in relation to the regional centres.

2.2   Mining Methods

The Project includes open cut mining areas (Eastern and Western Mining Areas) and an underground operation that utilises longwall mining methods. The Project is proposing to develop initially as an open cut, followed by more extensive underground mining operations later in the Project life. Initial open cut mining will commence following construction (approx. Year 2) and be carried out using excavators, haul trucks and other ancillary mining equipment to haul coal recovered from the Ulan and Coggan coal seams. Open cut mining will be complete by Year 10 of the Project. Underground mining will commence around Year 7 of the Project and will utilise longwall mining techniques to recover coal from the Coggan coal seam. Two decline drifts will initially be developed on the northern side of the Sandy Hollow-Gulgong Railway Line to facilitate coal clearance, materials, ventilation and employees access. The underground mine will have a life of approximately 23 years, with a total Project life of 29 years.

3   SCOPE OF WORK

The objective of the study was to address the requirements of the Gateway process. To achieve this objective the scope of work included:

- estimating quantities of water likely to be taken from each water source on an annual basis during and following cessation of the activity;

- outlining a strategy for obtaining appropriate water licence/s for maximum predicted annual water takes;

- establishing baseline groundwater conditions including groundwater depth, quality and flow based on sampling of all existing bores in the area, any existing monitoring bores and any new monitoring bores that may be required within A287 and A342;

- developing a strategy for complying with any water access rules applying to relevant categories of water access licences, as specified in relevant water sharing plans;

- providing estimates of potential water level, quality and pressure drawdown impacts on nearby water users who are exercising their right to take water under a basic landholder right;

- providing estimates of potential water level, quality and pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources;

- providing estimates of potential water level, quality and pressure drawdown impacts on groundwater dependent ecosystems;

- providing estimates of potential for increased saline and contaminated water inflows to aquifers and highly connected river systems;

- providing estimates of the potential to cause or enhance hydraulic connection between aquifers;

- providing estimates of the potential for river bank instability, or high wall instability or failure to occur; and

- outlining of the method for disposing of water inflows to a mine.

DPI (2013) fact sheets state *'this information should be based on a simple model that uses best available baseline data collected at an appropriate frequency and scale, and that is determined to be fit-for-purpose to the satisfaction of the Minister for Primary Industries. Proponents should also provide a strategy for impact assessment modelling using more detailed site specific data at the*

development application stage to better assess potential impacts. The information detailed above will be used to assess the Project against the criteria specified in 'Table 1 (DPI, 2013)– Minimal Impact Considerations for Aquifer Interference Activities' in the Aquifer Interference Policy'.

4   LEGISLATION, POLICY AND GUIDELINES

The Project will need to consider the requirements of the following NSW legislation, policy and guidelines for groundwater:

- Water Act 1912;
- Water Management Act 2000 (WM Act);
- Water Sharing Plan for Hunter Unregulated and Alluvial Water Sources ;
- Groundwater Quality Protection Policy;
- Groundwater Dependent Ecosystems Policy;
- Groundwater Quantity Management Policy;
- Aquifer Interference Policy (AIP);
- Strategic Regional Landuse Policy (SRLU Policy); and
- Strategic Regional Landuse Plan – Upper Hunter.

The Water Management Act 2000 defines an aquifer interference activity as that which involves any of the following:

- penetration of an aquifer;

- interference with water in an aquifer;

- obstruction of the flow of water in an aquifer;

- taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations; and

- disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.

Examples of aquifer interference activities include mining, coal seam gas extraction, injection of water, and commercial, industrial, agricultural and residential activities that intercept the water table or interfere with aquifers.

The AIP states that "*all water taken by aquifer interference activities, regardless of quality, needs to be accounted for within the extraction limits defined by the water sharing plans. A water licence is required under the WM Act (unless an exemption applies or water is being taken under a basic landholder right) where any act by a person carrying out an aquifer interference activity causes:*

- *the removal of water from a water source; or*

- *the movement of water from one part of an aquifer to another part of an aquifer; or*

- *the movement of water from one water source to another water source, such as:*
    - o   *from an aquifer to an adjacent aquifer; or*
    - o   *from an aquifer to a river/lake; or*
    - o   *from a river/lake to an aquifer.* "

Predictions need to be carried out to assess the likely volume of water taken from a water source(s) as a result of an aquifer interference activity. These predictions need to occur prior to Development Consent approval. After Development Consent approval and during operations, these volumes need to be measured and reported in the Annual Review. The water access licence must hold sufficient share component and water allocation to account for the take of water from the relevant water source at all times.

The AIP states that a water licence is required for the aquifer interference activity regardless of whether water is taken directly for consumptive use or incidentally. Activities may induce flow from adjacent groundwater sources or connected surface water. Flows induced from other water sources also constitute take of water. In all cases, separate access licences are required to account for the take from all individual water sources.

In addition to the volumetric water licensing considerations, the AIP requires details of potential:

- water level, quality or pressure drawdown impacts on nearby water users who are exercising their right to take water under a basic landholder right;

- water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources;

- water level, quality or pressure drawdown impacts on groundwater dependent ecosystems;

- increased saline or contaminated water inflows to aquifers and highly connected river systems;

- to cause or enhance hydraulic connection between aquifers; and

- for river bank instability, or high wall instability or failure to occur.

In particular, the AIP describes minimal impact considerations for aquifer interference activities based upon whether the water source is highly productive or less productive and whether the water source is alluvial or porous / fractured rock in nature. In general, the AIP applies a predicted 2 m drawdown maximum limit at existing groundwater users.

Strategic regional land use plans are a component of the Strategic Regional Land Use Policy. The Upper Hunter Strategic Regional Land Use Plan comprises multiple initiatives to address land use conflict in regional areas, particularly focused on managing coal and coal seam gas issues.

The Gateway process applies to State significant mining and coal seam gas proposals that extend beyond an existing mining lease and are located on strategic agricultural land. The process applies to both greenfield proposals and brownfield projects. The Gateway process is an independent, scientific and upfront assessment of how a mining proposal will impact the agricultural values of the land on which it is proposed to be located. It considers proposals at a very early stage before a development application is lodged.

To pass the Gateway process unconditionally, a proposal must demonstrate that it meets the Gateway criteria relating to agricultural and water impacts. If the proposal cannot demonstrate that it meets these criteria, it is subject to requirements. DPI (2013) released a guideline for applicants moving through the mining and petroleum gateway process. This report addresses the items requested within the guideline (refer Section 3).

5 REGIONAL SETTING

5.1 Location

The Project is located wholly within the coal tenement Authorisations (A) 287 and A342 in the western coalfield of NSW. The closest regional centre is Mudgee, located approximately 55 km south west of the Project Boundary. The small settlement of Bylong Village is located within the central portion of the Project Boundary. Figure 2.1 shows the Project and the regional centres, with Figure 5.1 providing the Project layout and locations of the proposed mining areas.

5.2 Surrounding Mines

A number of operational and proposed coal mines exist in the Western Coalfields which target the same coal seams as the Project. Active mines in the region are Moolarben, Ulan and Wilpinjong Mines. These mines are located west of the Project and despatch coal via Muswellbrook to the Port of Newcastle. Other projects planned for development in the region include the Mt. Penny Project. The Mt. Penny Project is adjacent to A287 and is proposed as an open cut mine.

5.3 Topography and Drainage

Figure 5.2 presents the drainage lines and regional topography, which is based on LIDAR[1] information collected within the Project Boundary and 30 m SRTM[2] Digital Elevation data outside.

The topography within the Project Boundary is characterised by rugged ridges, sandstone escarpments, plateaus and steep hills, incised by thin gently sloping valleys. The escarpments can reach 940 mAHD, with the gently sloping valleys falling from 440 mAHD down to 240 mAHD over the northern portion of the Project Boundary. The watercourses drain to the north-east to the Goulburn River.

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[1] Light Detection and Ranging

[2] Shuttle Radar Topography Mission
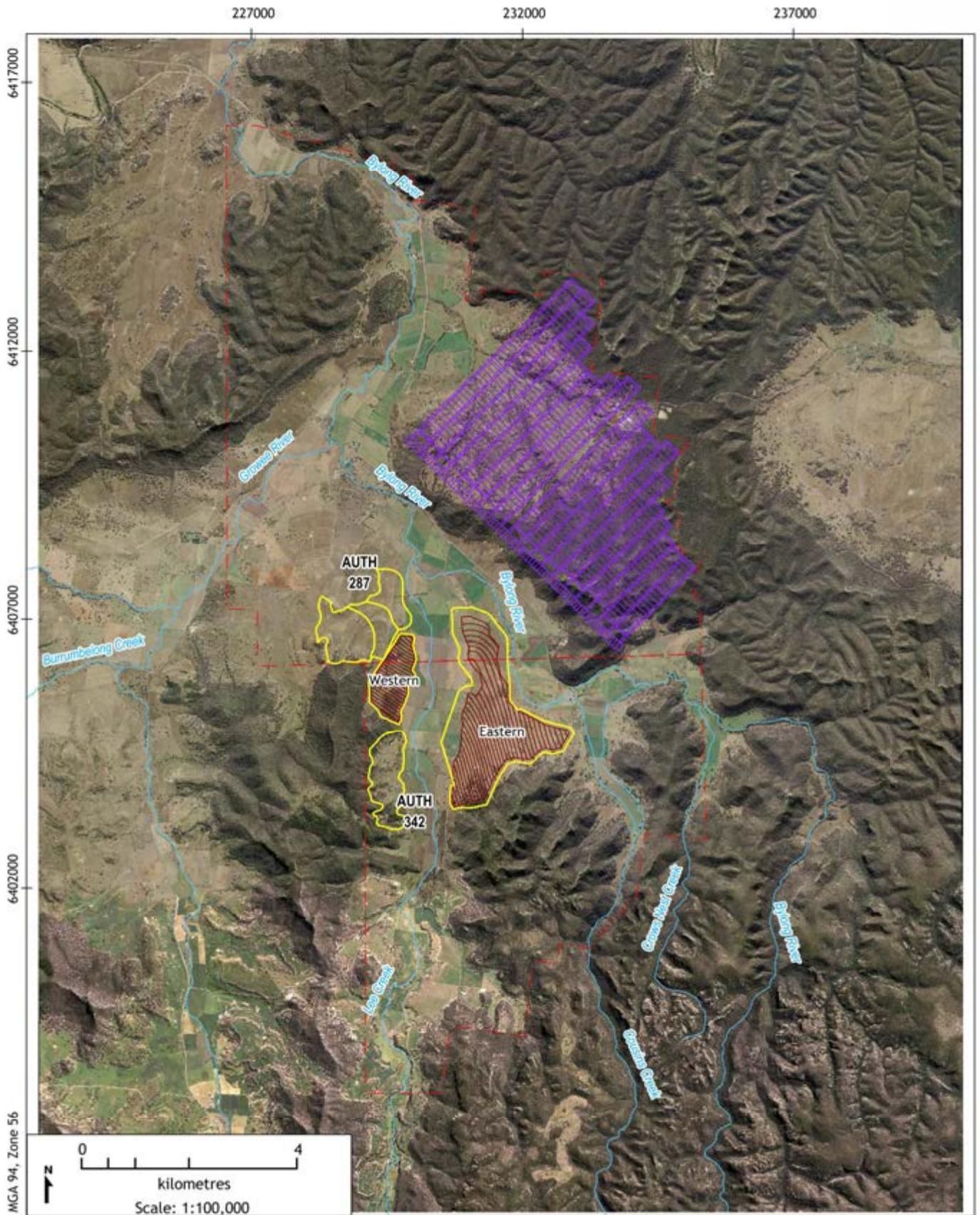
LEGEND:
— Underground Extraction Area
— Open Cut Mining Area
— Overburden Emplacement Area

⌐ ¸ Authorisation

— Major River / Creek

Topography (mAHD)

820
650
600
500

150

AUTH 287

Western   Eastern

AUTH 342

Goulburn River
Peggy Creek
Bylong River
Byong River
Goulburn River
Bylong Valley Way
Growee River
Barigan Road
Burrumbung Creek
Growee River
Bylong Valley Way
Lee Creek
Bylong River
Growes Creek
Wollar Creek
Reedy Creek
Myrtle Creek
Bylong River

MGA 94, Zone 56

0   10
kilometres
Scale: 1:200,000

N

Topography and Drainage

LEGEND:

- - - Authorisation   Major Road
—— Underground Extraction Area   Road
—— Open Cut Mining Area   +—+ Railway
—— Overburden Emplacement Area   —— River
                                      —— Drainage Line / Creek

AGE

DATE:
2/12/2013

FIGURE No:
5.2

The site is located within a northerly draining catchment, with northerly trending gullies containing watercourses which flow towards the Goulburn River. The Goulburn River is a major perennial feature and flows east-west across the northern extent of the Project Boundary, north of A287 and A342. Figure 5.3 shows the Goulburn River north of Bylong which is characterised by incised, meandering streambeds.

Figure 5.3: Goulburn River immediately north of the Project Boundary

The Bylong River catchment covers an area of approximately 700 km^2 and comprises agricultural properties on lower valley areas grazing livestock and cropping, and native forest in steeper rugged regions. The river flows from south to north through the Project area meeting the Goulburn River about 8 km north of the township of Bylong. There are several ephemeral minor creeks and streams in the exploration lease, including Crow's Nest Creek, Cousins Creek, Lee Creek, Growee River and Dry Creek.

Figure 5.4 shows the upper reaches of the Bylong River beside groundwater monitoring bore A20 and surface water monitoring location SW8. The river here is non-flowing, shallow at less than one metre deep, and is used as a water supply by the local landholder.

Figure 5.4: Bylong River looking northwest

Figure 5.5 shows the headwaters of Lee Creek on the southern portion of the Project Boundary. A minor flow was noted at the time of the photograph (September 2012) but the watercourse is often dry in the lower sections.

Figure 5.5: Lee Creek headwaters looking south

Figure 5.6 shows the central section of Growee River. This section of the Growee River is completely dry and is characterised by a very shallow and poorly defined drainage line across the floodplain.

Figure 5.6: Growee River looking north

5.4   Climate

The climate in the Bylong valley region is typical of temperate areas and is characterised by hot dry summers dominated by thunderstorms and cold winters with frequent frosts.

Two long standing BOM rainfall gauges are located in proximity to the Project area, one in the township of Wollar about 16 km to the west, and a second at Nullo Mountain 28 km south-southwest. The Wollar Station (BOM Station No. 62032) has the longest record of daily rainfall from between 1901 and 2012. The average total annual rainfall for this station is 588.9 mm (Table 5.1). Most rainfall occurs in summer with the lowest rainfall during winter. The Nullo Mountain Station (Station No. 062100) is located at an elevation of 1130 m and commenced recording in 1998. The mean rainfall over this period is significant higher than Wollar at 939.2mm. Table 5.1 summaries the monthly mean rainfall for both recording stations.

Table 5.1: MEAN MONTHLY RAINFALL		
Month	**Wollar Station**	**Nullo Mountain Station**
January	66.6	96.3
February	62.8	109.7
March	52.0	83.6
April	38.7	54.1
May	38.1	60.3
June	44.2	79.3
July	42.7	63.1

Table 5.1: MEAN MONTHLY RAINFALL		
Month	**Wollar Station**	**Nullo Mountain Station**
August	41.3	56.8
September	40.9	66.5
October	51.9	72.8
November	55.8	107.6
December	59.3	91.9
Annual	588.9	939.2

In order to place recent rainfall years into an historical context, the Cumulative Rainfall Departure (CRD) was calculated. This is a summation of the monthly departures of rainfall from the long-term average monthly rainfall. A positive slope in the CRD plot indicates periods of above average rainfall, whilst a negative slope indicates periods when rainfall is below average. Figure 5.7 shows the calculated CRD for Wollar Station.
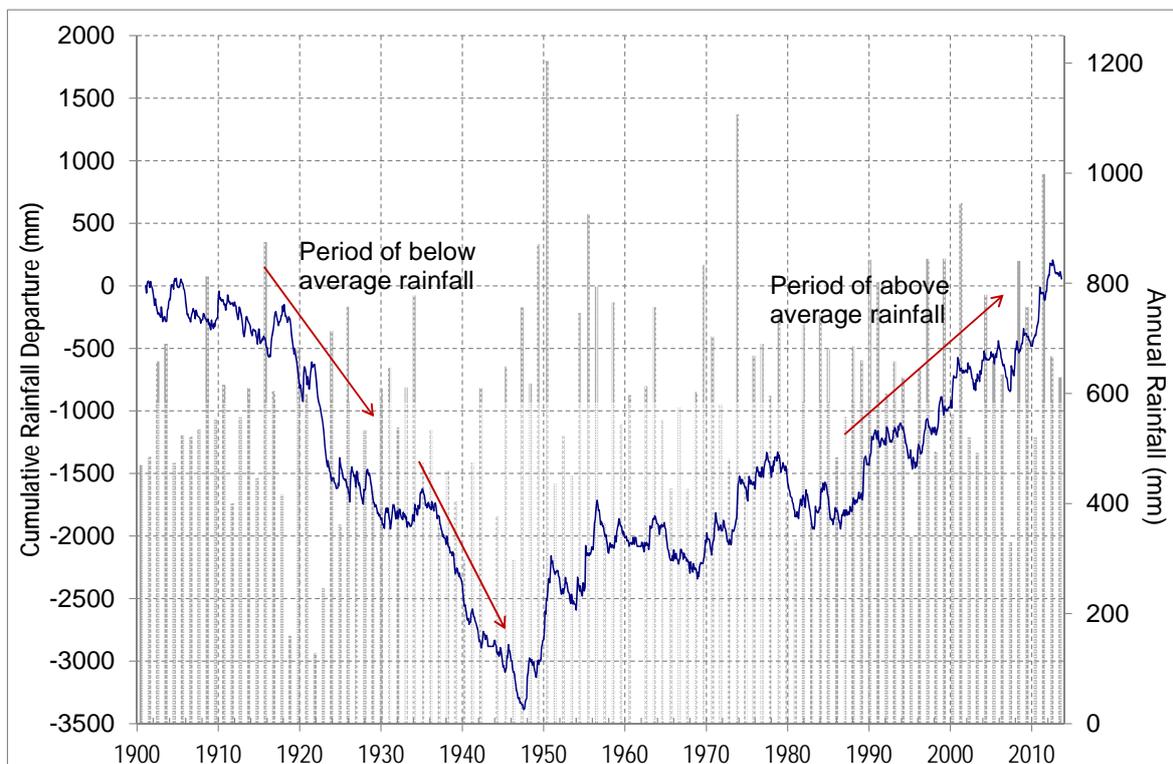
Figure 5.7: Cumulative Rainfall Departure – Wollar Station No. 62032

The CRD chart for the Wollar Station is unique in that it indicates an extended period of above average rainfall from the 1950s onwards as observed by the overall positive slope during this period (Figure 5.7). This extended period of above average rainfall is interspersed with short periods of below average rainfall as shown by a declining to static CRD. The general trend over the preceding 50 years, prior to the 1950's, was characterised by below average rainfall.

Figure 5.8 shows interpolated average annual rainfall across the Project region. The figure shows the higher average rainfall in the elevated country to the south-east, reducing to the north and north-west.

Average Annual Rainfall Distribution

Bylong Coal Project (G1606)

DATE: 2/12/2013

FIGURE No: 5.8

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Local scale rainfall data is available for a rain gauge installed by Cockatoo Coal within the Project Boundary in November 2011. Figure 5.9 shows the rainfall records and infilled data from surrounding rainfall gauges when records are missing. The available data highlights the heavy rainfall during late 2011 to mid-2012, and generally drier conditions since this time (~500 mm/year).
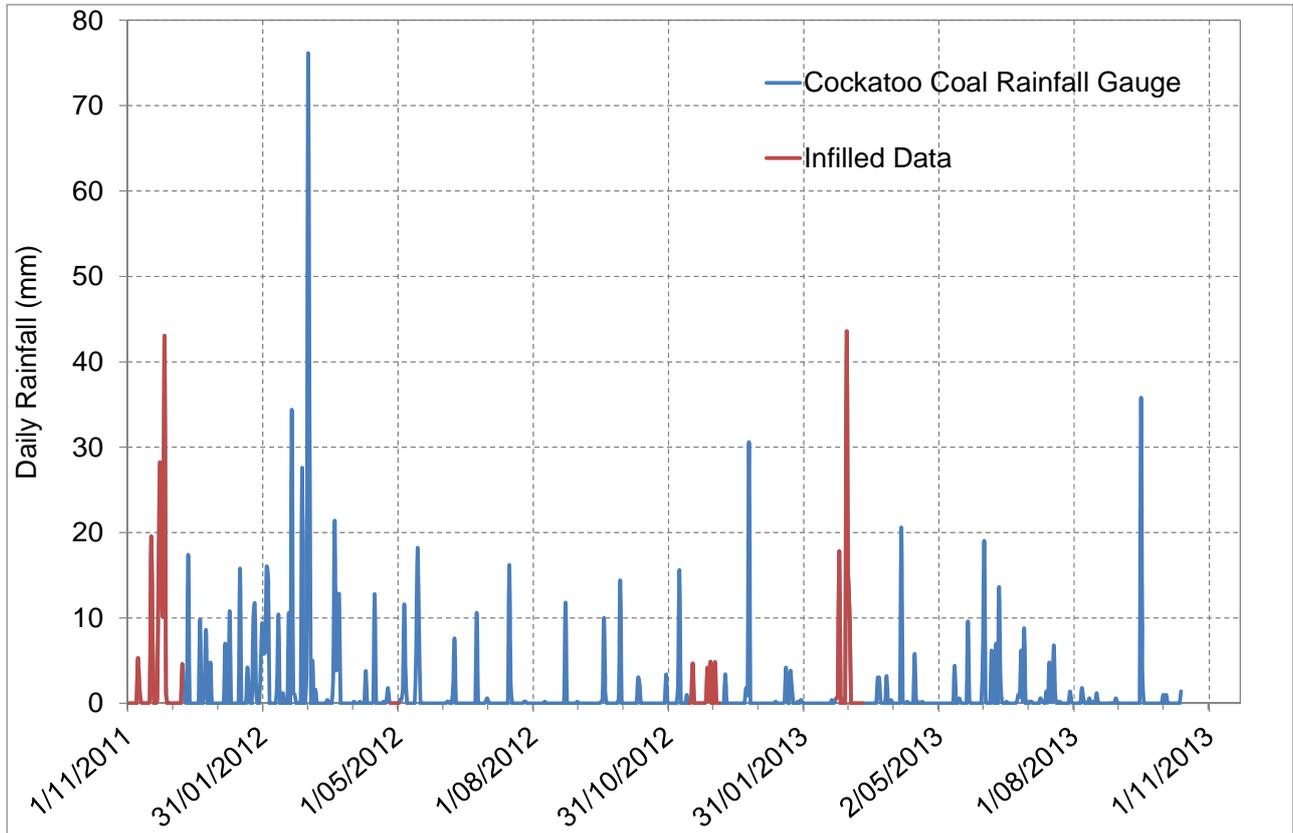
Figure 5.9: Daily rainfall for project site

Evaporation in the Project Boundary is generally higher than rainfall. Figure 5.10 shows that annual areal potential evaporation varies between 1,280 mm/year to 1,340 mm/year.
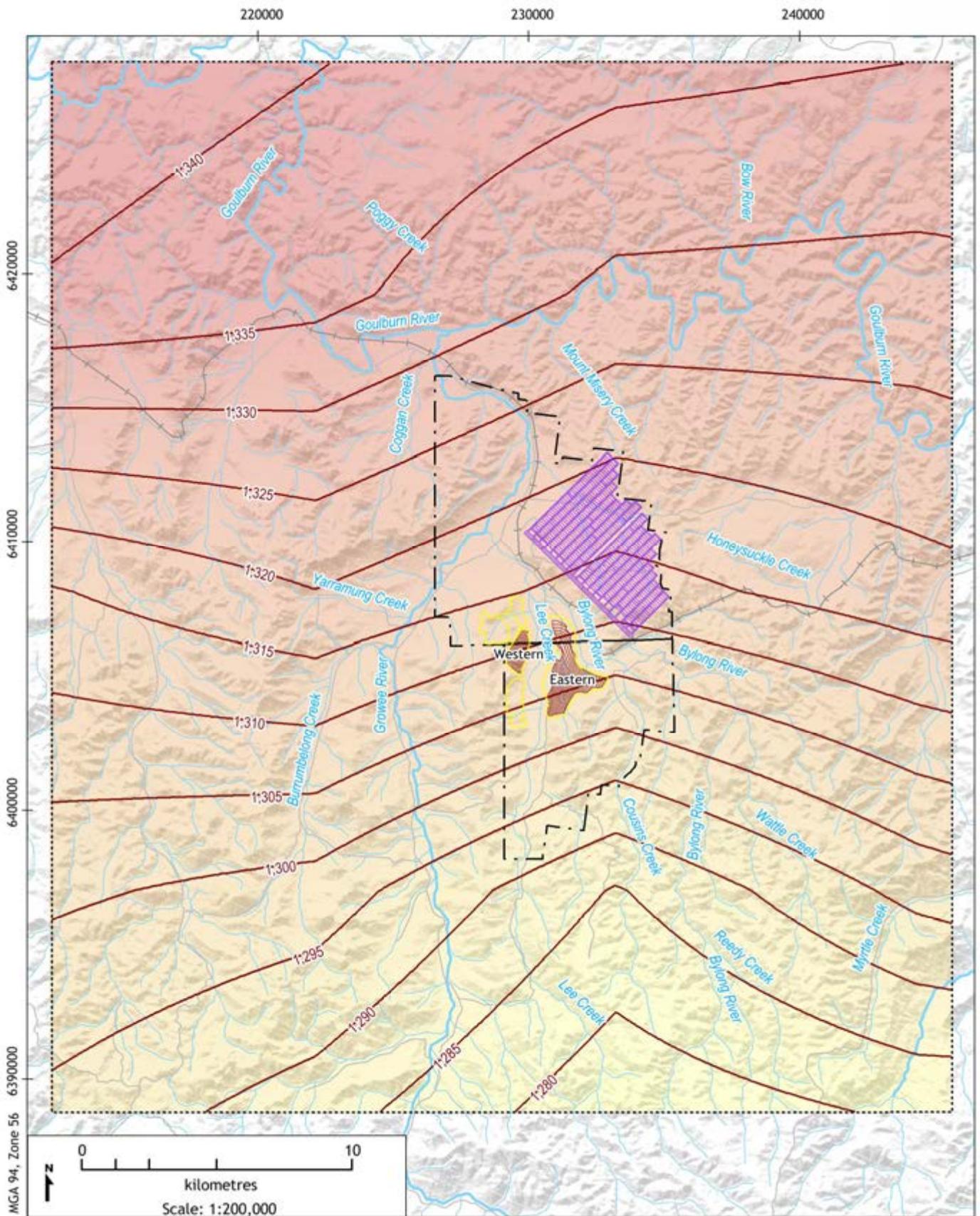
Areal Potential Evaporation

Bylong Coal Project (G1606)

LEGEND:

- Underground Extraction Area
- Open Cut Mining Area
- Overburden Emplacement Area
- Authorisation
- Model Boundary
- Potential Evapotranspiration Contour (mm/a)

- River
- Drainage Line / Creek
- Railway
- Major Road
- Road

DATE: 2/12/2013

FIGURE No: 5.10

MGA 94, Zone 56

Scale: 1:200,000

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5.5 River and Stream Flows

Douglas Partners Pty Ltd (DP) installed three stream gauges to monitor key sub-catchments within the Project Boundary located as follows:

- SW8 - Bylong River downstream from the proposed Eastern Open Cut Mining Area and adjacent to the proposed underground extraction area;

- SW9 - Lee Creek upstream of the proposed Open Cut Mining Areas; and

- SW4 - Growee River downstream of the confluence of the Bylong River and Lee Creek catchments.

Figure 5.11 shows stream flow data for the three gauges along with site rainfall data. Figure 6.1 shows the locations of the gauges.

The data from the three stream gauges show that the river systems within the Project Boundary are ephemeral. There is almost no flow recorded at all sites for the period between late October 2012 and early February 2013. It is also clear that flow at the two upstream gauges (SW8 and SW9) is not reflected in the downstream gauge on the Growee River (SW4).
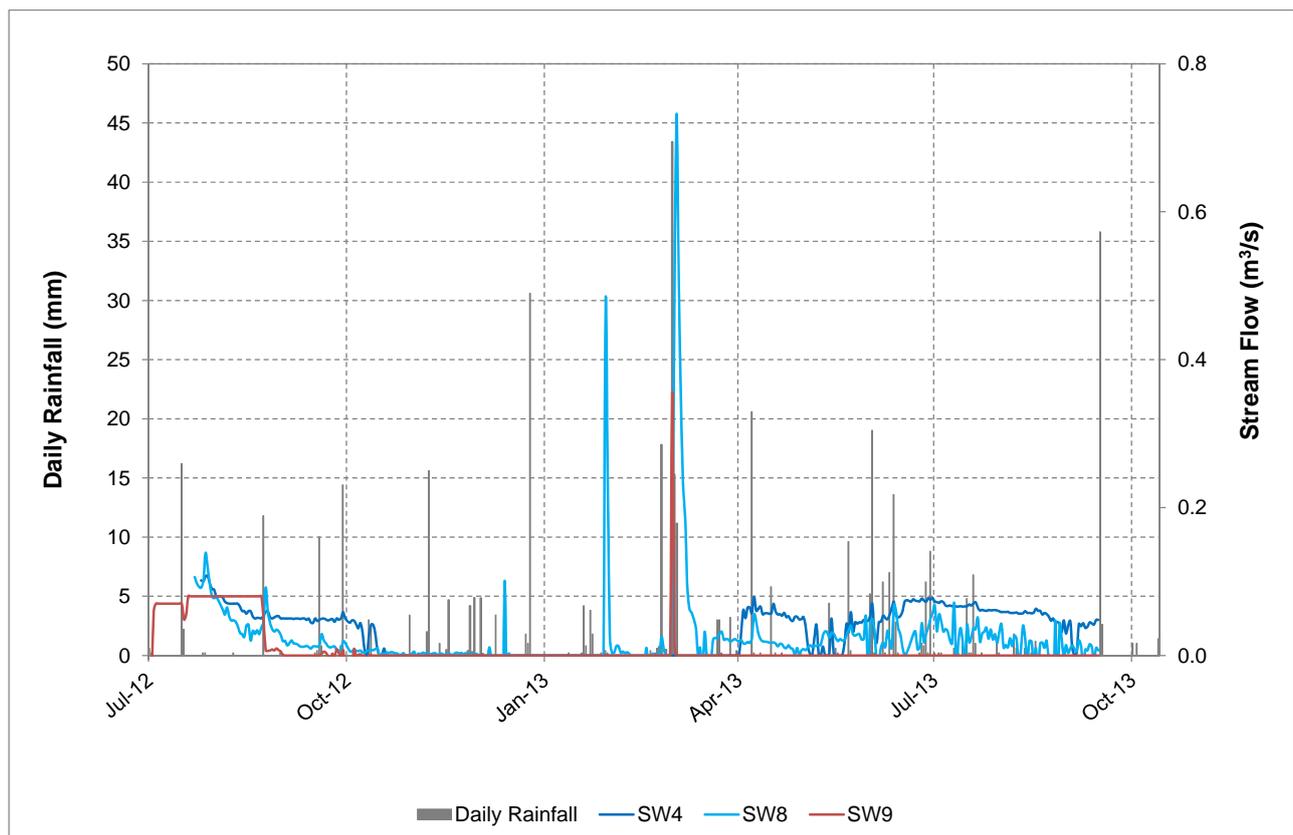
Figure 5.11: Stream Flow and Site Rainfall

5.6 Geology

The Project is located within the Western Coalfields of the Sydney-Gunnedah Basin. Figure 5.12 summarises the stratigraphy of the area whilst Figure 5.13 presents the Singleton geological map showing the regional geology units that outcrop within the Project Boundary.

5.6.1   Regional Geology

The Late Permian Shoalhaven Group forms the sedimentary basement within the Project Boundary consisting primarily of conglomerate, pebbly sandstone and sandstone. The Shoalhaven Group outcrops along the lower slopes of the Growee River catchment and in the upper reaches of Lee Creek.

The Permian Illawarra Coal Measures (ICM) overlies the Shoalhaven Group and contains the economic seams proposed to be mined. The dominant lithologies include mudstone, laminated siltstone, medium-grained quartz-lithic sandstone, lenses of polymictic conglomerate, coal, carbonaceous mudstone, rhyolitic tuff and sporadic torbanite. Thickness of the ICM varies across the Project Boundary from 100 m to 200 m, thickening toward the east into the Sydney Basin trough. The ICM dip approximately 2° to the east and include (but not limited to) the following seams:

- Farmers Creek Seam;
- State Mine Creek Seam;
- Goulburn Seam;
- Glen Davis Seam;
- Irondale Seam;
- Ulan Seam; and
- Coggan Seam.

Overlying the ICM is a Triassic sequence consisting of the Narrabeen Group and the Hawkesbury Sandstone. The Hawkesbury Sandstone is overlain by the Wianamatta Group to the south, and the Digby and Napperby Formations in the north.

5.6.2   Local Geology

Quaternary and 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 an upper layer sand/silt/clay with a basal layer of gravelly sand. DP assessed the extent of colluvium and Quaternary alluvium using LIDAR digital elevation data, stereoscopic images and Cone Penetration Testing (CPT). Figure 5.14 shows the mapped extent of alluvium/colluvium.

Triassic igneous intrusions and Tertiary volcanic flows have been intersected within the exploration lease. The largest igneous intrusion in the area is the Coggan Sill, which covers an area of approximately 12 km in the south-west of the lease.

The main economic coal seam within the Project Boundary is the Coggan Seam. Less than 10 m of interburden separates the overlying Ulan Seam from the underlying Coggan Seam. The Coggan Seam consists predominantly of dull coal with minor bright bands and average ash content 9% to 30%. While the dip of the seam is gentle, the depth to the Coggan Seam varies across the lease from 0 m to 360 m due to the irregular topography. In the valleys around Dry Creek and the Bylong River, the depth to the Coggan Seam is less than 60 m. The thickness of the Coggan Seam varies from 2 m on the western margin of the lease, to 5 m near the eastern boundary.
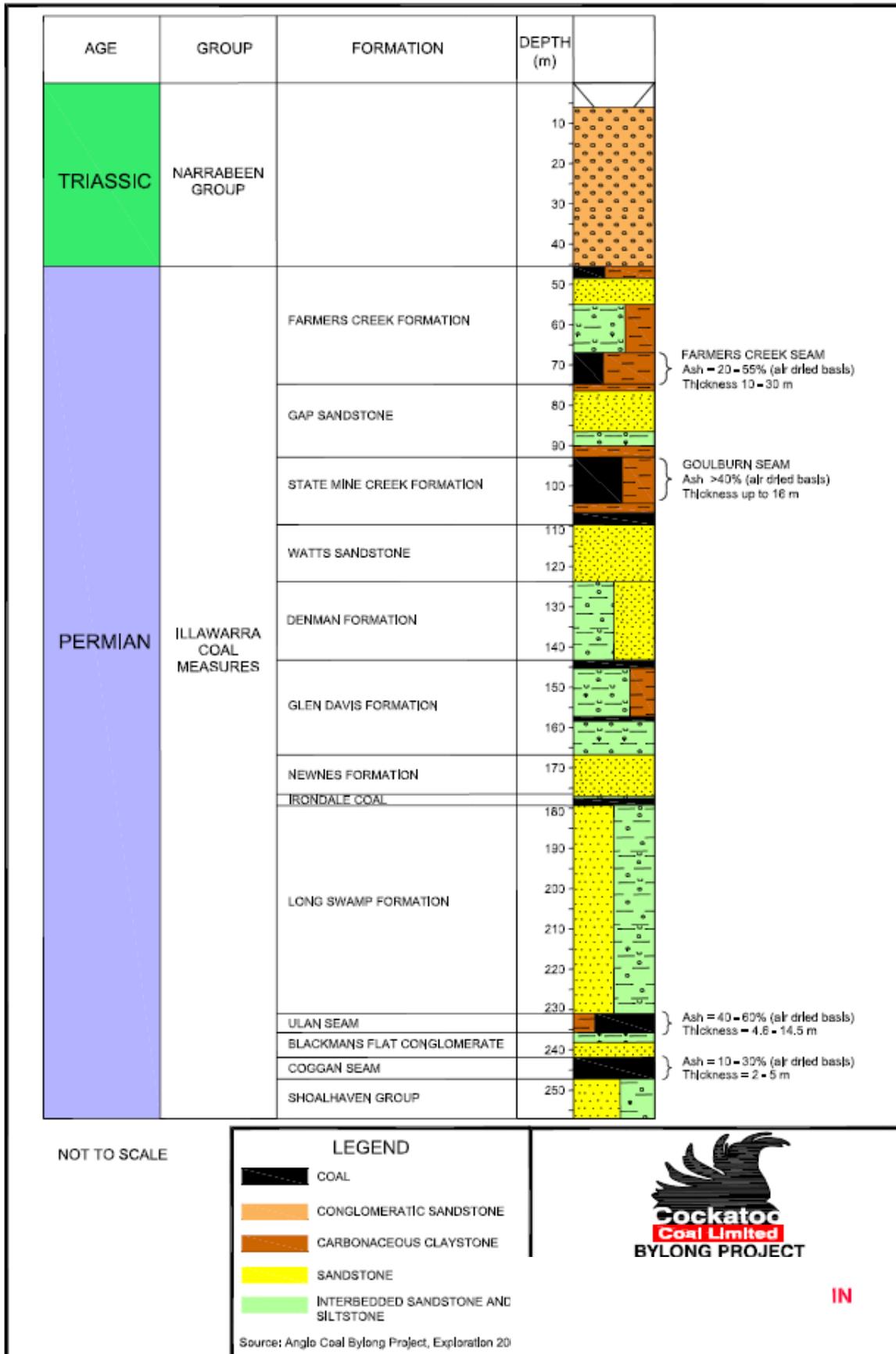
Figure 5.12: Stratigraphic Column (source: Cockatoo Coal, 2012)
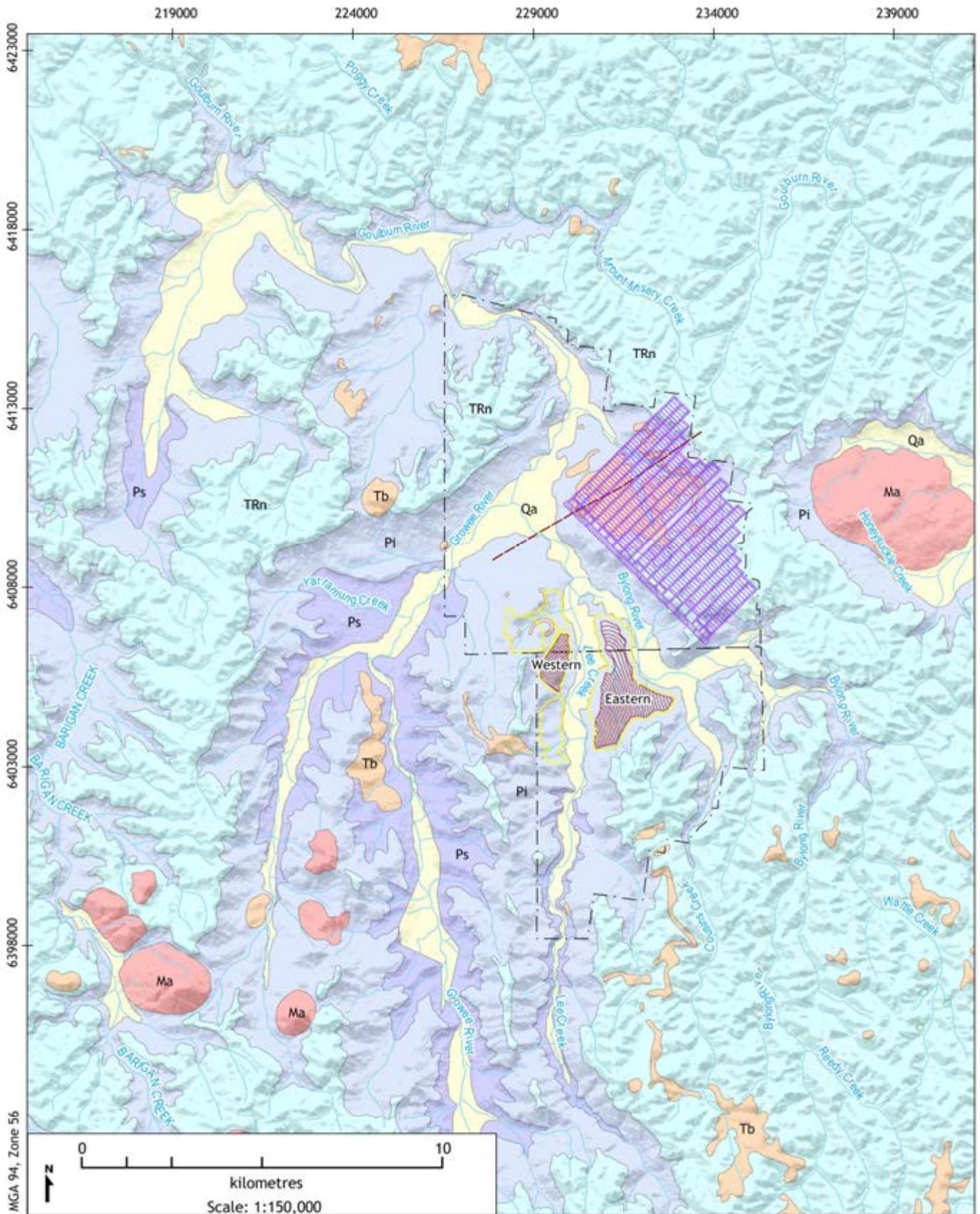
LEGEND:

—— Underground Extraction Area
—— Open Cut Mining Area
—— Overburden Emplacement Area

⌐·⌐ Authorisation

—— Inferred Fault

Geology

Qa - Quaternary - Alluvium
Tb - Tertiary - Basalt
Ma - Triassic - Phonolite Intrusion
Mt - Triassic - Tschenite Intrusion
TRn - Triassic - Narrabeen Group
Pi - Permian - Illawarra Coal Measures
Ps - Permian - Shoalhaven Group

MGA 94, Zone 56

Scale: 1:150,000

Geological Map - Project

Bylong Coal Project (G1606)
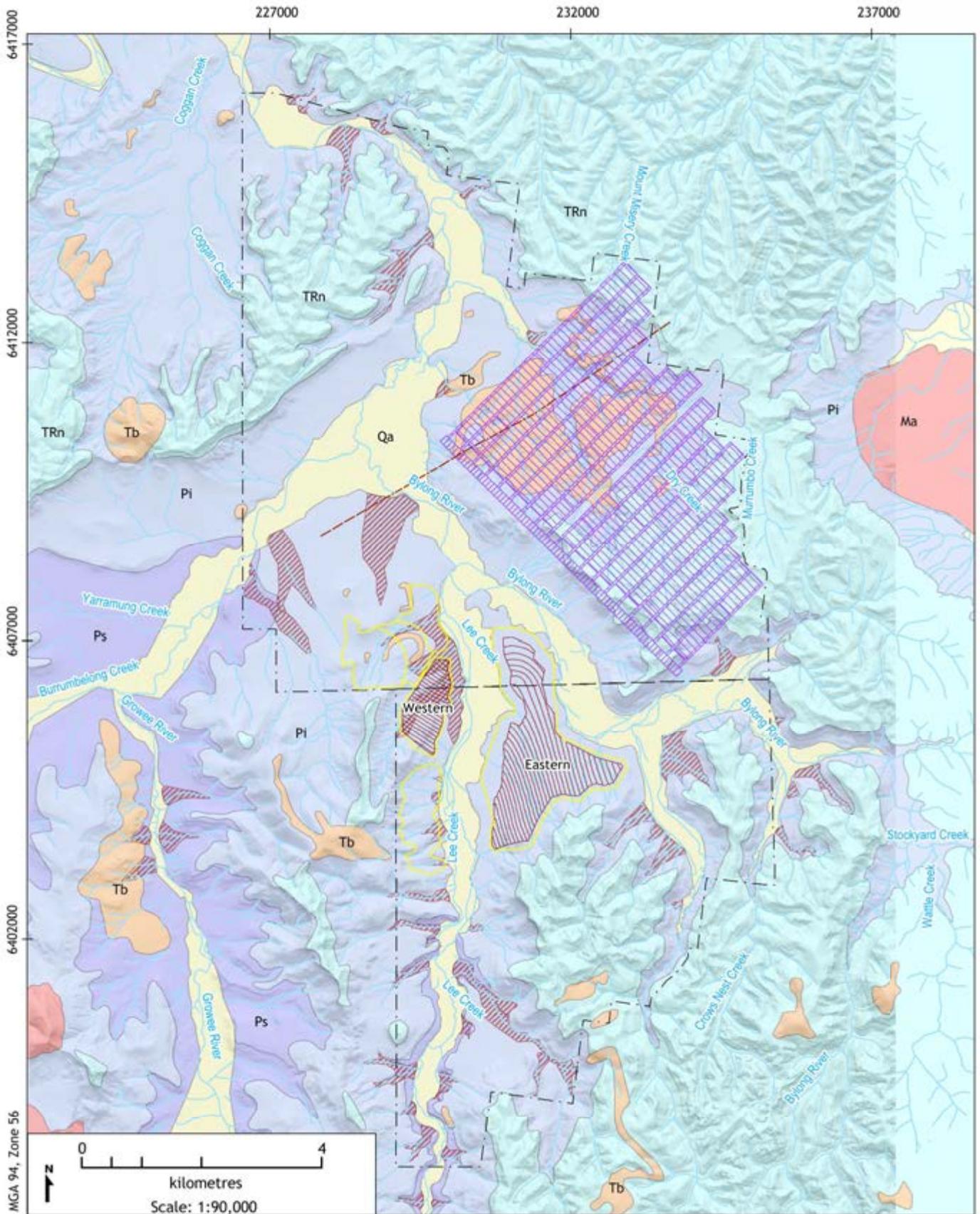
LEGEND:

— Underground Extraction Area
— Open Cut Mining Area
— Overburden Emplacement Area

⌐ ⌐ Authorisation

— Inferred Fault

— Drainage Line / Creek

Geology

Qa - Quaternary - Alluvium
Tb - Tertiary - Basalt
Ma - Triassic - Phonolite Intrusion
Mt - Triassic - Tschenite Intrusion
TRn - Triassic - Narrabeen Group
Pi - Permian - Illawarra Coal Measures
Ps - Permian - Shoalhaven Group

▨ Mapped Colluvium

MGA 94, Zone 56

0 _____ 4
kilometres
Scale: 1:90,000

DATE: 2/12/2013

FIGURE No: 5.14

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5.6.3   Geological Constraints to Mining

Three geological constraints to mining are recognised for the Project, these are:

- faults and other structural zones;
- igneous intrusions; and
- unconsolidated alluvial sediments.

Faults and structural zones mainly impact underground mining where they can act as conduits for groundwater and produce zones of poor ground conditions. A number of previous surveys, which included magnetic, seismic and photo-geological studies, failed to agree over the location and orientation of faults. None of the proposed faults have been confirmed by subsequent studies. A mini-SOSIE 2D seismic survey covering 38.2 km was conducted by Velseis Pty Ltd in June 2011 along public roads within the Project Boundary. The survey was conducted along the Bylong Valley Way, Wollar Road and Upper Bylong Road. Possible faults were identified which intersected both the Ulan and Coggan Seams; however, confidence in the location and throw of the faults was low. Estimated throws ranged from <5 m to 11 m with an error of ±2 m.

Figure 5.14 presents the location of one north-easterly trending fault occurring in the central section of the Project Boundary.

Igneous intrusions can impact both underground and open cut mining, replacing coal seams, affecting the quality of adjacent resources and reducing productivity in operations. There are a number of intrusive and extrusive igneous bodies present within the Project Boundary. Small areas of Tertiary basalt flows overly the ICM to the west and north-west of the Project Boundary and overlie the Narrabeen Group sediments in the east. Field mapping has identified a number of dolerite dykes to the north-west and south of the Project Boundary.

Drilling data indicates that the unconsolidated alluvial sediments generally comprise a layer of gravel from 8 m to 13 m within an unconsolidated sequence up to 19 m thick. DP conducted CPTs along Upper Bylong Road as part of a hydrogeological programme. Testing revealed refusal depths from <1 m to 18.8 m along the course of the Bylong River floodplain. The shallow refusal depths were interpreted to be weathered bedrock at shallow depth. Sediments were considered to be alluvial and consisted of consolidated clay and/or dense sands. Whilst some holes immediately adjacent to the Bylong River water course encountered water, the majority of holes were dry. DP concluded that the shallow alluvial sediments have relatively high permeability (Douglas Partners, 2013).

5.7   Previous Investigations in the Region

A number of groundwater investigations have been carried out as part of the EIS processes for surrounding projects, all of which are located to the north west of the Project Boundary and include existing and proposed mine developments. Appendix A contains a summary of these groundwater investigations completed for other mining developments to date.

6   FIELD INVESTIGATION PROGRAM

DP began hydrogeological field investigations in the Project Boundary in December 2011 under the direction of Cockatoo Coal.

As part of the conditions of A287 and A342, DP prepared a *Preliminary Hydrogeological Assessment and Water Monitoring Plan* (WMP) (Douglas Partners, 2013) which outlines the

groundwater and surface water monitoring program to be undertaken throughout the exploration phase and provides a conceptualisation of the groundwater regime within the Project Boundary. The WMP was initially prepared in close consultation with NOW and has been continually updated in consultation with NOW since its initial development in 2011.

Monitoring to date has included the following:

- mapping of alluvial extents based examination of stereo-pair photos and LIDAR survey data;

- testing rock strata permeability with packers within coal exploration bores;

- installing standpipe piezometers in exploration bores;

- drilling, soil logging and installing twin nested standpipe piezometers in alluvium;

- CPT to confirm the extent and depth of alluvium at selected locations;

- rising head hydraulic testing within installed standpipe piezometers;

- automated logging of piezometric head and electrical conductivity (EC) in selected locations;

- monitoring of piezometric levels;

- multi-level pore water pressure measurements (piezometric levels) through seven vibrating wire piezometer (VWP) installations;

- surface water and groundwater sampling and chemical analyses at selected locations; and

- automated logging of surface water flow velocity at three locations.

Cockatoo Coal engaged AGE in mid-2012 to undertake the numerical modelling and impact assessment for the project approvals. AGE recommended some additional hydrogeological investigations to provide data for numerical groundwater modelling which DP are supervising. This includes continuing the installation of a second stage of groundwater bores to obtain a better understanding of the weathered Permian formations, the Marrangaroo Sandstone and vertical gradients between the alluvium and Permian formations.

Appendix B contains the report on the field investigations prepared by Douglas Partners (2013). The raw data detailed in the DP report is not replicated in this report, but is analysed and discussed.

Figure 6.1 shows the location of installed monitoring bores, VWPs and surface water gauges.

Bylong Coal Project (G1606)

Groundwater Bores and Stream Gauge Locations

DATE: 2/12/2013

FIGURE No: 6.1
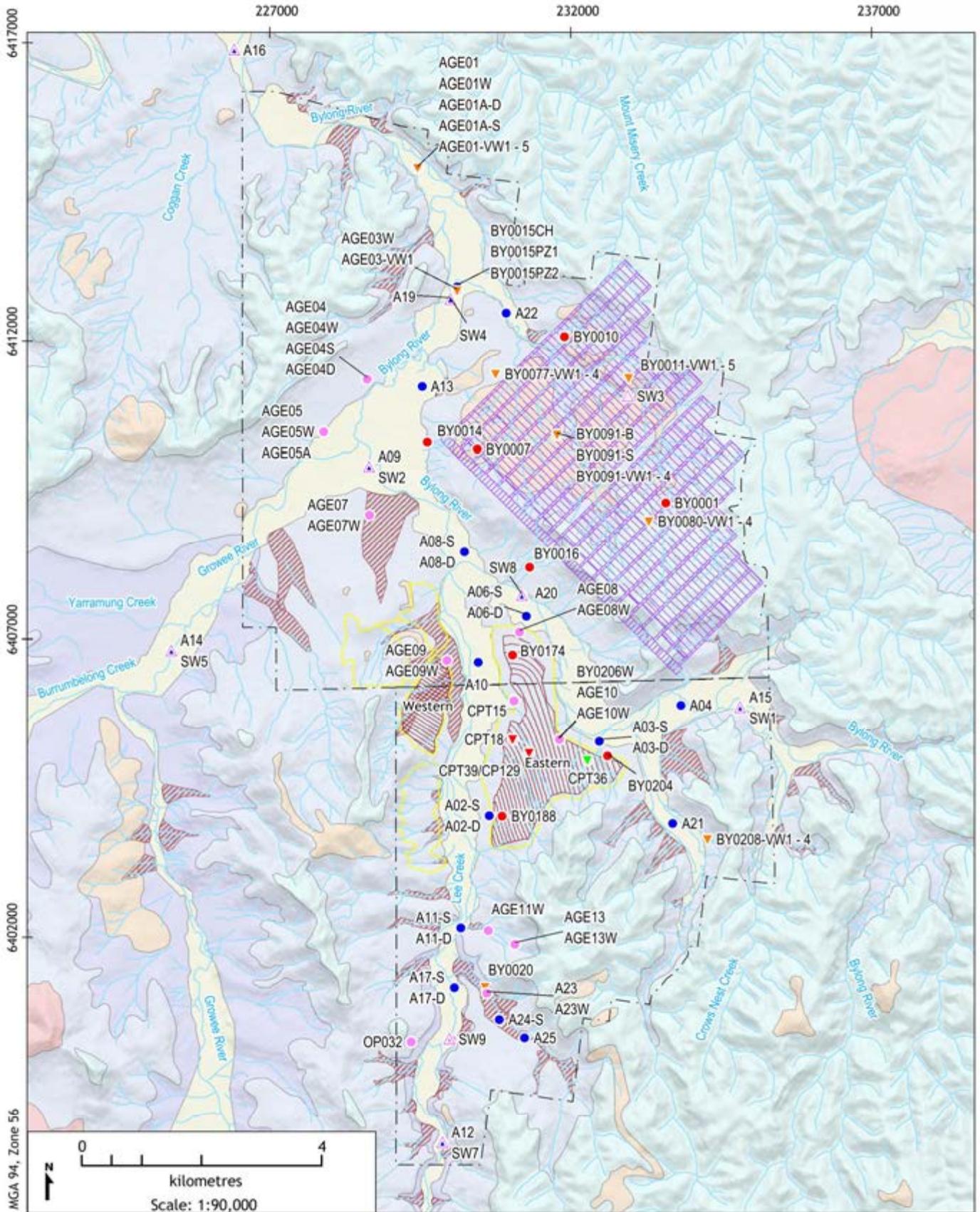
LEGEND:

△ Surface Water Sampling Point
● Monitoring Bore - Alluvium
● Monitoring Bore - Basalt
● Monitoring Bore - Weathered Permian
▼ VWP - Permian Interburden
▼ VWP - Ulan Coal Seam
● Monitoring Bore - Coggan Seam
▼ VWP - Coggan Seam
● Monitoring Bore - Marangaroo Sandstone
▼ VWP - Marangaroo Sandstone
⌐⌐ Authorisation
▨ Mapped Colluvium

—— Underground Extraction Area
—— Open Cut Mining Area
—— Overburden Emplacement Area
Geology (State Detailed)
Qa - Quaternary - Alluvium
Tb - Tertiary - Basalt
Ma - Triassic - Phonolite Intrusion
Mt - Triassic - Tschenite Intrusion
TRn - Triassic - Narrabeen Group
Pi - Permian - Illawarra Coal Measures
Ps - Permian - Shoalhaven Group

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							Table 6.1: GROUNDWATER BORE, VWP LOCATION AND TARGET FORMATION			
Bore	Easting (m) MGA96 Z56	Northing (m) MGA96 Z56	Elevation (mRL)	Total Depth (mbgl)	Stickup (magl)	Screened Interval (mbgl)	Bore Type	Unit	Lithology	Date Installed
A01-D	230111	6412947	247.2	20.6	0.66	15.6 - 18.6	MB	Alluvium - Lower	Gravel/Sand and Residual Clay	26/08/2011
A01-S	230111	6412947	247.2	8.5	0.70	1.9 - 7.9	MB	Alluvium - Upper	Clay and Gravel/Sand	26/08/2011
A02-D	230645	6404074	299.5	8.5	0.80	5.5 - 8.5	MB	Alluvium - Lower	Soil/Sandy Clay	28/02/2012
A02-S	230645	6404074	299.5	3.8	0.80	0.8 - 3.8	MB	Alluvium - Upper	Silty Clay/ Clayey Silt	28/02/2012
A03-D	232473	6405319	288.0	9.4	0.75	6.4 - 9.4	MB	Alluvium - Lower	Clay/Silty Clay/Clayey Silt	30/05/2012
A03-S	232475	6405320	288.0	3.5	0.75	0.5 - 3.5	MB	Alluvium - Upper	Sandy Clay/Clayey Sand	30/05/2012
A04	233828	6405926	294.8	5.2	0.80	0.2 - 5.2	MB	Alluvium - Upper	Sand	16/05/2012
A06-D	231260	6407410	275.3	10.0	0.70	7.0 - 10.0	MB	Alluvium - Lower	Sandy Clay and Gravelly Clay	28/02/2012
A06-S	231260	6407410	275.3	4.5	0.70	1.5 - 4.5	MB	Alluvium - Upper	Silty Clay and Silty Sand and Sand	28/02/2012
A08-D	230231	6408492	267.4	8.6	0.60	5.6 - 8.6	MB	Alluvium - Lower	Clay/Sand	23/05/2012
A08-S	230229	6408492	267.4	5.0	0.60	2.0 - 5.0	MB	Alluvium - Upper	Clay/Sand	23/05/2012
A09	228646	6409921	255.4	6.6	0.60	0.6 - 6.6	MB	Alluvium - Upper	Alluvium	26/07/2012
A10	230457	6406650	278.3	9.0	0.60	3.0 - 9.0	MB	Alluvium - Upper	Sand/ Clay/ Sandy Clay	24/05/2012
A11-D	230167	6402188	312.8	12.2	0.60	0.9 - 3.9	MB	Alluvium - Lower	Sand and Sandy Clay/Clayey Sand	1/03/2012
A11-S	230167	6402188	312.8	3.9	0.60	6.2 - 12.2	MB	Alluvium - Upper	Silty Clay and Sand and Sandy Gravel	1/03/2012
A12	229867	6398595	341.5	6.2	0.60	0.9 - 3.9	MB	Alluvium - Upper	Sand and Sandy Clay/Clayey Sand	17/05/2012
A13	229527	6411267	251.8	7.6	0.84	1.2 - 7.2	MB	Alluvium - Upper	Clay and Sand and Sand/Gravel	26/08/2011
A14	225363	6406840	280.2	8.3	0.60	2.1 - 8.3	MB	Alluvium - Upper	Alluvium	27/07/2012
A15	234816	6405886	299.8	6.3	0.60	0.3 - 6.3	MB	Alluvium - Upper	Alluvium	16/05/2012
A16	226404	6416905	219.5	1.3	0.60	0.2 - 1.3	MB	Alluvium - Upper	Alluvium	26/07/2012
A17-D	230062	6401194	321.3	11.3	0.65	7.3 - 11.3	MB	Alluvium - Lower	Alluvium	28/02/2012
A17-S	230062	6401194	321.3	4.2	0.65	1.2 - 4.2	MB	Alluvium - Upper	Alluvium	28/02/2012
A18	229979	6400329	327.5	6.2	0.60	0.2 - 6.2	MB	Alluvium - Upper	Sandy Silt/Gravelly Sand	21/05/2012
A19	229995	6412730	246.3	5.2	0.60	2.2 - 5.2	MB	Alluvium - Upper	Clay /Clayey Sand/ Gravelly Sand	24/07/2012
A20	231188	6407756	273.5	7.2	0.60	1.2 - 7.2	MB	Alluvium - Upper	Sandy Clay/Clay/Silty Clay	10/07/2012
A21	233695.9	6403940	313.7	14.95			MB	Alluvium - Upper	Alluvium	30/04/2013
A22	230924	6412502	258.5	7.2	0.63	2.2 - 7.2	MB	Alluvium - Upper	Clayey sand, clay & Sandstone	22/10/2012
A23	230607	6401103	334.1	9.4	0.63	3.4 - 9.4	MB	Alluvium - Upper	Clayey sand, sand, gravelly sand	15/10/2012
A23W	230607	6401103	334.1	16.4	0.52	10.4 - 16.4	MB	Weathered Permian	Weathered Zone	23/10/2012
A24-D	230810	6400659	342.7	8.6	0.45	5.6 - 8.6	MB	Alluvium - Lower	Alluvium	16/10/2012
A24-S	230810	6400659	342.7	5.4	0.58	2.4 - 5.4	MB	Alluvium - Upper	Gravelly sand and clay	16/10/2012
A25	231233	6400354	351.6	5.5	-	2.5 - 5.5	MB	Alluvium - Lower	Gravel, sand and sandstone	17/10/2012
AGE01A-D	229453	6414926	237.3	9.4	0.62	6.4 - 9.4	MB	Alluvium - Lower	Sandy gravel	22/10/2012
AGE01A-S	229453	6414926	237.3	4.8	0.76	1.8 - 4.8	MB	Alluvium - Upper	Clay and sandy gravel	15/10/2012
AGE01W	229453	6414926	237.3	20.5	0.50	14.45 - 20.45	MB	Weathered Permian	Weathered siltstone/ sandstone	23/10/2012
AGE03W	230106	6412878	247.7	24.2	0.55	18 - 24.15	MB	Weathered Permian	Siltstone/ sandstone	16/10/2012

	Table 6.1: GROUNDWATER BORE, VWP LOCATION AND TARGET FORMATION									
Bore	Easting (m) MGA96 Z56	Northing (m) MGA96 Z56	Elevation (mRL)	Total Depth (mbgl)	Stickup (magl)	Screened Interval (mbgl)	Bore Type	Unit	Lithology	Date Installed
AGE04	228616	6411395	259.0	66.2	0.81	57.17 - 63.17	MB	Coggan Coal Seam	Coal seam	16/10/2012
AGE04-D	228616	6411395	259.0	17.3	0.70	14.3 - 17.3	MB	Alluvium - Lower	Sand and gravel	17/10/2012
AGE04-S	228616	6411395	259.0	11.3	0.76	5.3 - 11.3	MB	Alluvium - Upper	Silty sand and sand	23/11/2012
AGE04W	228616	6411395	259.0	26.0	0.76	19.95 - 25.95	MB	Weathered Permian	Siltstone, minor tuff and coal	23/11/2012
AGE05	227892	6410504	259.8	50.9	0.55	41.9 - 47.9	MB	Coggan Coal Seam	Coal seam	29/11/2012
AGE05A	227892	6410504	259.8	8.4	0.55	5.4 - 8.4	MB	Alluvium - Upper	Gravelly sand	29/11/2012
AGE05W	227892	6410504	259.8	15.7	0.52	9.7 - 15.7	MB	Weathered Permian	Siltstone/ sandstone	29/11/2012
AGE07	228650.9	6409109	313.7	42.03	-	-	MB	Coggan Coal Seam	Coal seam	9/05/2013
AGE07W	228650.9	6409109	313.7	20	-	-	MB	Weathered Permian	Weathered Zone	9/05/2013
AGE08	231144	6407148	282.1	36.4	-	29.4 - 33.4	MB	Coggan Coal Seam	Coal seam	13/12/2012
AGE08W	231144	6407148	282.1	13.8	-	7.8 - 13.8	MB	Weathered Permian	Sandstone and coal	13/12/2012
AGE09 / BY0173W	229945	6406680	285.8	36.5	-	24.1 - 28.6	MB	Coggan Coal Seam	Coal seam	3/04/2013
AGE09W	229945	6406680	285.8	18.1	-	7.56 - 15.06	MB	Weathered Permian	Weathered Zone	2/05/2013
AGE11W	230630	6402144	326.1	14.2	0.57	5.2 - 14.2	MB	Weathered Permian	Sandstone	4/12/2012
AGE12W	230017	6400321	327.6	22.6	0.35	13.4 - 22.6	MB	Weathered Permian	Siltstone	29/10/2012
AGE13	231072	6401915	357.3	45.1	0.52	37.6 - 43.6	MB	Coggan Coal Seam	Sandstone and coal	6/12/2012
AGE13W	231072	6401915	357.3	14.1	0.55	4.1 - 14.1	MB	Weathered Permian	Siltstone	6/12/2012
BY0001	233577	6409321	375.4	195.0	0.86	185 - 191	MB	Coggan Coal Seam	Coal seam	1/11/2011
BY0007	230443	6410218	368.7	169.5	0.56	161 - 167	MB	Coggan Coal Seam	Coal seam	1/11/2011
BY0010	231897	6412111	301.4	141.5	0.74	133 - 139	MB	Coggan Coal Seam	Coal seam	1/11/2011
BY0014	229611	6410328	259.5	57.1	0.74	50.2 - 56.2	MB	Coggan Coal Seam	Coal, siltstone, sandstone, conglomerate	1/11/2011
BY0015	230111	6412947	247.2	97.6	0.70	90 - 96	MB	Coggan Coal Seam	Sandstone, coal, carbonaceous shale	1/11/2011
BY0015PZ1	230110.6	6412947	247.24	20.6	-	-	MB	Alluvium - Upper	Alluvium	1/11/2011
BY0015PZ1	230110.6	6412947	247.24	8.5	-	-	MB	Alluvium - Upper	Alluvium	1/11/2011
BY0016	231315	6408236	292.9	47.5	0.69	39.8 - 45.8	MB	Coggan Coal Seam	Coal seam	31/10/2011
BY0020 (OP028)	230574	6401202	-	36.0	-	36	VWP	Marangaroo Sandstone	Sandstone	1/12/2011
BY0091-S	231773	6410454	363.9	36.0	0.60	30 - 36	MB	Marangaroo Sandstone	Sandstone	27/11/2012
BY0091-B	231773	6410454	363.9	23.0	0.62	11.4 - 16.0	MB	Basalt	Basalt	21/11/2012
OP032	229350	6400282	383.1	7.9	0.52	4.8 - 6.35	MB	Weathered Permian	Weathered Zone	12/12/2012
BY0174	231034	6406771	290.93	39.4		28.9 - 33.4	MB	Coggan Seam	Coal seam	5/04/2013
BY0188	230858	6404064	326.6	43.56			MB	Coggan Seam	Coal seam	5/04/2013
BY0204	232611	6405080	296.74	62.5			MB	Coggan Seam	Coal seam	4/04/2013
AGE10 / BY0206	231810	6405356	298.3	54.24		41.5 - 45.5	MB	Coggan Seam	Coal seam	8/04/2013
BY0206W	231810	6405356	298.3	20.98			MB	Weathered Permian	Weathered Zone	6/04/2013
CPT15	231054	6406004	284.15	14.91			MB	Weathered Permian	Weathered Zone	29/05/2013
CPT18	231030	6405355	297.5	23.53			MB	Weathered Permian	Weathered Zone	29/05/2013

Table 6.1: GROUNDWATER BORE, VWP LOCATION AND TARGET FORMATION										
Bore	Easting (m) MGA96 Z56	Northing (m) MGA96 Z56	Elevation (mRL)	Total Depth (mbgl)	Stickup (magl)	Screened Interval (mbgl)	Bore Type	Unit	Lithology	Date Installed
CPT18	231030	6405355	297.5				VWP	Ulan Coal Seam	Coal seam	23/05/2013
CPT18	231030	6405355	297.5				VWP	Coggan Coal Seam	Coal seam	23/05/2013
CPT36	232278	6405003	302.75	59.15			MB	Weathered Permian	Weathered Zone	23/05/2013
CPT36	232278	6405003	302.75				VWP	Ulan Coal Seam	Coal seam	7/06/2013
CPT36	232278	6405003	302.75				VWP	Coggan Coal Seam	Coal seam	7/06/2013
CPT39/CP129	231304	6405128	306.5	41.96			MB	Weathered Permian	Weathered Zone	7/06/2013
CPT39/CP129	231304	6405128	306.5				VWP	Ulan Coal Seam	Coal seam	17/05/2013
CPT39/CP129	231304	6405128	306.5				VWP	Coggan Coal Seam	Coal seam	17/05/2013
BY0011-VW1	232963	6411410	360.2	73.4	-	73.4	VWP	Permian Interburden	Sandstone	17/05/2013
BY0011-VW2	232963	6411410	360.2	148.8	-	148.8	VWP	Permian Interburden	Sandstone	1/11/2011
BY0011-VW3	232963	6411410	360.2	190.4	-	190.4	VWP	Ulan Coal Seam	Sandstone, minor coal	1/11/2011
BY0011-VW4	232963	6411410	360.2	202.4	-	202.4	VWP	Coggan Coal Seam	Coal seam	1/11/2011
BY0011-VW5	232963	6411410	360.2	220	-	220	VWP	Marangaroo Sandstone	Sandstone	1/11/2011
BY0077-VW1	230750	6411475	297.3	48.3	-	48.3	VWP	Permian Interburden	Sandstone, siltstone	1/11/2011
BY0077-VW2	230750	6411475	297.3	107.9	-	107.9	VWP	Ulan Coal Seam	Sandstone and coal	28/09/2012
BY0077-VW3	230750	6411475	297.3	118.8	-	118.8	VWP	Coggan Seam	Coal seam	28/09/2012
BY0077-VW4	230750	6411475	297.3	139.75	-	139.75	VWP	Marangaroo Sandstone	Sandstone	28/09/2012
BY0080-VW1	233295	6409002	405.9	177.2	-	177.2	VWP	Permian Interburden	Siltstone/ sandstone	28/09/2012
BY0080-VW2	233295	6409002	405.9	200	-	200	VWP	Ulan Coal Seam	Coal seam	5/11/2012
BY0080-VW3	233295	6409002	405.9	210.7	-	210.7	VWP	Coggan Coal Seam	Coal seam	5/11/2012
BY0080-VW4	233295	6409002	405.9	230	-	230	VWP	Marangaroo Sandstone	Sandstone	5/11/2012
BY0091-VW1	231773	6410454	363.9	57	-	57	VWP	Permian Interburden	Sandstone	23/11/2012
BY0091-VW2	231773	6410454	363.9	103.4	-	103.4	VWP	Permian Interburden	Sandstone/ siltstone	23/11/2012
BY0091-VW3	231773	6410454	363.9	172.5	-	172.5	VWP	Coggan Coal Seam	Coal seam	23/11/2012
BY0091-VW4	231773	6410454	363.9	185	-	185	VWP	Marangaroo Sandstone	Sandstone	23/11/2012
BY0208-VW1	234269	6403672	327.08	37.3	-	37.3	VWP	Permian Interburden	-	16/04/2013
BY0208-VW2	234269	6403672	327.08	60	-	60	VWP	Permian Interburden	-	16/04/2013
BY0208-VW3	234269	6403672	327.08	87.5	-	87.5	VWP	Coggan Coal Seam	Coal seam	16/04/2013
BY0208-VW4	234269	6403672	327.08	98.5	-	98.5	VWP	Marangaroo Sandstone	Sandstone	16/04/2013
AGE01-VW1	229453	6414926	237.3	27.7	-	27.7	VWP	Permian Interburden	Carbonaceous siltstone with interbedded tuff	16/04/2013
AGE01-VW2	229453	6414926	237.3	67.1	-	67.1	VWP	Permian Interburden	Sandstone	30/04/2013
AGE01-VW3	229453	6414926	237.3	120.2	-	120.2	VWP	Ulan Coal Seam	Coal, sandstone and siltstone	30/04/2013
AGE01-VW4	229453	6414926	237.3	128.2	-	128.2	VWP	Coggan Coal Seam	Interburden and coal seam	30/04/2013
AGE01-VW5	229453	6414926	237.3	140.7	-	140.7	VWP	Marangaroo Sandstone	Sandstone/ siltstone	30/04/2013
AGE03-VW1	230106	6412878	247.7	30.5	-	30.5	VWP	Marangaroo Sandstone	Fresh Sandstone	30/04/2013

7   HYDROGEOLOGICAL REGIME

7.1   Hydrostratigraphic Units

The available data indicates the presence of the following stratigraphic units:

- alluvium and colluvium
- weathered Permian bedrock
- Tertiary basalt capping
- coal seams

The sections below detail the properties of the hydrostratigraphic units.

7.1.1   Alluvium and Colluvium

The fieldwork to date indicates that the alluvium in the valley floors is predominantly permeable sand and gravels and provides a groundwater source to the majority of registered bores within the area. Investigative drilling has indicated that these sediments consist of an upper layer of sand/silt/clay overlying a basal layer of sand and gravel. Whilst the upper sediments in the alluvial sequence are commonly fine grained, groundwater levels respond rapidly to rainfall indicating recharge readily infiltrates the upper sequence.

Testing indicates alluvial sediments are typically less than 20 m in depth along the Bylong River flood plain. The transmissivity varies from high in the thicker sequences of sand and gravel, to low where shallow rock bars act as local barriers to groundwater flow. No surface water is present in the lower reaches of the Growee River, suggesting the permeability of the alluvium is sufficient to allow all rainfall runoff to flow underground.

Figure 7.1 shows the interpreted thickness of alluvial sediment within the Project Boundary. Local scale mapping by DP of the alluvial and colluvial boundary replaced the 1:100,000 scale data from the Singleton Geological Sheet. Figure 7.2 shows the distance between the proposed mine and the mapped alluvial boundary and water courses. The proposed open cut pits are up to 180 m from the alluvium, 190 m of the Bylong River and 260 m from Lee Creek.

DP has installed a number of groundwater monitoring bores (piezometers) across the Project Boundary, primarily in the Quaternary alluvium and the Coggan Coal Seam. Rising head tests were undertaken for all alluvial piezometers following installation. Hydraulic testing suggests that the hydraulic conductivity of the alluvium is generally moderate to high ranging from 0.04 m/day to 14 m/day. The basal gravelly sand reports the highest values.

7.1.2   Weathered Tertiary and Permian Formations

The weathering of the Tertiary and Permian within the Project Boundary ranges from 5 m to 30 m below ground surface. This zone of weathering likely acts as a zone of enhanced permeability in the weathered rock matrix, however this unit is unsaturated in the elevated terrain.

Regional groundwater levels from observation bores were used to determine the areas where the weathered zone is saturated. Figure 7.3 presents the depth to the water table and indicates that majority of the weathered zone above the proposed underground extraction area is potentially unsaturated. Weathered formations in elevated areas to the south east also appear unsaturated (Figure 7.3). Some preliminary data from vibrating wire piezometers indicates the potential for localised perching of groundwater in elevated areas at the base of the weathered zone, or possibly where basalt is present.
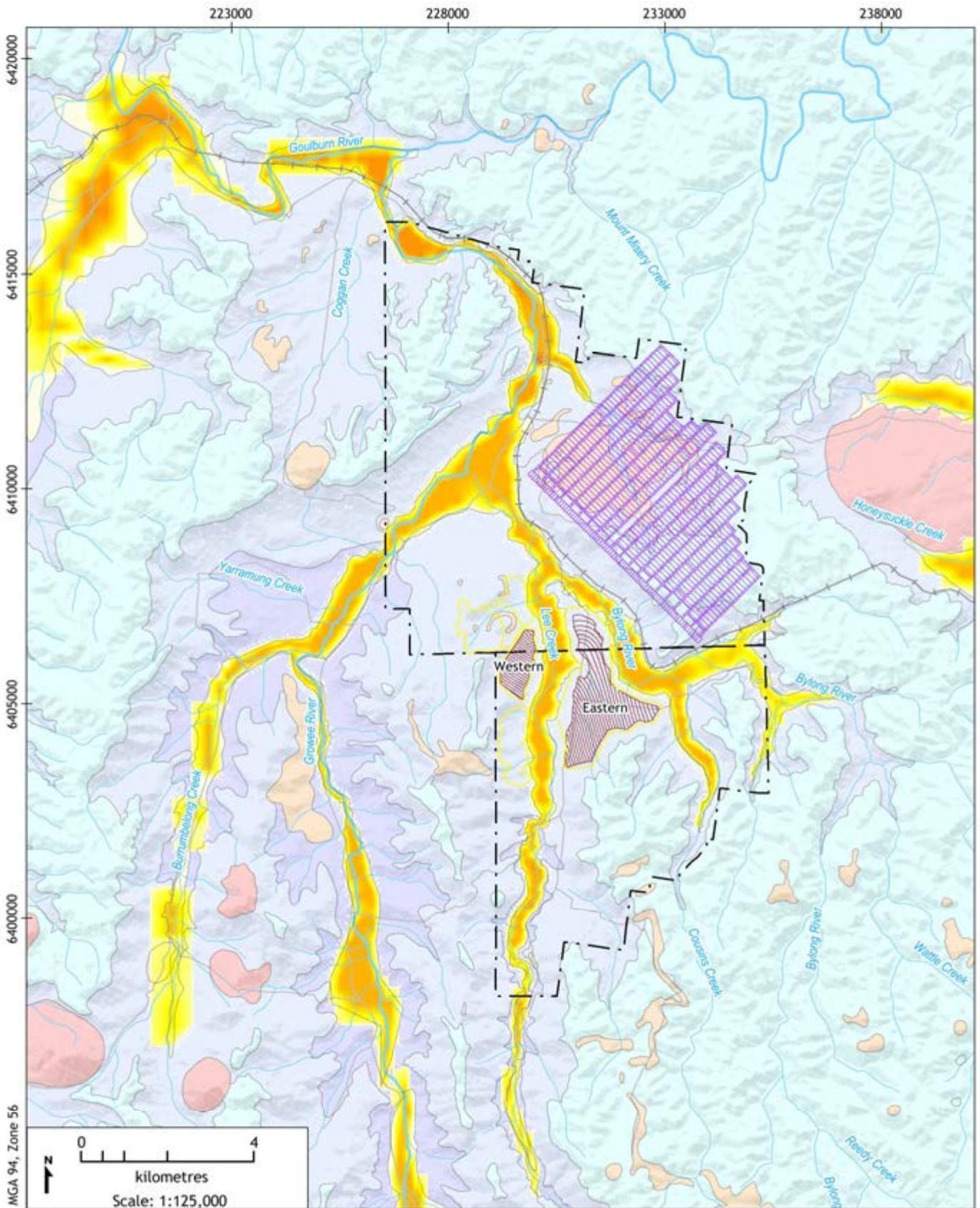
LEGEND:

— Underground Extraction Area
— Open Cut Mining Area

---·· Authorisation
—— River
—— Drainage Line / Creek
—— Road / Track
—+— Railway

Geology (State Detailed)

Qa - Quaternary - Alluvium
Tb - Tertiary - Basalt
Ma - Triassic - Phonolite Intrusion
Mt - Triassic - Tschenite Intrusion
TRn - Triassic - Narrabeen Group
Pi - Permian - Illawarra Coal Measures
Ps - Permian - Shoalhaven Group

Alluvial
Thickness (m)
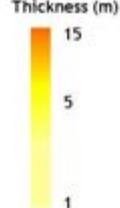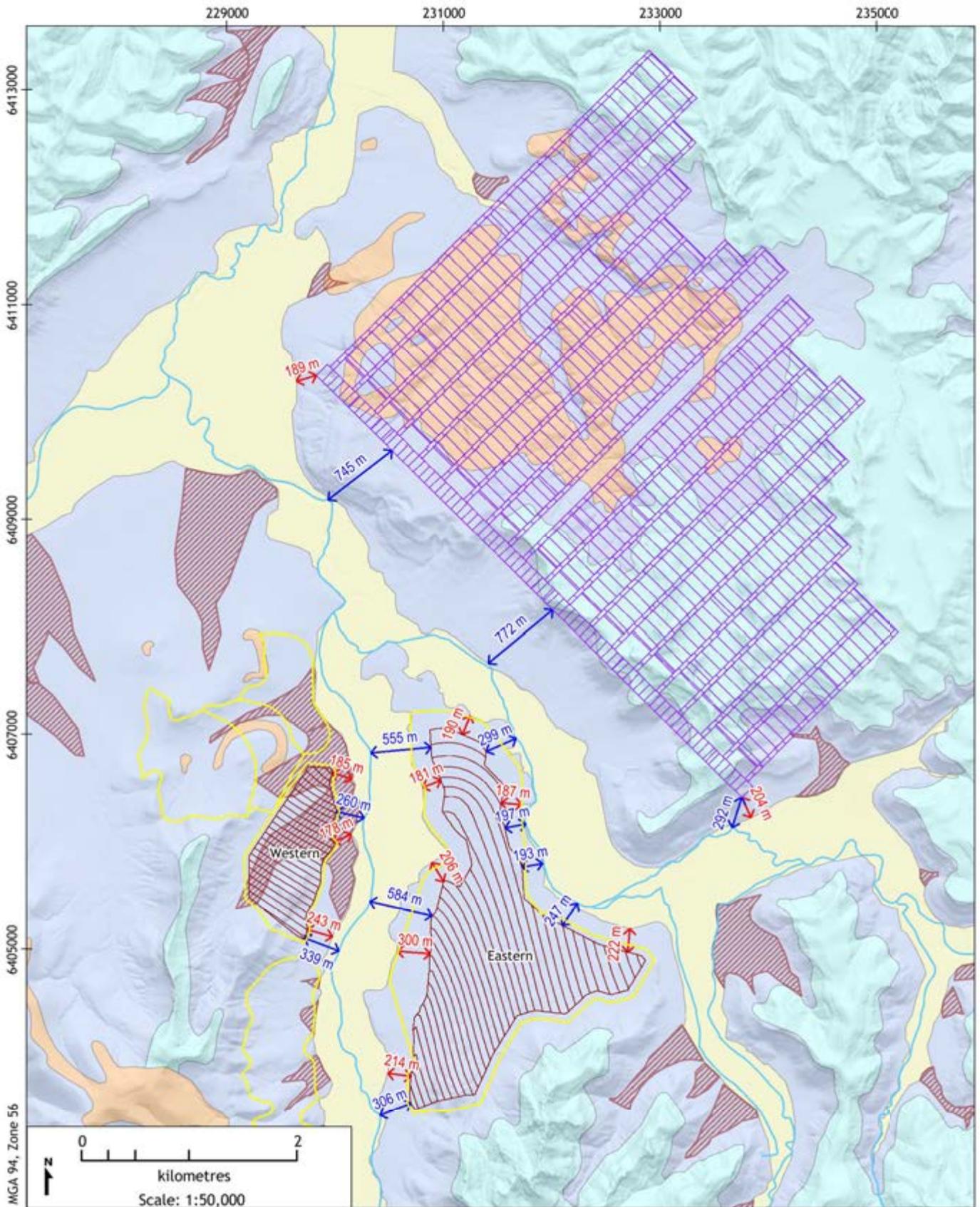
15

5

1

MGA 94, Zone 56

0   4
kilometres
Scale: 1:125,000

MGA 94, Zone 56

0   2

kilometres

Scale: 1:50,000

LEGEND:

— Underground Extraction Area
— Open Cut Mining Area
— Overburden Emplacement Area

— Major River / Creek

⟷ Distance Proposed Mining Area to Creek
⟷ Distance Proposed Mining Area to Alluvium

Geology

Qa - Quaternary - Alluvium
Tb - Tertiary - Basalt
Ma - Triassic - Phonolite Intrusion
Mt - Triassic - Tschenite Intrusion
TRn - Triassic - Narrabeen Group
Pi - Permian - Illawarra Coal Measures
Ps - Permian - Shoalhaven Group

▨ Mapped Colluvium

Bylong Coal Project (G1606)

Mining Area Setback Distance

AGE

DATE: 2/12/2013

FIGURE No: **7.2**

Depth to
Groundwater (m)

429
400

300

150

2.0
0.0
-2.0

Bylong Coal Project (G1606)

Depth to the Watertable and Stream Flow Interaction
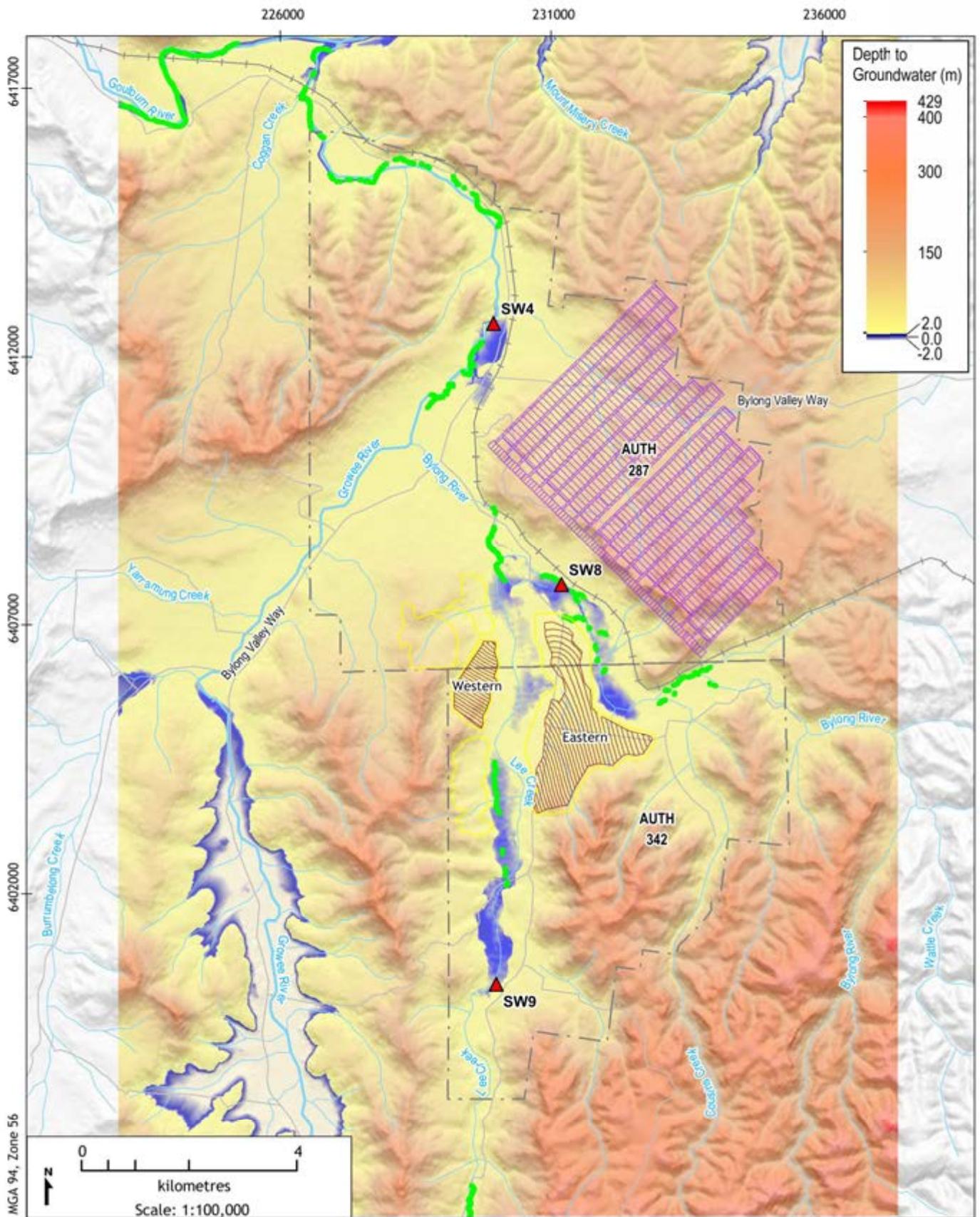
LEGEND:

Underground Extraction Area — River
Open Cut Mining Area — Drainage Line / Creek
Overburden Emplacement Area — Major Road
Authorisation — Road
▲ Streamflow Measurement Location — Railway
River/Creek Water Presence

MGA 94, Zone 56

Scale: 1:100,000

DATE: 2/12/2013

FIGURE No: 7.3

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In contrast, in areas of the lower lying valley floors, the weathered zone rock that is adjacent to and underlies the alluvium is saturated. 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. The potential for the weathered zone to act as a conduit for flow through from the alluvium during mining appears high in the northern portion of proposed Eastern Open Cut Mining Area and the eastern edge of the proposed Western Open Cut Mining Area. Groundwater levels and hydraulic gradients in this area are discussed further below. Field testing is ongoing by DP to better understand the hydraulic conductivity of the weathered material.

7.1.3   Permian Coal Measures

The Ulan and Coggan Coal Seams are the main economic targets for mining. These also represent the most permeable units within the Permian strata. There are several coal seams overlying the Ulan and Coggan Coal Seams, including the Farmers Creek, State Creek Mine Seam and Goulburn Seam. These upper seams are likely to be unsaturated over most of the Project Boundary, but may contain groundwater at lower elevations below about 250 mAHD further to the north east.

The sandstone, interbedded siltstone and claystone of the Permian interburden, overburden and unweathered overburden constitute lower permeability units that are considered aquitards.

Packer testing was undertaken on selected exploration holes to provide an estimate of the hydraulic conductivity of the consolidated hydrostratigraphic units within the Project Boundary. Testing focused on overburden and coal seams in areas where underground mining is proposed. DP carried out rising head tests on six piezometers within the Coggan Coal Seam which indicated that the hydraulic conductivity of the coal seams can be high compared to interburden and overburden. The coal seams recorded a median hydraulic conductivity of 0.05 m/day (Douglas Partners, 2013).

7.1.1   Tertiary Basalts and Localised Perched Aquifers

The presence of potentially permeable basalt capping on the elevated terrain overlying less permeable Permian units suggest there is potential for perched localised groundwater systems in some of the elevated plateau areas. Groundwater elevations (Section 7.3) from multi-level vibrating wire piezometers in the Dry Creek area (above the proposed underground extraction area) suggest that perched groundwater can occur in the upper units. However, this groundwater system is not thought to be extensive, or connected to the regional groundwater system.

7.1.2   Marrangaroo Sandstone

The Marrangaroo Sandstone underlies the Coggan Coal Seam across most of the area within the Project Boundary. DP are currently assessing and testing the Marangaroo Sandstone to determine if this formation is a geotechnical or hydrogeological risk to mine operations. Packer testing to date has focused on the upper section of the Marrangaroo Sandstone, which is typically of low permeability with a hydraulic conductivity of less than 0.001 m/day. This contrasts with the Wilpinjong area where drilling has shown the Marrangaroo Sandstone is a clean, coarse sandstone and forms a thin, but productive aquifer. This does not appear to be the base at Bylong.

7.1.3   Summary

Table 7.1 summarises the hydraulic conductivity values attained from packer and rising head testing.

Table 7.1: SUMMARY OF HYDRAULIC CONDUCTIVITY VALUES			
Unit	**Number of Tests**	**Hydraulic Conductivity (m/day)**	
		Range	**Median**
Quaternary alluvium	23	0.04 - 14	4.6
Tertiary Volcanics	2	$4.5 \times 10^{-5} - 0.2$	0.1
Permian interburden	47	$1.9 \times 10^{-5} - 0.9$	1.5×10^{-3}
Ulan coal seam	4	$1.4 \times 10^{-3} - 5.0 \times 10^{-3}$	2.0×10^{-3}
Coggan coal seam	10	$5.5 \times 10^{-4} - 2.1$	0.15
Marrangaroo Sandstone	4	$2.9 \times 10^{-4} - 8.2 \times 10^{-4}$	3.7×10^{-4}

7.2 Yields and Usage

The WSP report card for the Bylong River water source indicates the area has a total groundwater entitlement of 5,843 ML/year (100% used for irrigation purposes). There are 23 groundwater licences in the area and the groundwater is primarily extracted from the Quaternary alluvium for agricultural purposes. Figure 7.4 shows the location of existing private bores sourced from the PINNEENA database and groundwater allocations obtained from a Freedom of Information Search.

Figure 7.4 — Groundwater Users and Licence Allocation — Bylong Coal Project (G1606)
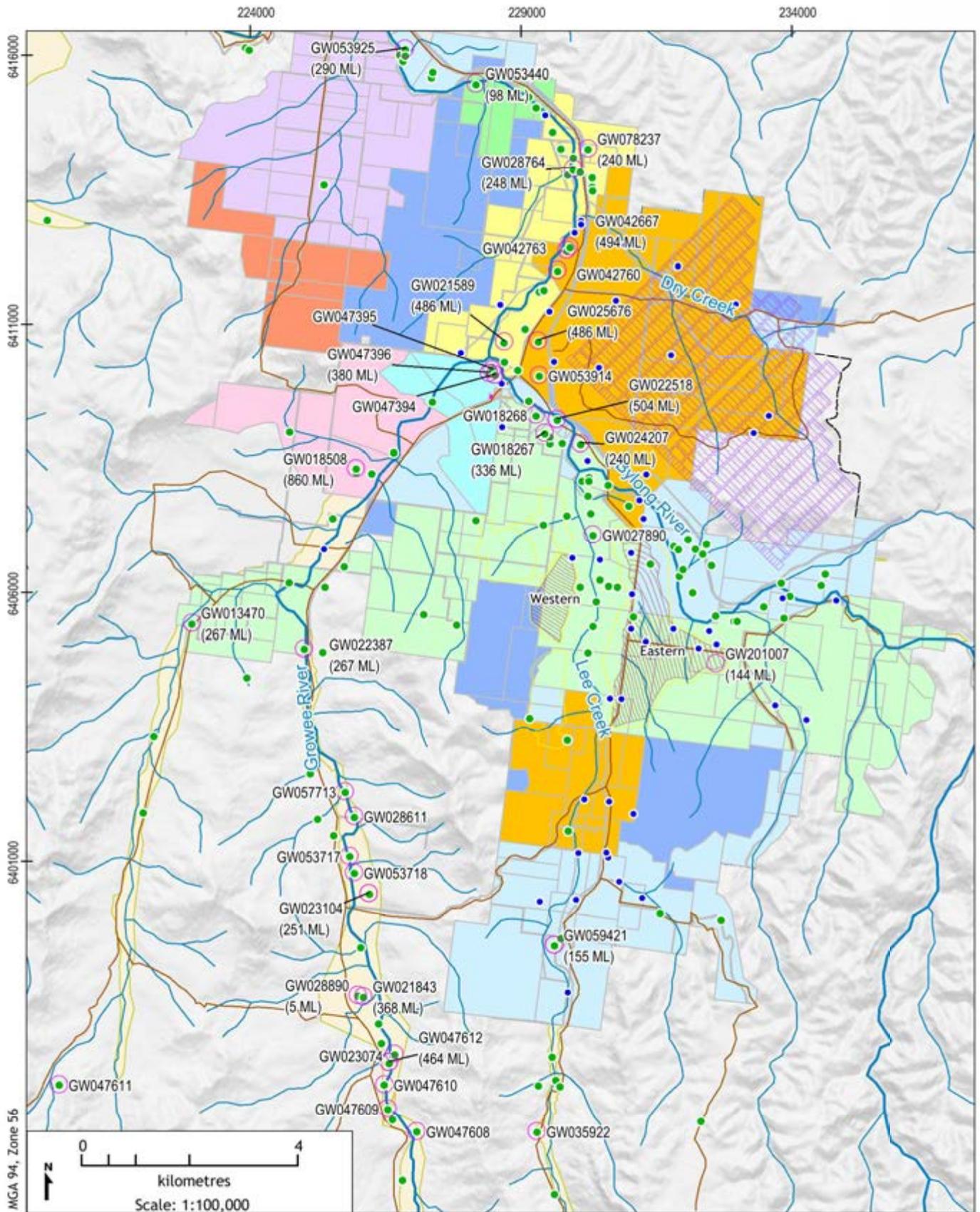
LEGEND:

- Monitoring Bore
- Registered Bore (Pineena)
- Licence Allocation (Volume in ML)
- Authorisation
- Quaternary Alluvium
- Underground Extraction Area
- Open Cut Mining Area
- Overburden Emplacement Area
- Drainage Line/ Creek
- Road

Landownership

- KEPCO Bylong Australia Pty Ltd
- Crown
- Wallings Pastoral Co Pty Ltd
- Private Freehold
- Accomac Holdings Pty Ltd
- Geble Pty Ltd
- Jarvet Pty Ltd
- Justin Kennedy Lewis Pty Ltd
- Locaway Pty Ltd
- Suntala Pty Ltd

MGA 94, Zone 56

Scale: 1:100,000

DATE: 2/12/2013

FIGURE No: 7.4

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7.3 Hydraulic Gradients and Water Levels

Figure 7.5 presents time variant groundwater levels from the PINNEENA database for the region around the Project Boundary from 1992 to 2011. Groundwater levels are presented against the CRD to infer where historical bore records are influenced by climate and hence groundwater recharge patterns.
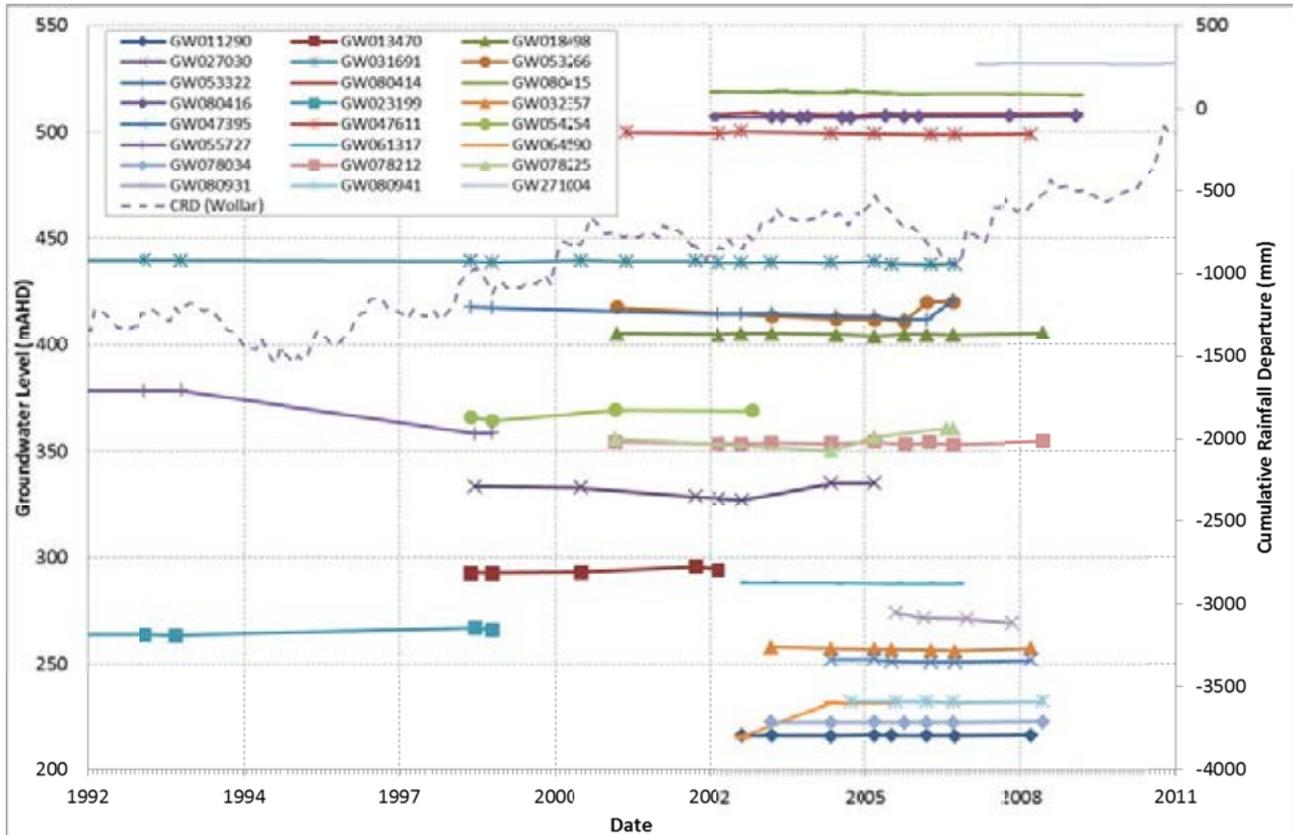
Figure 7.5: Regional Historical Groundwater Levels (source PINNEENA)

Generally, groundwater levels are relatively stable, with only a handful of bores following the CRD curve (e.g. GW027030 and GW047611). However, the monitoring frequency has not been sufficient to detect subtle water level fluctuations due to recharge events. Several alluvial bores have recorded falling groundwater levels of up to 7 m between the period 1999 and 2006 (e.g. GW053322, GW053266, and GW027030). The falling trends are likely to be associated with groundwater pumping or below average rainfall over this period.

Figure 7.6 shows an interpreted regional groundwater flow pattern. Data for this contour map was sourced from historical information from the PINNEENA database (NOW, 2013) as well as from site monitoring bores. This regional groundwater contour map is not specific to any specific hydrostratigraphic unit. There is a general north easterly flow direction from contours. It should be noted that no information was available for the elevated area to the south east of the Project Boundary in the headwaters of the Bylong River and adjoining catchments. It is probable that groundwater levels would be elevated in this area supporting the general northerly flow direction.
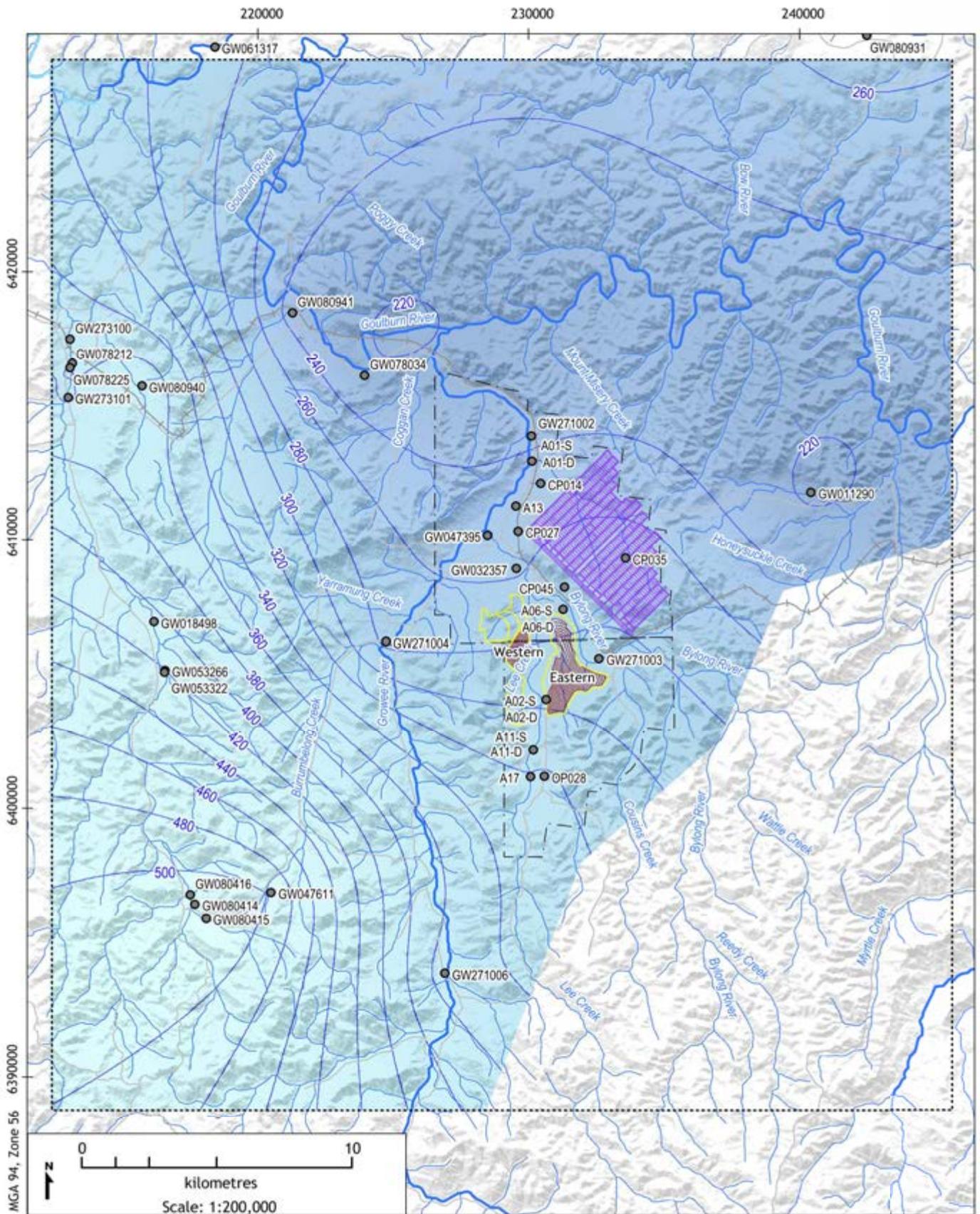
Figure 7.7 shows groundwater levels within the alluvium associated with the Bylong River compared against stream flow gauge data (SW8).
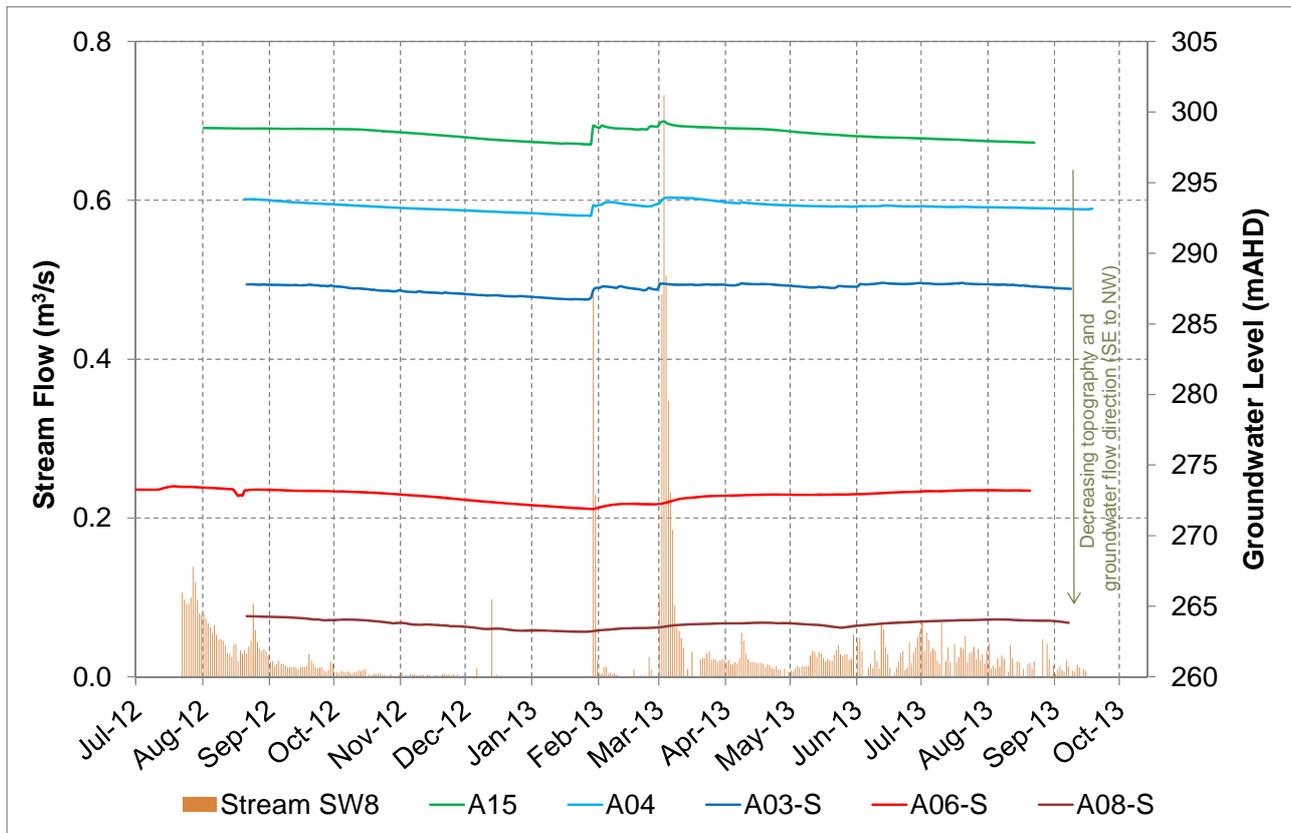
Figure 7.7: Alluvial Groundwater Levels - Bylong River Valley

Groundwater levels decline during periods of low stream flow and low rainfall from late 2012 to early 2013. Increases in groundwater levels occurred following significant stream flow events in February and March 2013. Interestingly the peak in groundwater levels and stream flows in February 2013 does not match rainfall at the site gauge, while increase in noted in March 2013 does correlate with rainfall. This suggests that rainfall alone may not be the only contributor to recharge to the alluvial groundwater system. Rainfall in the upper catchment generating stream flow events may also be a recharge source to the groundwater system further downstream as stream flow leaks from the river bed into the underlying aquifer as the slopes flatten and the creek bed becomes less defined.

Figure 7.8 shows alluvial groundwater levels from within the Lee Creek valley. Whilst similar to the Bylong River Valley, the groundwater levels lack the increase observed in the Bylong River Valley during February 2013. The long duration of low flow in the stream gauge record, and the flatter groundwater hydrographs, suggest that the Lee Creek catchment may have either a more subdued response to groundwater recharge or less groundwater recharge than the Bylong River Valley.

It is unknown if the observed declines in groundwater levels are influenced by licensed groundwater extraction, or just lack of recharge, but likely a combination of both. Flow directions within the Bylong and Lee Creek alluvium follow topography, that is, downhill in each valley.
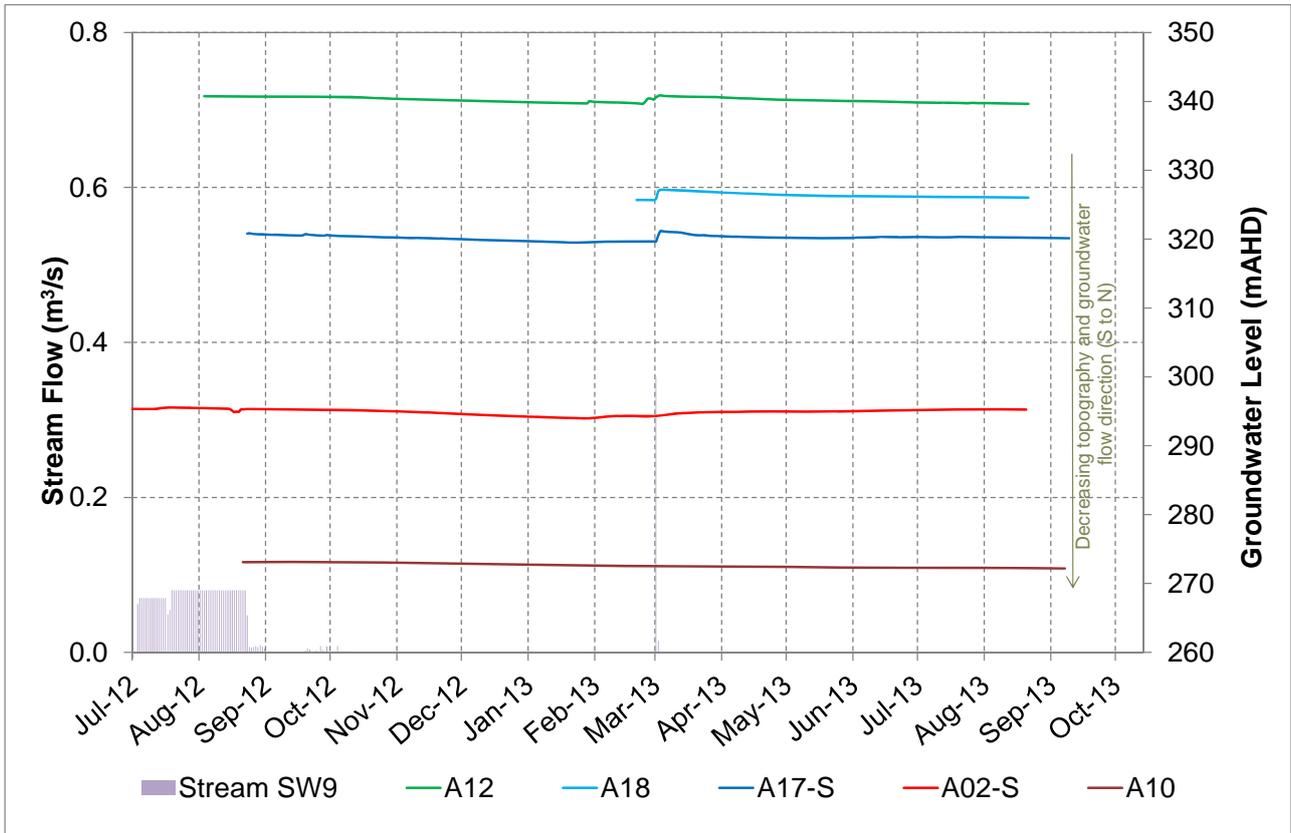
Figure 7.8: Alluvial Groundwater Levels - Lee Creek Valley

Figure 7.9 shows groundwater levels for the Coggan Coal Seam compared against rainfall. The groundwater levels remain fairly static throughout the record with only a slight downward trend. Groundwater levels show the flow direction in the Coggan Coal Seam is in a northerly or north easterly direction consistent with the direction of dip and regional groundwater contours (Figure 7.5). The recharge event during March 2013 (noted in alluvial bores) is not apparent in groundwater data from the Coggan Coal Seam. This suggests the Coggan Coal Seam is more limited and buffered from specific climatic events, which is to be expected given the greater depth of the seam.
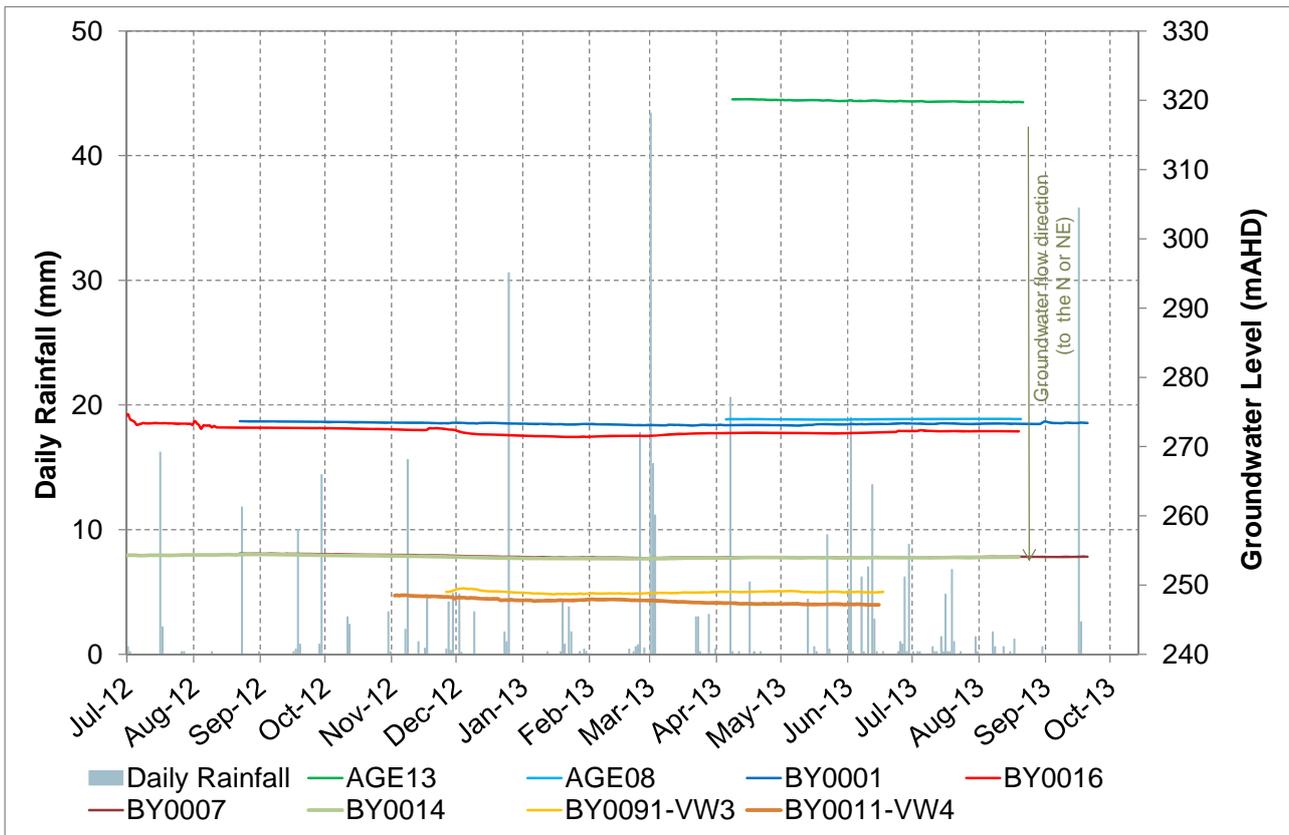
Figure 7.9: Coggan Coal Seam Groundwater Levels

Figure 7.10 shows groundwater levels in both the alluvium (associated with the Bylong River) and the Coggan Coal Seam adjacent to and sub-cropping below the alluvium. The vertical gradient is either neutral or upwards. Further investigation for the EIS will identify areas where downward vertical gradients occur and recharge occurs to the Permian strata. This will be done by review of data from the VWP network.

Figure 7.11 presents data from the Permian strata from the VWP installed at BY0011. The pore pressures below, within and directly above the Coggan and Ulan Coal Seams (VW3) show similar pressures. The shallow VWP sensor (VW1) has significantly higher heads than the four lower sensors. Data from the VWP installed in BY0091 shows very similar data. The data from the sensors is more variable more than the deeper sensors. Data suggests a shallow or perched system may be present in elevated areas with significant aquitards separating the shallow Permian overburden from the lower Permian sequence. A Tertiary basalt cap in this area may enhance recharge resulting in perching of water on the less permeable Permian sequence.
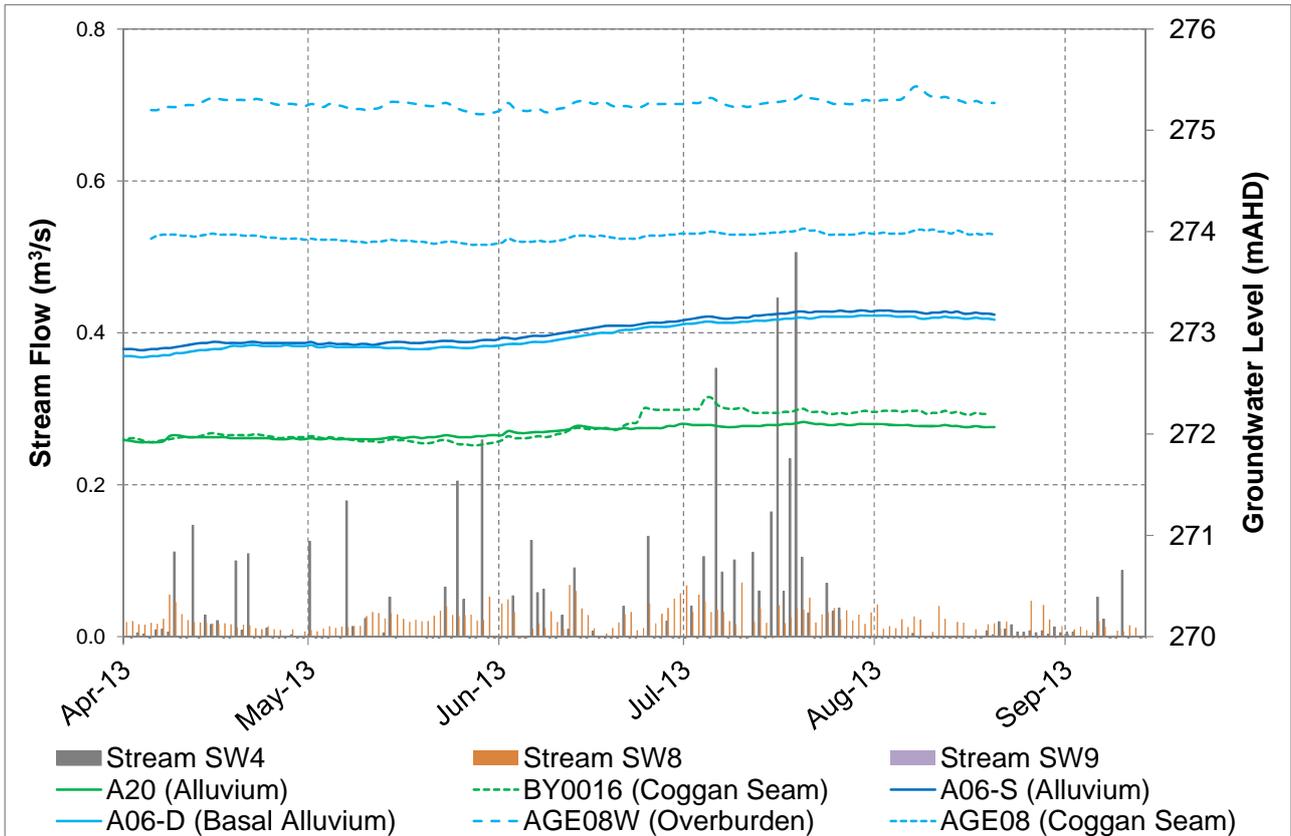
Figure 7.10: Vertical hydraulic gradients - alluvium and Coggan Coal Seam
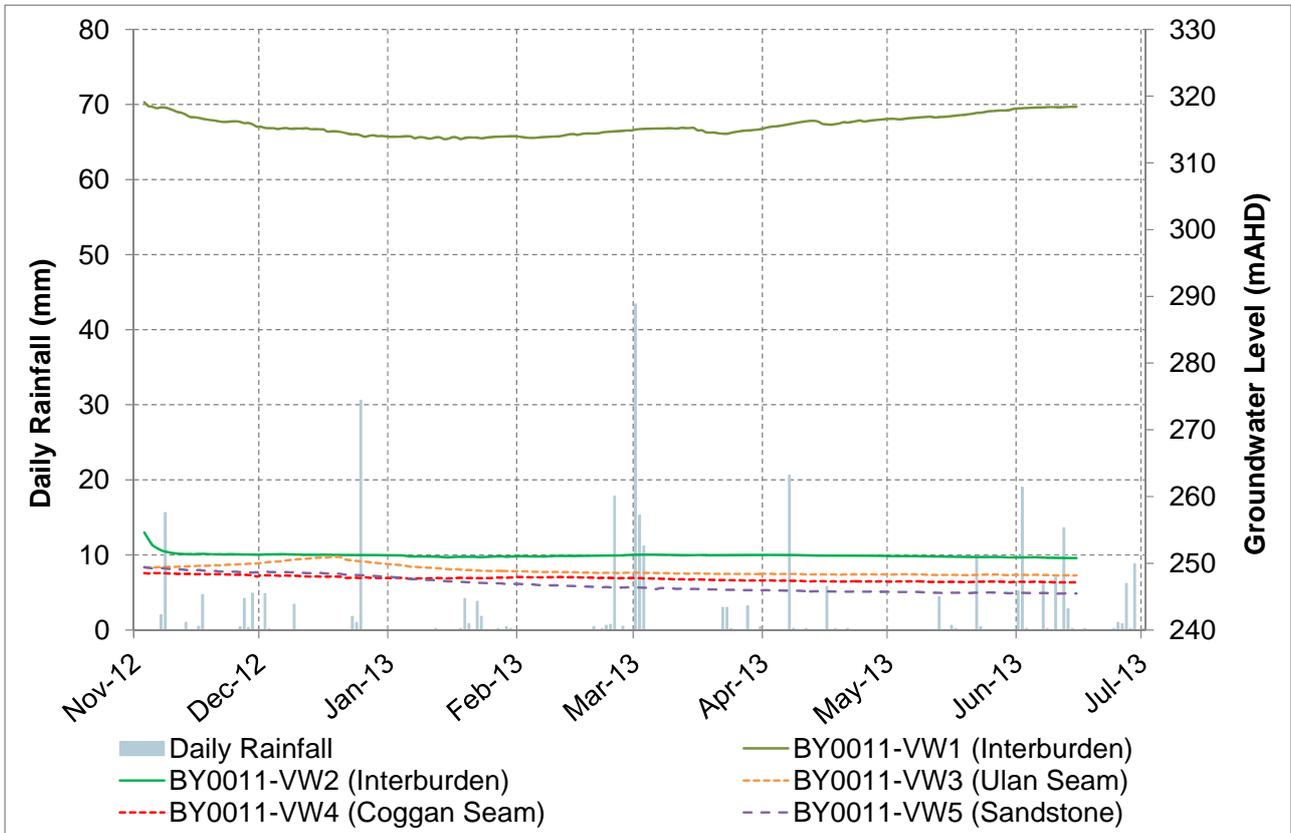
Figure 7.11: Vertical hydraulic gradients in the Permian sequence

7.4   Recharge, Discharge and Groundwater Flow

Recharge to the groundwater system within the Project Boundary can be characterised from two major sources. Firstly, direct rainfall recharge through the soil zone to the water table. Secondly, infiltration of surface water through the beds of rivers and creeks. Leakage from river or creek beds is only likely to be significant when rivers are flowing and when surface water levels are higher than groundwater levels. Rainfall recharge through the soil zone will only be possible when soil moisture deficits are overcome and the soil profile reaches saturation (field capacity).

Variable rainfall in the area likely means, daily rainfall and / or stream flow may vary significantly on a catchment scale. This may explain water table rises when there is no rainfall recorded in the site gauge. Further monitoring will confirm the variability in rainfall patterns.

Recharge processes are highly likely to form an important component in the Project site water balance. An effort has been made to investigate recharge process using the available baseline data. Stage 2 modelling beyond the Gateway process will further investigate recharge processes.

Experience in similar environments in the Western Coalfields and Hunter Valley has shown that recharge rates to alluvium are generally five to ten times higher than those of the consolidated strata. This is a direct reflection on the ground permeability and storage potential of the two formations.

Recharge to the Permian ICM is presumed to be through lateral migration along dip where units sub-crop near the surface, particularly in low lying areas underneath or adjacent to alluvium. Due to the low bulk vertical hydraulic conductivity in the Permian overburden, downward recharge through the Permian sequence to the Ulan and Coggan Coal Seams would be very limited. This theory is supported by evidence of perching in elevated terrain above the proposed underground extraction area.

Groundwater hydrographs from the monitoring bores show that groundwater levels (particularly in the alluvium) do rise rapidly in the order of 0.5 m to 1 m in response to significant climatic events. Groundwater levels also demonstrate that recharge episodes are infrequent, leading to long term declines in groundwater levels over prolonged dry periods.

A simplistic soil moisture balance (SMB) approach to temporal recharge estimation was used to investigate the type of climatic event that produces measurable recharge to the shallow groundwater system. Daily (in-filled) site rainfall was used along with data from the Wollar rainfall gauge to back track the dataset to the start of 2010. Additional data and assumptions are as follows:

- Evapotranspiration – 2.5 mm/day, considered within the middle range of the available data;
- Rooting depth – 50 mm, to replicate pasture; and
- Max daily recharge cap – 25 mm to replicate increased run-off under significant intensity rainfall events.

Figure 7.12 shows the result of the calculation with capped effective recharge shown as a red line. The soil moisture deficit is tracked as the green line with recharge only simulated where soil moisture deficit reaches zero. The extended records from the Wollar rainfall data shows the period prior to June 2012 was wetter than after this period. This wetter period potentially produced a larger number of recharge events. Figure 7.13 compares the recharge results against alluvial groundwater levels. This comparison shows reasonable correlation against peaks in both the recharge model and groundwater levels.
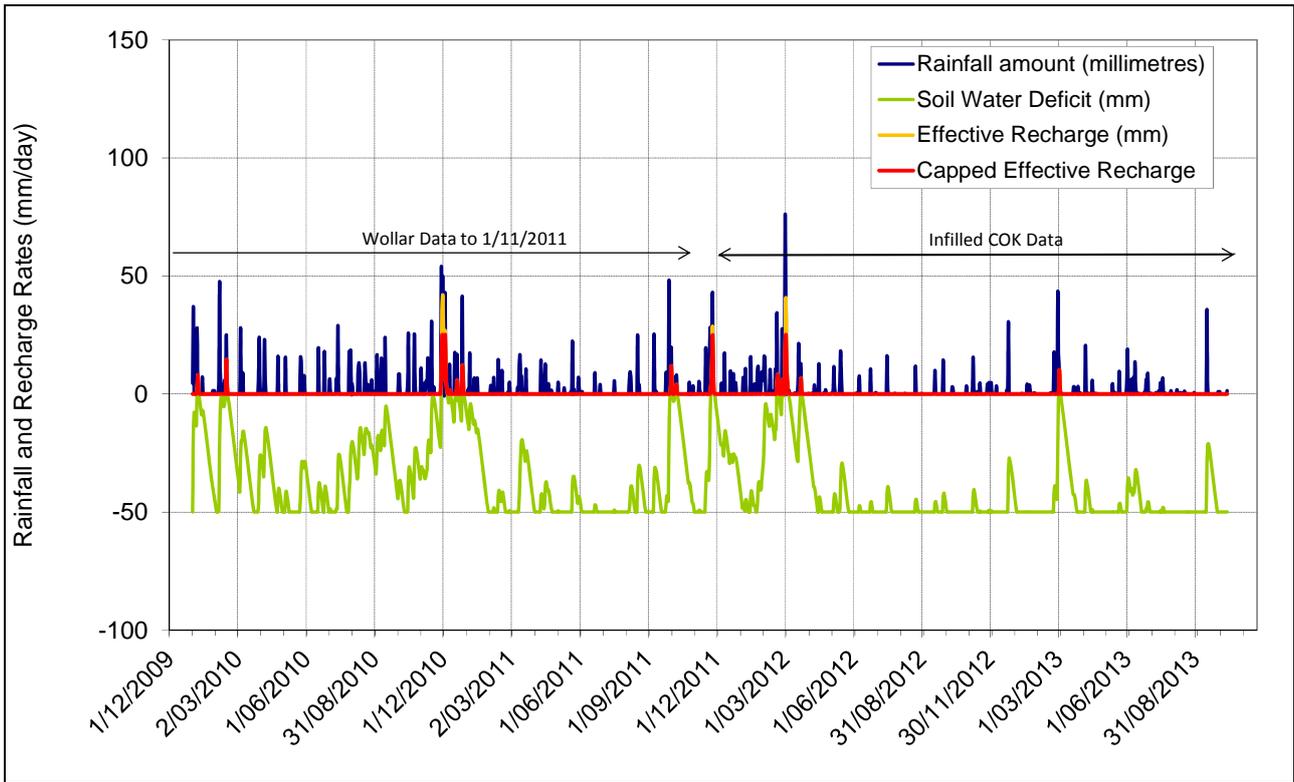
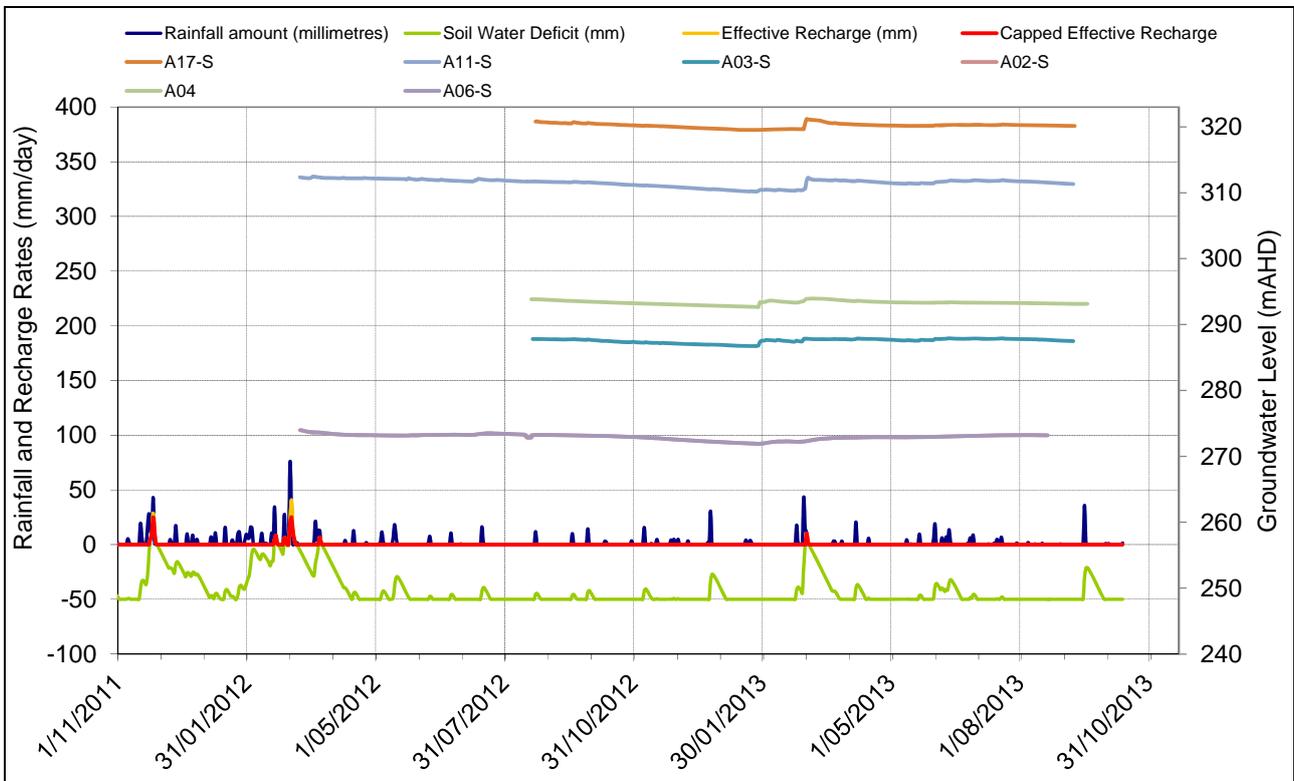**Figure 7.12: Rainfall Recharge**

Figure 7.13: Rainfall Recharge versus Alluvial Groundwater Levels

Discharge from the groundwater system will be either as baseflow to surface water systems, evapotranspiration, pumping from bores and down valley flow within the alluvium.

Stream flow data suggests that baseflow to streams may not be significant enough to sustain perennial flows. Figure 7.3 shows mapped occurrences of surface water during periods of low flow, this aligns well with an area of shallow water table. It is probable that spatially and temporally, sections of creeks and rivers could either recharge the groundwater system or receive discharge from the groundwater system (baseflow).

Evapotranspiration is likely to be a significant component of the water balance at maximum of 3.5 mm/day. Evapotranspiration will be greater in areas of shallow water table depth along the alluvial valley flats (Figure 7.3).

Groundwater abstraction from private bores is not measured in the region, however a FOI search indicates it is also a significant component of the water balance and will be investigated further during the EIS.

Groundwater through flow within the alluvium is also expected to be significant. The majority of outflow is expected where alluvium merges with the Goulburn River.

A spring survey is recommended to be carried out in conjunction with the proposed landholder bore census. A similar survey was carried out as part of the Moolarben Coal Project groundwater investigation and provided information on the discharge of saline water from the Permian Coal Measures adjacent to Moolarben Creek (Dundon, 2006).

7.5   Water Quality and Environmental Values / Beneficial Use

DP (2013) presents statistical and graphical data of collected water quality samples from groundwater and surface water sampling locations. This report should be consulted for original sample data as well as QA and QC information.

This section presents a summary of the background water hydrochemical data collected to date. This is presented in the context of the requirements of this Gateway report to support the conceptual process and discusses the water quality in terms of Strategic Agricultural Land and also the AIP. Defining the baseline surface water and groundwater quality also presents a basis for discussion of potential changes to water quality from the Project.

Up until October 2013, a total of 295 water quality samples have been collected from 11 alluvial monitoring bores, six Permian monitoring bores and eight surface water sites. The analysis of samples includes EC, pH and a full major ion sample suites. The dataset represents a high quality spatial and temporal set of baseline groundwater quality within the Project Boundary. Table 7.2 summarises the minimum, mean and maximum data for each site.

Electrical conductivity (EC) for each alluvium site ranges from relatively fresh (277 µS/cm) to slightly saline (2,547 µS/cm). EC for the Permian Coal Measures is relatively fresh to slightly saline ranging from 1,042 µS/cm to 2,774 µS/cm. This low salinity for the Permian Coal Measures suggests that the alluvium is a recharge area to the Permian sequence.

Surface water sites average EC ranges from 224 µS/cm to 1,790 µS/cm with six of the sites below 1,000 µS/cm. The salinity of surface water suggests a significant groundwater baseflow component. Figure 7.14 shows the average EC for each sample site.

Figure 7.15 shows major ions ratios of all samples plotted in a Piper diagram, with the average for each site shown in Figure 7.16. The Piper diagrams show that whilst EC is similar in a large proportion of samples, there is a clear comparison between most surface water samples and alluvium water samples. This suggests interaction between the two water types which is consistent

with other hydrogeological data. The majority of the Permian samples plot in a separate group due to the higher Na proportion. The one surface water sample that plots with Permian results is site SW3 located on Dry Creek within weathered Permian strata. Figure 7.17 shows the average major ion data for each site on an extended Durov diagram. The extended Durov diagram is often useful to show differences in samples with similar major ion concentrations but variable EC. The Durov diagram generally shows the similarity in most of the samples based on major ion concentration, pH and EC.

The water quality results suggest that the alluvium has is suitable for stock watering and suitable for irrigation in many, but not all bores. The interpretation of data also suggests a strong interaction between the surface water systems and alluvium, but also to lesser extent the deeper Permian and the shallow systems.

| | | Table 7.2: GROUNDWATER AND SURFACE WATER QUALITY SUMMARY | | | | | | | | | | | | | | | | | | | | | | | | | | | |

	Bore ID	No. Samples	EC (µS/cm)			pH			SO$_4$ (mg/L)			Na (mg/L)			Cl (mg/L)			Mg (mg/L)			K (mg/L)			HCO$_3$ (mg/L)			Ca (mg/L)		
			Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.
Alluvium	A01-S	18	1200	3100	2547	6.3	8.5	7.4	33	320	250	200	385	288	120	570	442	83	140	108	5	8	7	440	500	467	100	150	128
	A02-S	18	1100	1900	1350	7.0	8.0	7.3	41	69	59	33	58.5	51	130	180	159	56	76	66	6	9	8	290	380	343	100	120	115
	A06-S	16	940	1600	1262	6.8	8.5	7.4	9	27	14	85	150	113	41	260	181	42	85	60	2	4	3	330	470	388	48	92	68
	A09	11	680	2200	1533	7.2	7.8	7.4	37	210	124	85	250	158	68	390	250	23	93	65	5	10	7	200	430	324	27	99	71
	A12	10	250	310	277	6.5	8.0	6.9	13	21	17	15	22	19	22	28	26	9	14	11	3	3	3	65	93	79	13	19	16
	A13	19	1200	1600	1341	6.9	8.3	7.3	65	140	86	89	130	112	180	280	214	50	80	61	5	6	6	260	320	294	64	110	79
	A14	12	1600	1800	1733	7.1	8.1	7.4	55	270	216	120	180	147	160	230	189	77	110	87	4	6	5	440	470	454	110	150	120
	A15	10	260	350	308	6.6	8.0	6.9	4	20	7	21	29	25	25	42	35	10	16	13	3	3	3	77	110	93	10	15	13
	A18	10	320	380	355	6.6	8.2	6.9	10	31	20	17	26	21	20	28	24	12	19	14	5	19	14	110	140	126	18	28	21
	A19	3	2000	2100	2033	7.4	7.7	7.6	250	280	267	190	200	197	330	350	337	86	97	91	8	8	8	330	340	337	110	120	117
	A20	9	740	1300	989	7.1	8.4	7.6	24	76	46	80	130	103	76	210	133	26	58	41	5	6	6	240	360	289	34	71	52
Permian	AGE08	4	1200	1300	1250	7.2	8.3	7.6	1	1	1	190	230	215	38	93	74	25	27	26	11	14	13	570	590	583	31	35	34
	AGE10	4	1900	2000	1933	6.9	7.3	7.1	23	33	26	130	325	245	190	250	217	52	65	59	19	28	23	660	850	737	54	60	56
	AGE13	3	1600	1700	1633	6.8	8.1	7.3	41	58	49	100	190	157	130	150	140	65	73	70	15	18	17	660	670	663	65	71	69
	BY0014	20	980	1100	1042	6.7	8.6	7.8	1	1	1	160	230	190	71	93	80	17	22	18	9	12	11	400	500	461	31	39	33
	BY0015	20	1100	1200	1182	6.8	8.2	7.5	24	310	49	160	230	193	110	460	136	22	28	24	10	14	12	410	510	434	38	47	42
	BY0016	20	2400	3900	2774	7.0	8.8	7.5	16	130	44	495	740	619	200	630	314	20	88	33	15	26	19	890	1100	1036	30	71	41
Surface water	SW1	10	120	290	224	6.7	7.7	7.3	2	6	4	13	28	21	18	35	29	4	13	9	2	4	3	28	87	65	3.5	13	9
	SW2	9	120	290	228	7.0	8.5	7.8	2	5	4	13	28	22	23	120	81	4	13	9	2	4	3	28	87	67	3.5	13	9
	SW3	8	330	1200	981	7.2	8.6	8.1	6	29	13	40	180	149	41	140	103	10	46	32	3	8	6	100	440	336	13	36	29
	SW4	25	380	2200	1734	7.1	8.3	7.9	19	320	206	33	240	169	47	370	263	15	120	82	5	14	7	2.5	410	321	19	160	104
	SW6	14	480	2300	1790	7.1	8.5	8.1	29	260	182	43	300	192	64	400	302	19	130	85	6	11	8	120	400	330	25	110	89
	SW7	6	180	360	271	6.9	7.8	7.3	3	18	11	13	26	20	18	26	22	8	13	11	3	3	3	68	140	91	8.7	17	14
	SW8	12	250	950	681	6.9	8.2	7.8	4	18	10	23	99	68	30	120	76	9	43	27	4	8	6	71	310	220	11	52	34
	SW9	4	320	370	340	7.3	7.8	7.5	12	24	17	19	24	22	21	22	21	14	19	16	5	7	6	110	150	125	22.5	28	25
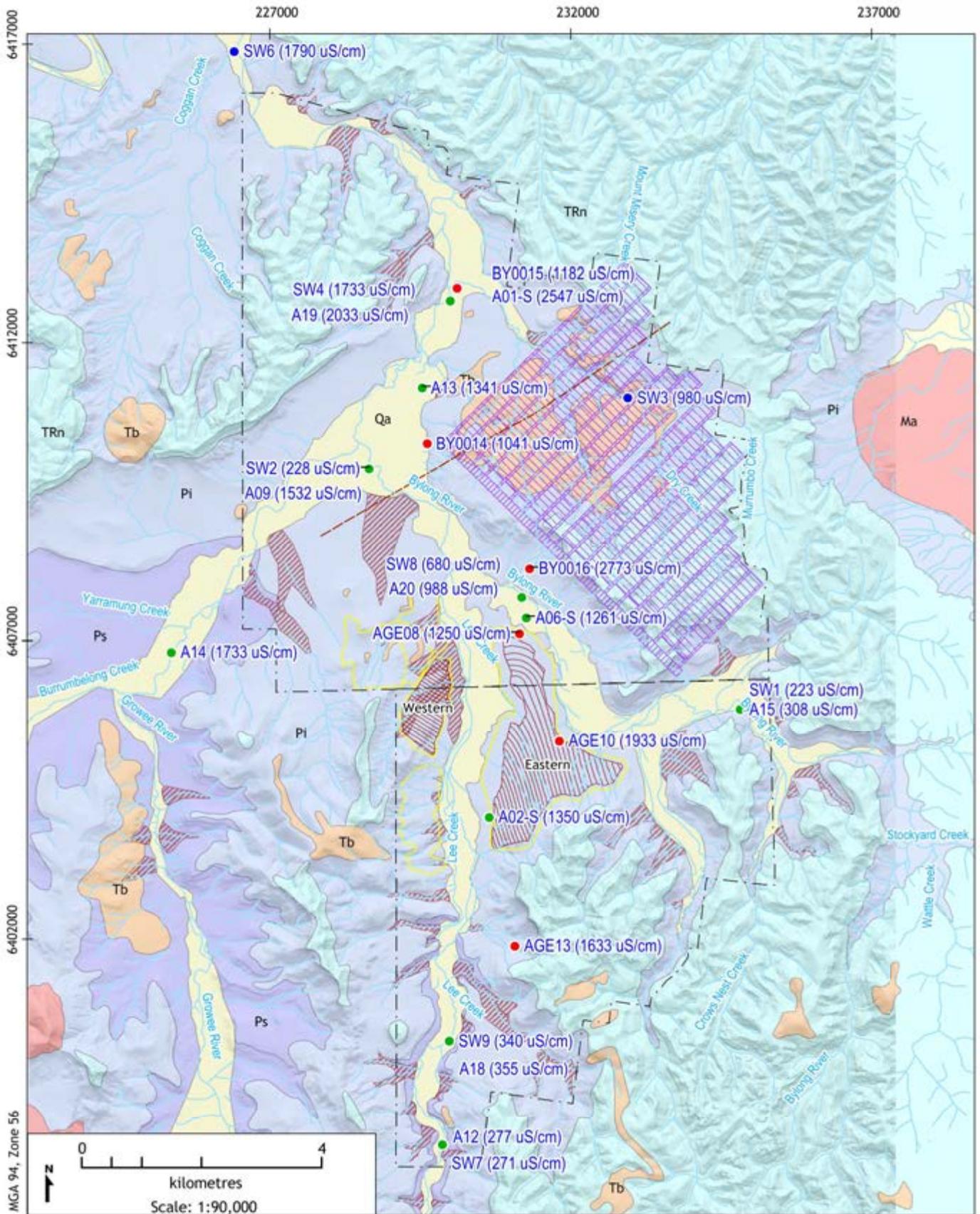
Electrical Conductivity Distribution

Bylong Coal Project (G1606)

DATE: 2/12/2013

FIGURE No: 7.14

Figure 7.15: Piper Diagram - All Data

Figure 7.16: Piper Diagram - Average for Each Site
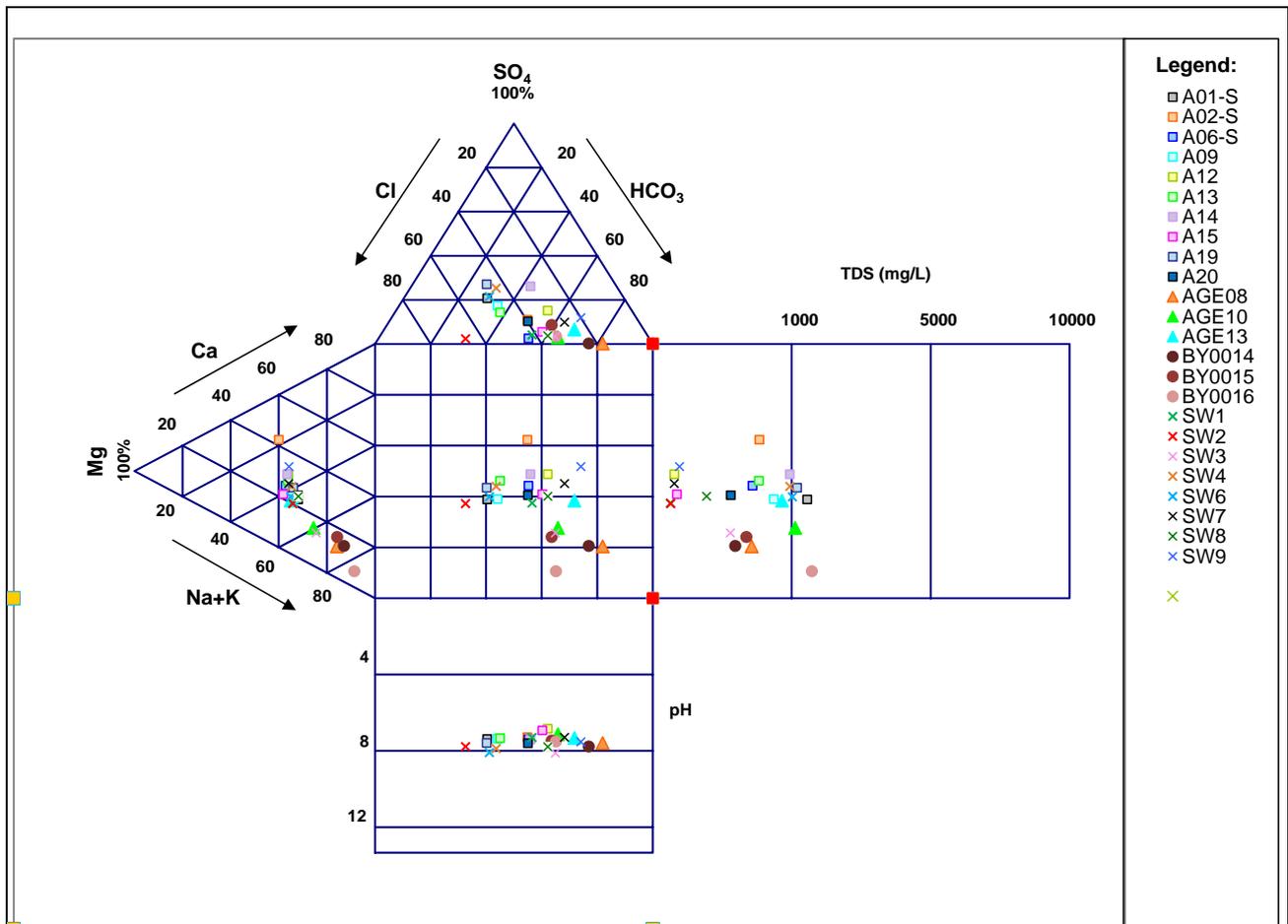
Figure 7.17: Extended Durov Diagram - Average for Each Site

7.6   Groundwater Dependent Ecosystems

Figure 7.18 presents the data from the National GDE Atlas[3] within the Project Boundary. There are no mapped GDE in the Bylong River and Lee Creek catchments. The Growee River is mapped as low to moderate potential for GDE supported by surface expressions of groundwater.

The National GDE Atlas only presents a guide to potential GDE. Field investigations are being undertaken to determine if GDEs are present within both the alluvial flats and elevated hill tops during the EIS process. An early survey on the hills on Tal Tal Mountain and Mt Penny identified some patches of swampy land dominated by *Backhousia myrtifolia;* however, these appear to be more rainfall dependent rather than groundwater dependent.

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[3] http://www.bom.gov.au/water/groundwater/gde/

Goulburn River National Park

Goulburn River

Poggy Creek

Goulburn River National Park

Bow River

6420000

Goulburn River

Goulburn River

Coggan Creek

Mount Misery Creek

Honeysuckle Creek

6410000

Yarramung Creek

Lee Creek

Bylong River

Bylong River

Western

Eastern

Wollemi National Park

Growee River

Burrumbelong Creek

Cousins Creek

Bylong River

6400000

Wattle Creek

Reedy Creek

Bylong River

Myrtle Creek

Lee Creek

MGA 94, Zone 56

0   10

kilometres

Scale: 1:200,000

N

LEGEND:

GDE Atlas (Surface Expression)

- High potential for GW interaction
- Moderate potential for GW interaction
- Low potential for GW interaction

Reserve / National Park

Authorisation

Model Boundary

—— Underground Extraction Area
—— Open Cut Mining Area
—— Overburden Emplacement Area

—— Road
—+— Railway
—— River
—— Drainage Line / Creek

Bylong Coal Project (G1606)

Groundwater Dependent Ecosystems

AGE
GROUNDWATER & ENVIRONMENTAL

DATE: 2/12/2013

FIGURE No: 7.18

7.7   Conceptual Hydrogeology

Figure 7.19 shows a conceptual cross-section of the geology and groundwater regime. The valley floor areas in this schematic represent the present day alluvial valleys incised into the Permian Coal Measures. The Permian Coal Measures can be seen dipping to the right of the diagram (north east). The schematic illustrates what is supported by hydrochemistry data, that is the Permian Coal Measures are recharged in part by leakage from alluvium. Although in some areas, higher pressures within the Permian Coal Measures may in-turn discharge groundwater to alluvium. During mining, water levels within the Permian Coal Measures will decline with the potential to increase flow from the alluvium to the Permian Coal Measures. This is illustrated in the schematic with the blue dotted line representing the depressurised groundwater level.

Baseline data presents two main groundwater systems within the Project Boundary. A shallow surface water and alluvial groundwater system, that based on water level and hydrochemistry data has significant interaction.   Alluvial groundwater levels suggest sub-surface flow within the alluvium along the alignment of present day water courses.   The depth to water table against mapped surface water occurrence suggests further evidence of significant interaction between alluvial groundwater and surface water. The Permian Coal Measures, in particular the Coggan Coal Seam and to a lesser extent the Ulan Coal Seam, represent the second main groundwater system. A third minor perched groundwater system is also potentially present associated with the Tertiary basalt cap in area overlying the proposed underground extraction area.

Recharge to the system is thought to be from rainfall infiltration through the soil zone during periods of above average rainfall when the soil moisture deficits are overcome. Leakage from creeks and rivers represents the second source of recharge to the system.   Due to the permeability and storage of the alluvial sediments, a larger volume of recharge is probable to the alluvium over recharge to the Permian Coal Measures and other consolidated and weathered formations.   The majority of recharge to the Permian Coal Measures is likely through rainfall recharge where sediment outcrops or sub-crops below the alluvium with recharged groundwater migrating down dip within the coal seams.   The lower permeability interburden and overburden are thought to significantly retard migration of recharge through the vertical profile where a thicker Permian sequence is present above the coal seams.   In summary, recharge to the Permian Coal Measures is more likely where the units sub-crop or outcrop rather than where a complete Permian and Tertiary profile is present. Based on current data the underlying Marrangaroo Sandstone appears to be an aquitard; however, further investigation will be undertaken during the preparation of the EIS to confirm this.

Volcanic intrusions are likely to form barriers to groundwater flow within the subsurface groundwater environment.

Discharge in the current environment is from evaporation from open water bodies, evapotranspiration where water tables are near surface, baseflow to creeks and rivers and extraction from bores. Discharge from the Permian Coal Measures to the alluvium is also possible.

The current conceptual understanding of the system has been tested during development of a groundwater model and is discussed further in the following sections of this report.

WEST
212000mE

EAST
246000mE

Elevation (mAHD)

600

450

300

150

0

Rainfall Recharge

BYLONG STATE FOREST

Evapotranspiration

Eastern Open Cut Mining Area

Landholder Pumping

River Recharge Discharge

Runoff

Goafing

Mine Dewatering

Underground Extraction Area

Base of model
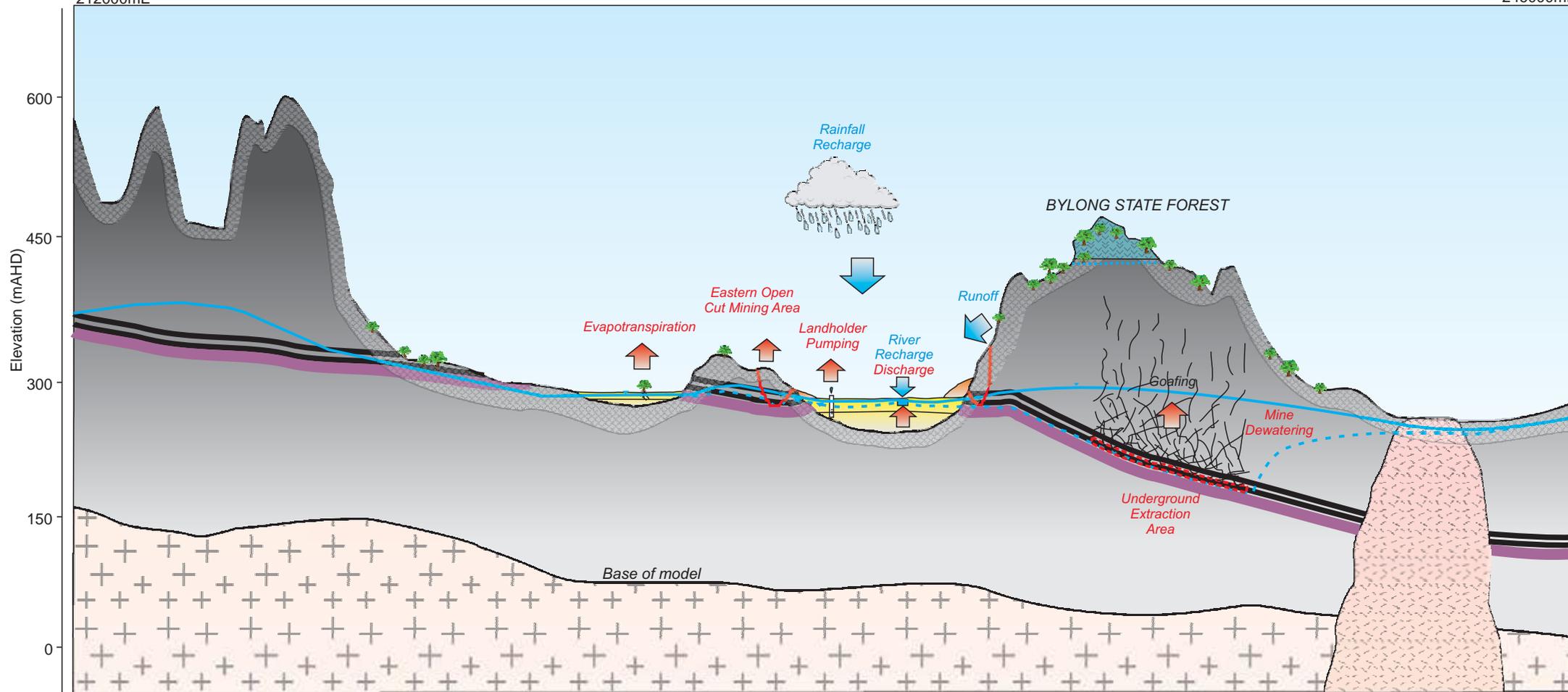
	Alluvium		Interburden		Carboniferous Volcanics
	Colluvium		Coal Seam	—	Potentiometric Head
	Tertiary Basalt		Marrangaroo Sandstone		Groundwater Inflow
	Weathered Interburden		Triassic Volcanics		Groundwater Outflow

Schematic Section Showing Conceptualised Hydrogeology

Figure 7.19
BYLONG COAL PROJECT - GROUNDWATER ASSESSMENT (G1606)

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8   NUMERICAL MODEL DESIGN

8.1   Modelling Objectives

The primary objective of the groundwater modelling was to develop a groundwater model that could quantify the impact of the proposed mining, allowing the preliminary impacts to be compared with the AIP. The design, construction and calibration of the model was tailored to this objective, while also providing a framework for future iterations of the model following the addition of new data during the preparation of the EIS. The model was calibrated so that it broadly replicated groundwater flow directions, gradients and system dynamics. Following calibration, the model simulated the impact of the Project on the groundwater regime.

8.2   Model Design

8.2.1   Model Code

The MODFLOW SURFACT code simulated groundwater flows within the Project Boundary. SURFACT is a commercial derivative of the standard MODFLOW code. It has some distinct advantages over the standard MODFLOW that are beneficial for simulating mining. SURFACT simulates variably saturated conditions, which is critical where mining progressively de-saturates model cells within the mining footprint. The MODFLOW pre and post processor PMWIN (Chaing and Kinzelbach, 1996) and Groundwater Vistas (Environmental Simulations Inc., 2011) generated some of the input files along with in house FORTRAN code.

8.2.2   Model Extent and Boundary Conditions

The model grid was 33 km wide (E-W) and 39 km long (N-S). The model grid aligned to the principal groundwater flow direction from south to north in the alluvial aquifer. The boundaries were set distant at 10 km to 11 km from the proposed mining areas, to minimise the effect of boundaries on the predictions. Figure 8.1 shows the model domain.

The model included a zone of general head boundary cells along a portion of the western boundary, where previous models predicted a slight drawdown from the Wilpinjong Mine could occur. These cells were included to simulate a cumulative impact, should the drawdown from the Project extend to this boundary.

8.2.3   Model Layers

The aim of the layer discretisation was to find a balance between having sufficient layers to represent some detail in the geology, while still limiting the number of cells to ensure the model ran quickly. To achieve this, the model grouped geological units with similar hydraulic properties into single layers. Section 7 outlines the key hydrostratigraphic units that control groundwater flow in the region.
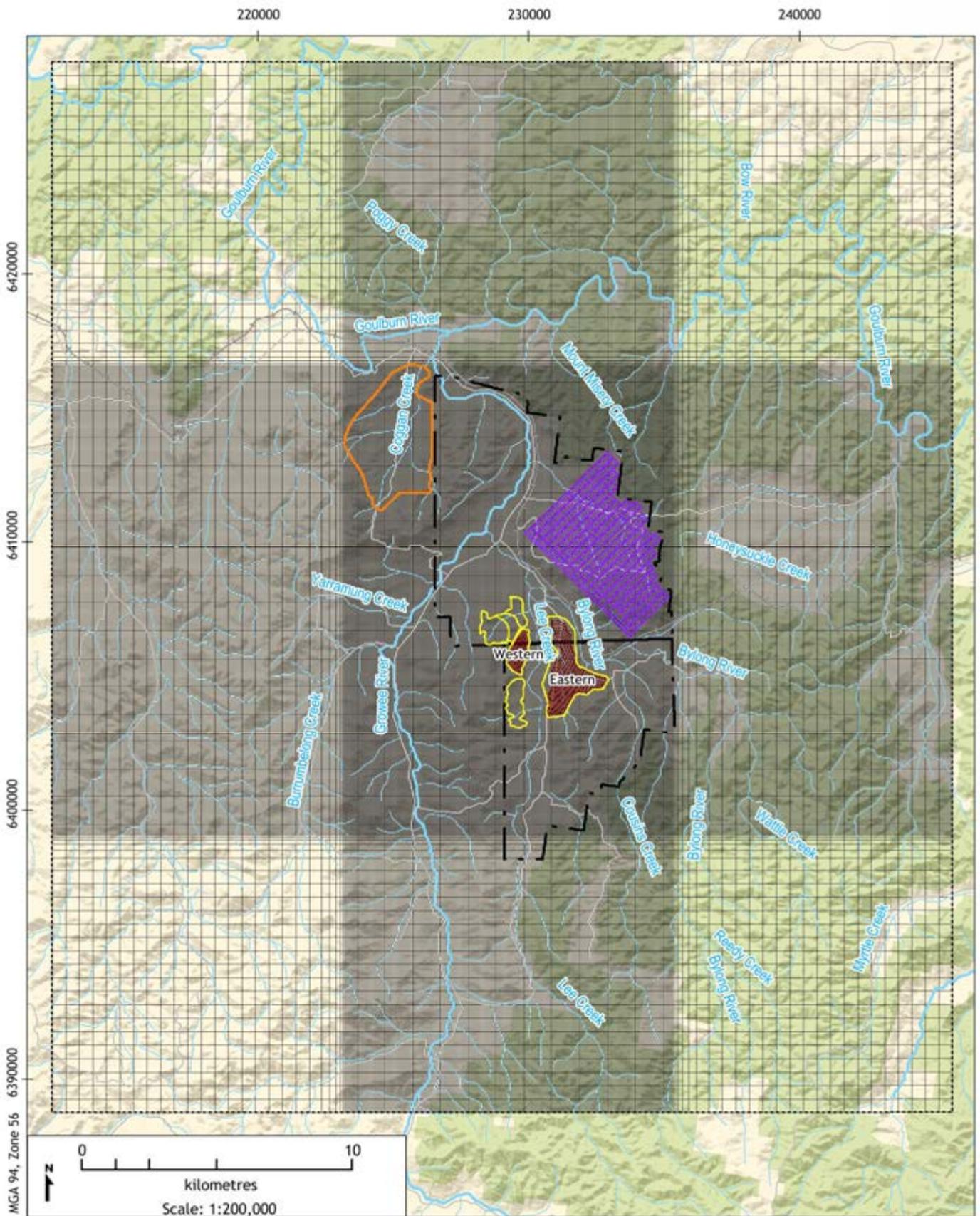
Bylong Coal Project (G1606)

Model Extent

LEGEND:

- ⬚ Model Boundary
- ☐ Model Grid
- — Underground Extraction Area
- — Open Cut Mining Area
- — Overburden Emplacement Area
- ☐ Mt Penny Mining Area
- ▪ Authorisation

- ▨ Reserve / National Park
- — River
- — Drainage Line / Creek
- — Major Road
- — Road
- + Railway

MGA 94, Zone 56

0   10
kilometres
Scale: 1:200,000

DATE: 2/12/2013

FIGURE No: 8.1

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The model represented these hydrostratigraphic units in ten layers, as follows:

		avg. thickness
•	Layer 1 – Quaternary alluvium (upper), colluvium, regolith	5 m
•	Layer 2 – Quaternary alluvium (lower), colluvium, regolith	5 m
•	Layer 3 – Weathered interburden	10 m
•	Layer 4 – Farmers Creek Seam, State Mine Creek interburden	18 m
•	Layer 5 – Interburden	115 m
•	Layer 6 – Ulan Seam	7 m
•	Layer 7 – Interburden	4 m
•	Layer 8 – Coggan Seam	5 m
•	Layer 9 – Marrangaroo Sandstone	20 m
•	Layer 10 – Underburden	100 m+

The model represented the:

- alluvium as two layers, with a lower, more permeable zone, and an upper, less permeable layer;

- sporadically occurring Tertiary basalts and Triassic intrusives to the east of the proposed mining area as zones within model layers, not as separate layers; and

- all units between the base of the Marrangaroo sandstone and the Carboniferous volcanics basement as Layer 10.

8.2.4 Grid and Cell Size

The model adopted a cell size of 500 m x 500 m, which was refined to 50 m x 50 m within the proposed mining areas, comprising a total of 1,164,000 cells.

8.2.5 Recharge and Discharge

8.2.5.1 Rainfall

Topography is controlling factor to rainfall patterns in the region, with an average of 580 mm/year in the lower lying areas in the northeast, to 860 mm/year in the elevated land to the south-east. The model represented the spatial distribution of rainfall in the recharge rates adopted within the model. The model applied recharge as a portion of interpolated rainfall to zones based on outcropping geology.

8.2.5.2 Evapotranspiration

The model represented evapotranspiration from the aquifers with the SURFACT Evapotranspiration package. The package removed water from the water table at a maximum rate of 10% of the potential evapotranspiration rates. The package set the extinction depth at 2 m from the ground surface to simulate root system capillary action and the natural decline of evapotranspiration with depth.

8.2.5.3 Rivers and Drainage

The SURFACT river package simulated the rivers and creeks drainages in the region. The bed of the Goulburn River was set at 1 m below the LIDAR digital elevation data along the river alignment, with 0.5 m of permanent water in the river. The model represented all other creeks and drainage lines as drains, where only flow of water from the aquifer to the stream could occur. Figure 8.2 displays the river cells in the model.
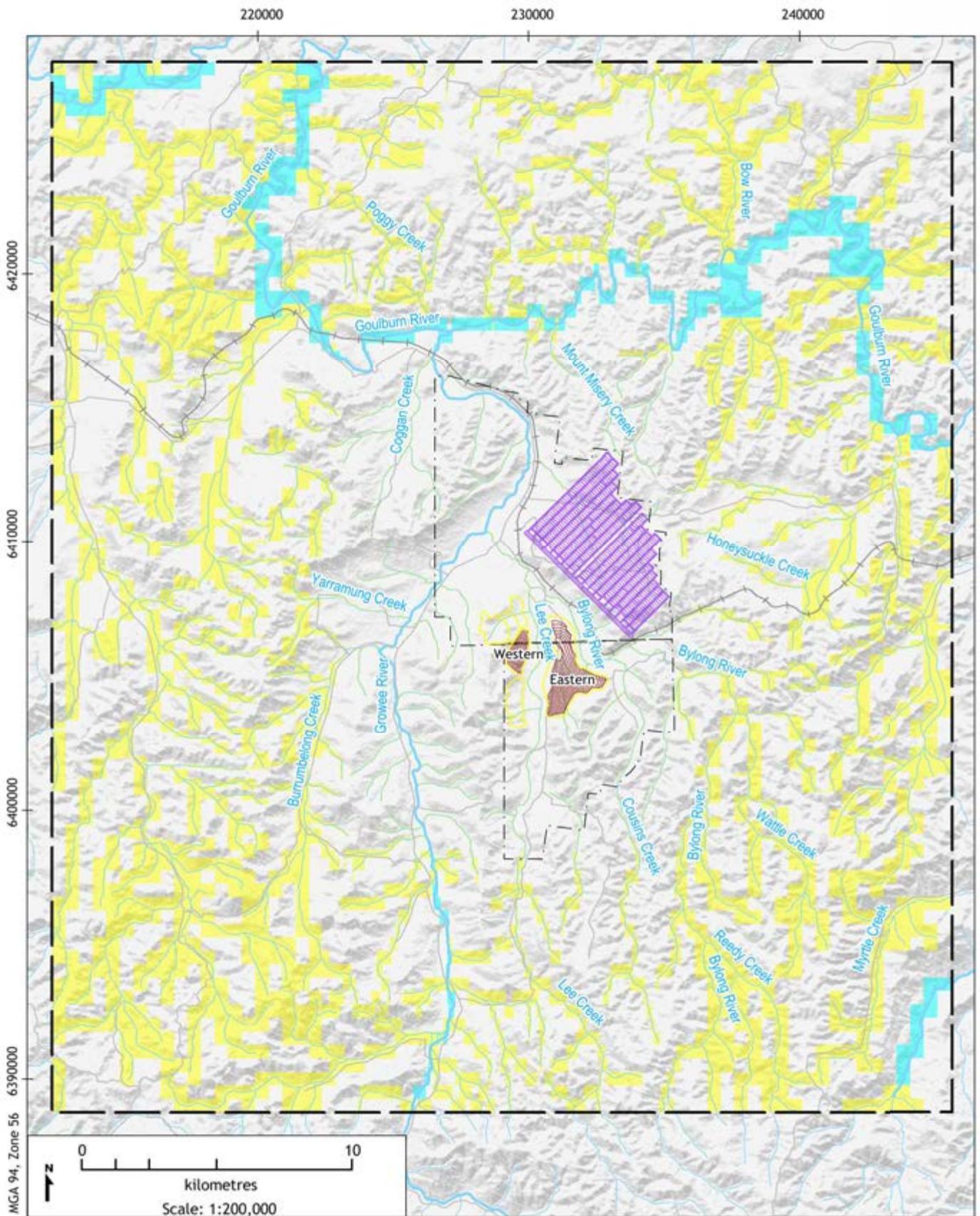
0   10
kilometres
Scale: 1:200,000

LEGEND:
— Underground Extraction Area
— Open Cut Mining Area
— Overburden Emplacement Area

Model Boundary

Authorisation

— Road

+—+ Railway

— River

— Drainage Line / Creek

Model River Cell
■ Major Creek / River
■ Minor Creek

Bylong Coal Project (G1606)

Model River Cells

DATE:
2/12/2013

FIGURE No:
8.2

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9   MODEL CALIBRATION AND VERIFICATION

9.1   Calibration

9.1.1   Calibration Objectives

Guidelines[4] for the gateway process indicate *'information should be based on a simple model that uses best available baseline data collected at an appropriate frequency and scale and that is determined to be fit-for-purpose to the satisfaction of the Minister for Primary Industries. Proponents should also provide a strategy for moving to modelling using more detailed site specific data that will be used at the development application stage to better assess potential impacts.'*

Given the requirement for a simple numerical model, it was decided to calibrate to steady state (i.e. long term average) water levels from the monitoring bore network. The steady state model was calibrated by adjusting aquifer parameters and stresses to produce the best match between the observed and simulated water levels. A more detailed transient calibration to time series water level measurements was not considered necessary. Instead, a transient model run verified the model roughly reproduced the transient water level fluctuations measured in the monitoring bore network installed for the Project.

9.1.2   Calibration Data Points

Thirty-four bores were utilised for the steady state calibration, consisting of:

- 20 bores from the NOW PINNENA database, which are predominantly screened in the Quaternary alluvium; and

- 14 monitoring bores from the Project area, which provided data on the Quaternary alluvium, weathered Permian, interburden and coal seam water levels.

The calibration excluded data from VWPs, as only a limited dataset was available at the time of the calibration. Further data is being gathered and will be used within the EIS modelling.

9.1.3   Steady State Calibration

The objective of the calibration of the model was to reproduce groundwater levels at the individual monitoring bores and replicate the general pattern of the groundwater potentiometric surface and the direction of groundwater flow. The steady state model was calibrated manually by adjusting parameters across the entire model domain. The model parameters were uniform for each geological unit represent in the model.

9.2   Calibration Results

9.2.1   Aquifer Properties

Table 9.1 presents the calibrated hydraulic properties for each geological unit.

---

[4] NSW Government Fact Sheet – Strategic Regional Land Use Policy, Guideline for Gateway Applicants, September 2013. http://www.mpgp.nsw.gov.au/docs/Guideline%20for%20Gateway%20Applicants.pdf.

Table 9.1: CALIBRATED HYDRAULIC PARAMETERS				
Unit	Horizontal Hydraulic Conductivity (m/day)	Vertical Hydraulic Conductivity (m/day)	Specific Yield (Sy)	Specific Storage (Ss)
Alluvium upper	1	0.1	10 %	2.0×10^{-5} m^{-1}
Alluvium Lower	4.6	0.46	10 %	2×10^{-5} m^{-1}
Colluvium	4.6	0.46	10 %	2×10^{-5} m^{-1}
Weathered Permian	0.1	0.01	5 %	2×10^{-5} m^{-1}
Tertiary basalts	0.11	0.011	3 %	2×10^{-5} m^{-1}
Interburden	1.5×10^{-3}	1.5×10^{-4}	1 %	2×10^{-5} m^{-1}
Ulan Coal Seam	0.3 to 1×10^{-5}	0.03 to 1×10^{-6}	2 %	2×10^{-5} m^{-1}
Coggan Coal Seam	0.3 to 1×10^{-5}	0.03 to 1×10^{-6}	2 %	2×10^{-5} m^{-1}
Marangaroo Sandstone	4×10^{-4}	4×10^{-5}	1 %	2×10^{-5} m^{-1}
Basement	1.5×10^{-3}	1.5×10^{-4}	1 %	2×10^{-5} m^{-1}
Cretaceous Volcanics	1.5×10^{-3}	1.5×10^{-4}	1 %	2×10^{-5} m^{-1}

The hydraulic conductivity of the coal seams incorporated an exponential decrease in response to mechanical loading of overburden. The decline in the hydraulic conductivity parameter with depth was based on a combination of site testing data, and data from other coal mine hydraulic testing studies within the Mid-Western Region.

Figure 9.1 presents a box and whisker plot of the hydraulic testing data obtained from the Bylong field-testing program, with the calibrated values used in the Bylong model for reference. The plot displays the range of the field-testing data, median value, and the 25th/75th percentiles. Parameters used in the model were close to the median hydraulic testing values. Hydraulic parameters obtained for the Marangaroo sandstone and Ulan coal seams are low, when compared to the surrounding studies. Figure 9.2 to Figure 9.4 show the calibrated horizontal hydraulic parameters for Layers 1, 2 and 8.
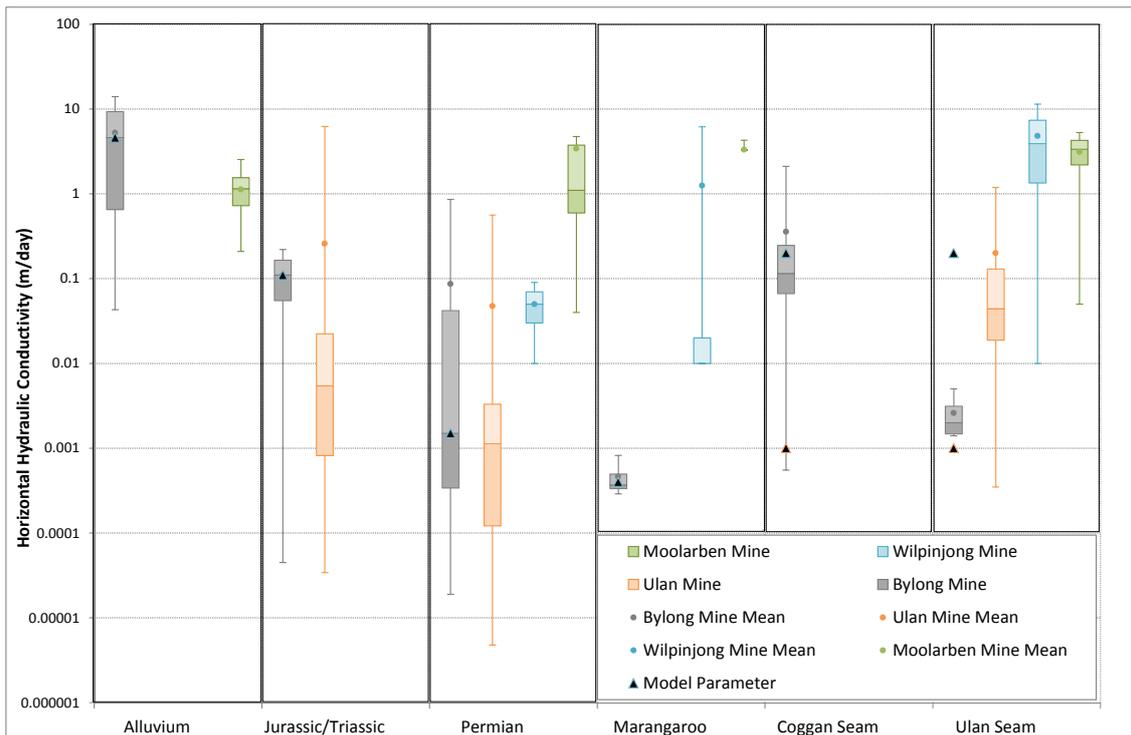
Figure 9.1: Box and Whisker of Hydraulic Conductivity Values
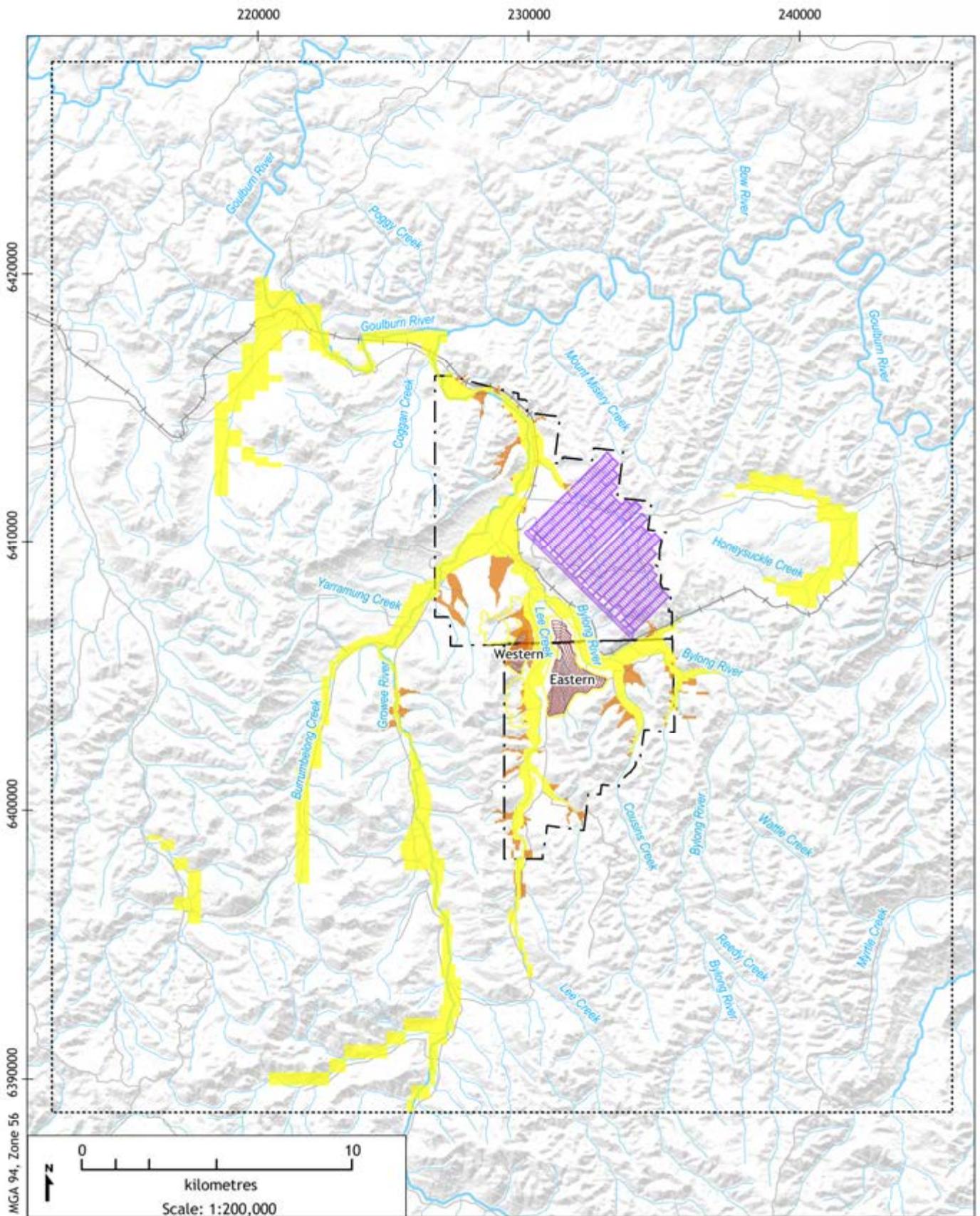
LEGEND:

Underground Extraction Area
Open Cut Mining Area
Overburden Emplacement Area
Model Boundary
Authorisation
River
Drainage Line / Creek
Road / Track
Railway

Hydraulic Conductivity
1 m/day
4.6 m/day

Bylong Coal Project (G1606)

**Calibrated Hydraulic
Parameter Distribution - Layer 1**

DATE: 2/12/2013

FIGURE No: **9.2**

MGA 94, Zone 56

0   10
kilometres
Scale: 1:200,000

LEGEND:

Underground Extraction Area
Open Cut Mining Area
Overburden Emplacement Area

Model Boundary

Authorisation

River

Drainage Line / Creek

Road / Track

Railway

Hydraulic Conductivity

4.6 m/day

Bylong Coal Project (G1606)
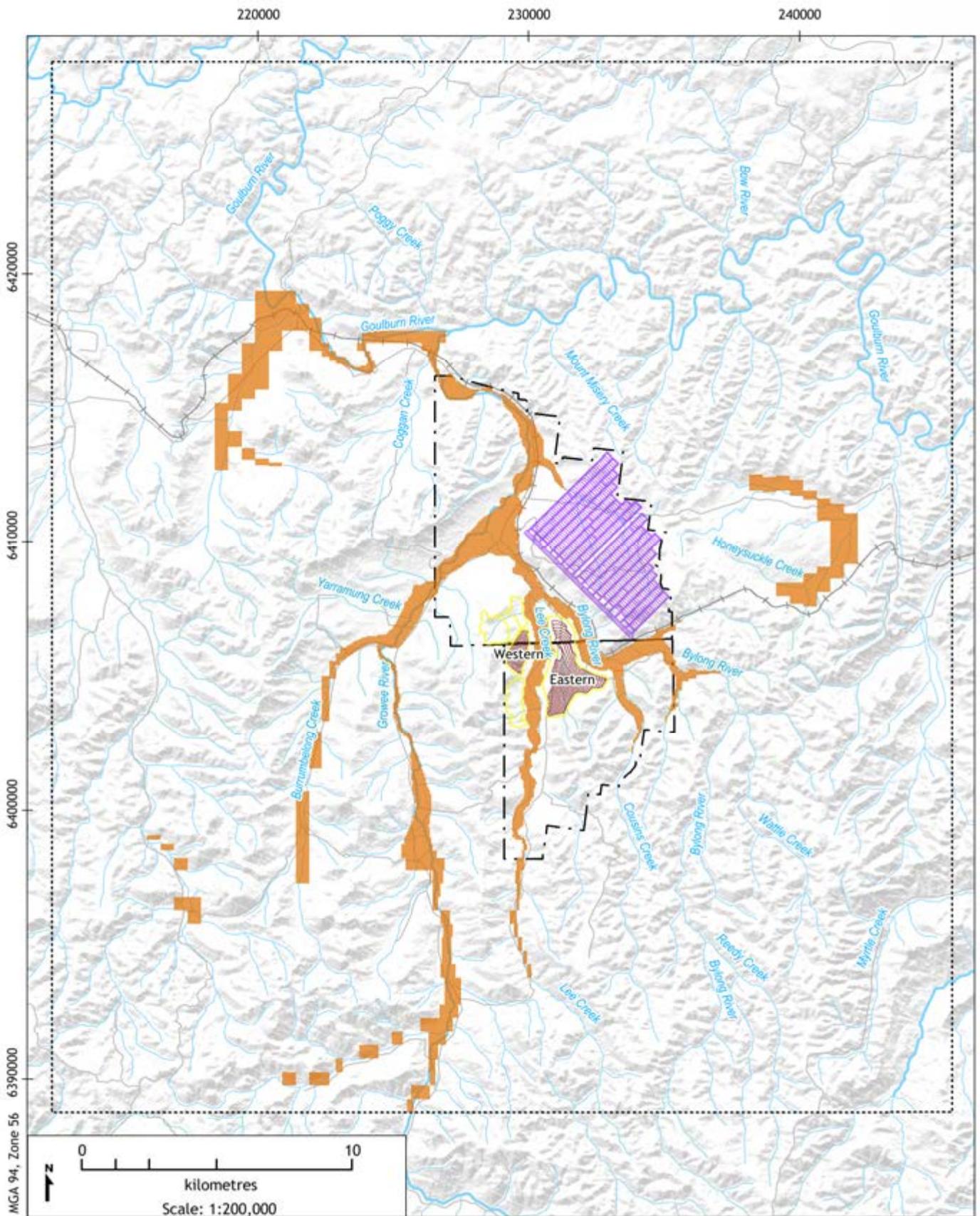
**Calibrated Hydraulic
Parameter Distribution - Layer 2**

DATE:
2/12/2013

FIGURE No:
9.3
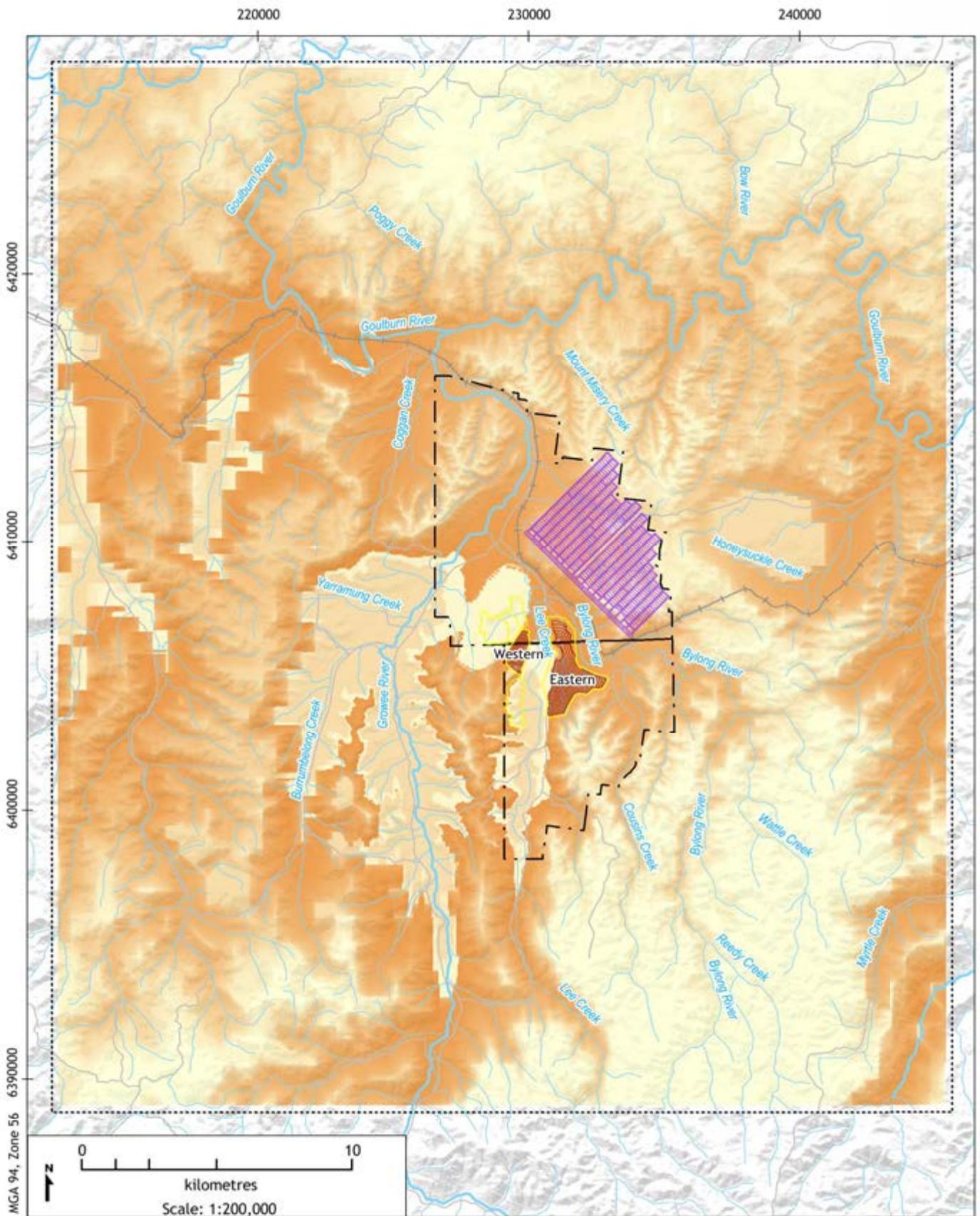
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9.2.2   Recharge

The recharge zones adopted during the steady state calibration were:

- Alluvium   7 % of rainfall
- Colluvium   5 % of rainfall
- Regolith/Permian outcrop   1 % of rainfall
- Tertiary Basalt   5 % of rainfall
- Cretaceous Volcanics   0.5 % of rainfall

As detailed above, the percentage of rainfall was set based on geological distribution; however, the rates (mm/day) varied across the Project Boundary based on local rainfall records. Figure 9.5 presents the spatial distribution of the recharge for each zone.

9.2.3   Steady State Hydraulic Heads

Figure 9.6 presents the steady state groundwater heads for Layer 1 in the model.
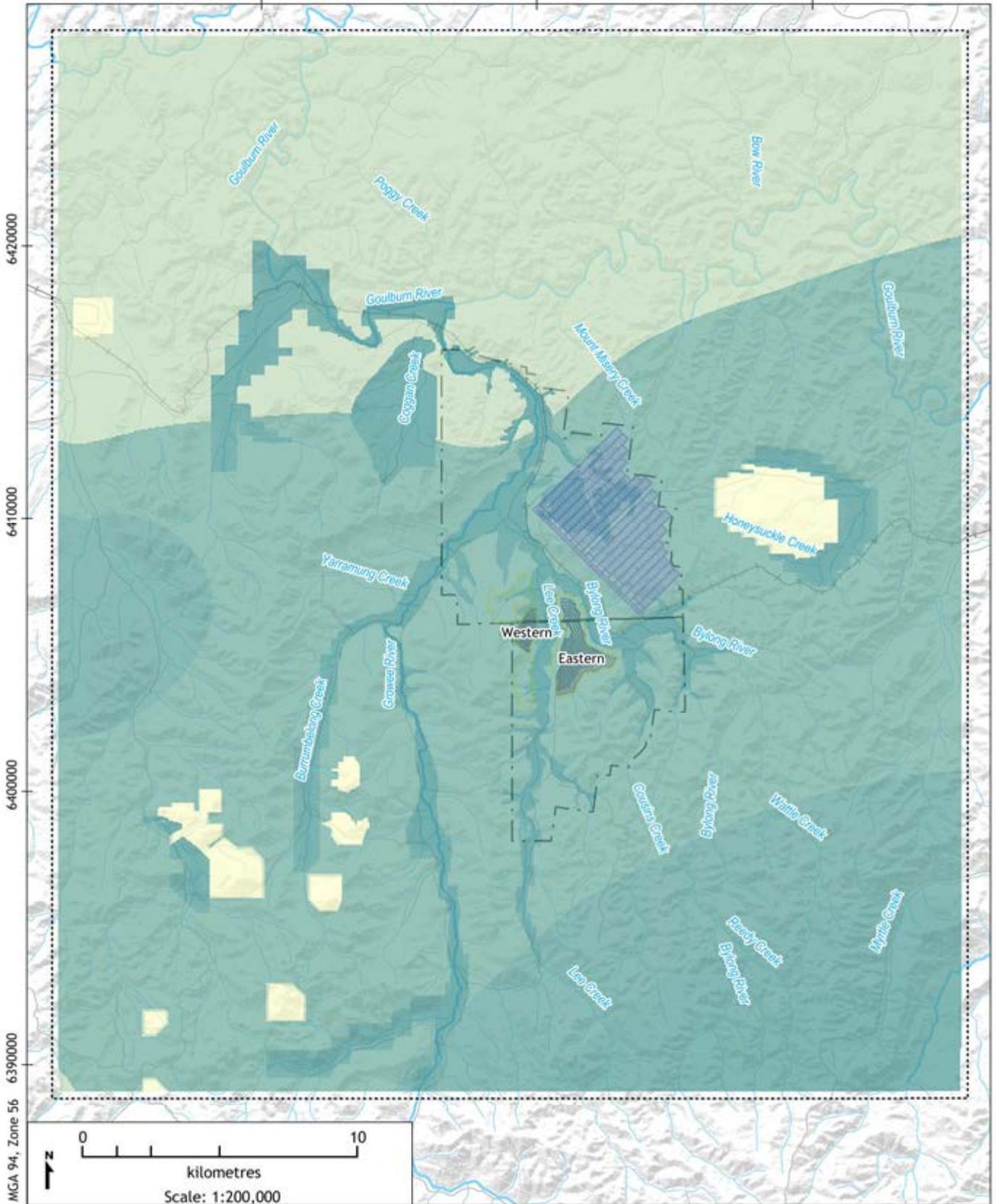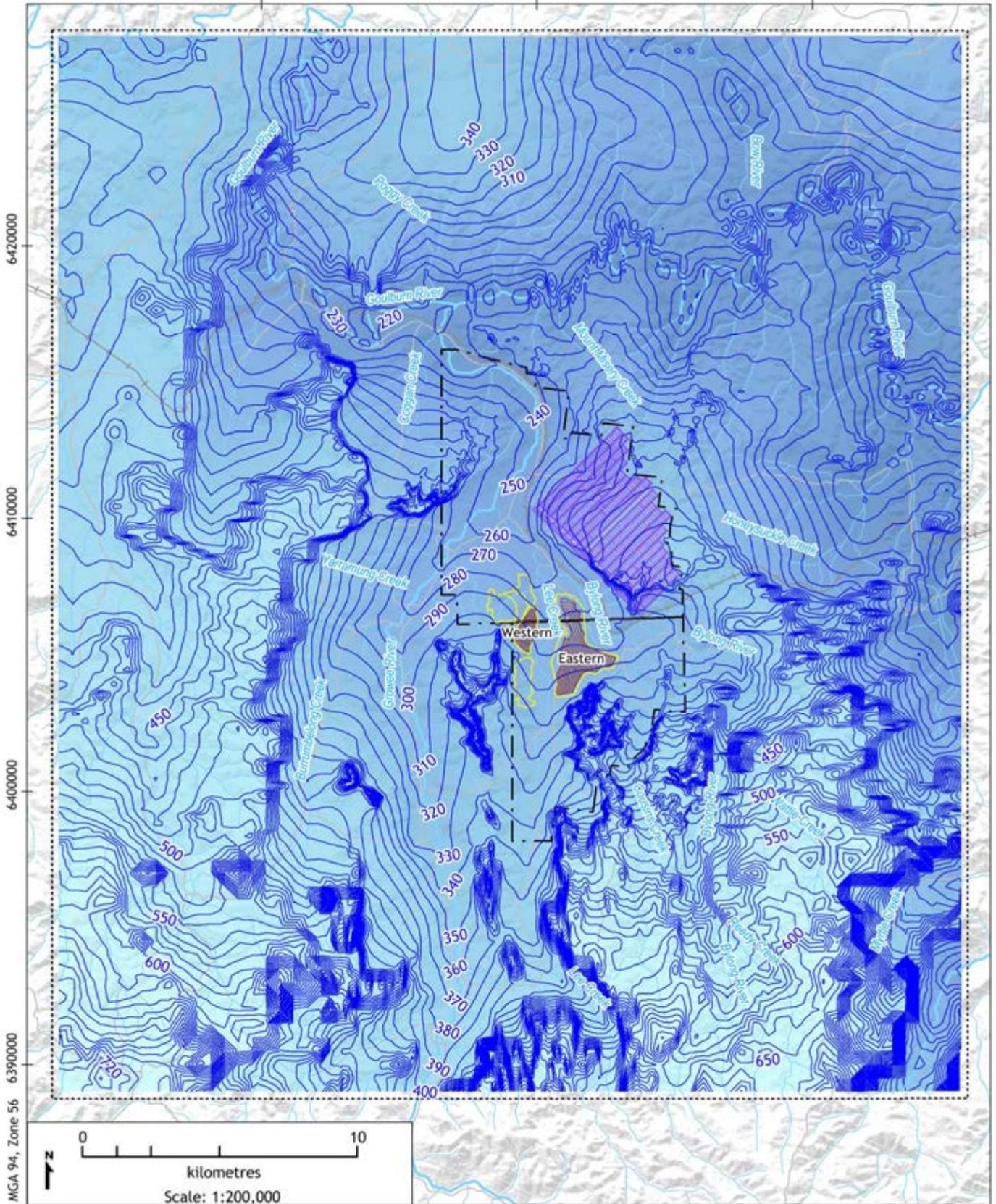
LEGEND:

Underground Extraction Area
Open Cut Mining Area
Overburden Emplacement Area
Model Boundary
Authorisation
River
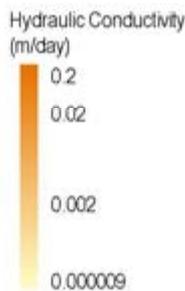Drainage Line / Creek
Road / Track
Railway

10m Groundwater Contour (mAHD)

Bylong Coal Project (G1606)

**Calibrated Steady State Heads
Layer 1**

DATE:
2/12/2013

FIGURE No:
9.6

MGA 94, Zone 56

kilometres
Scale: 1:200,000

9.2.4 Hydraulic Head Statistics

Figure 9.7 compares the model simulated steady state groundwater levels with the values measure in the monitoring network in the Quaternary and Permian stratigraphy.
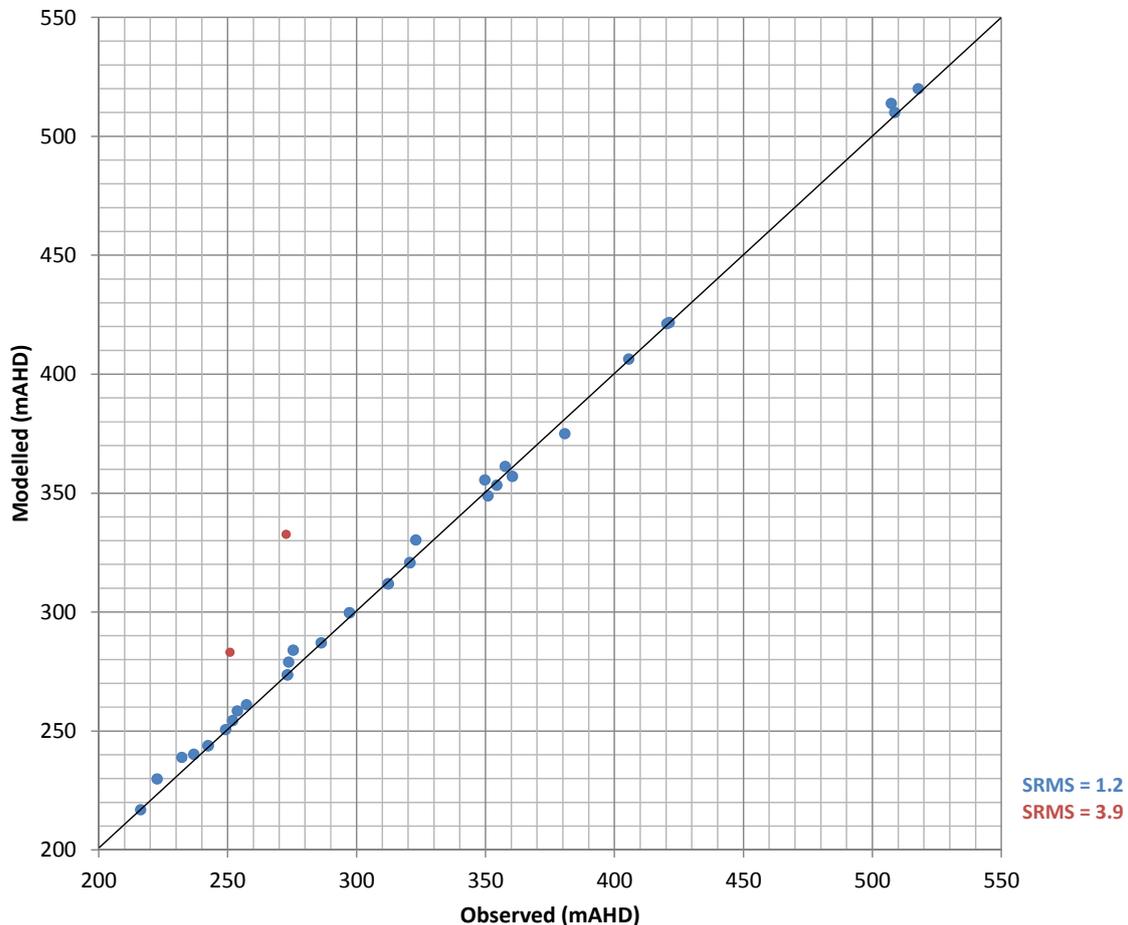
Figure 9.7: Scattergram – observed versus modelled steady state heads

Figure 9.7 shows a good correlation between the simulated water levels and the measured values. There are some areas of the model, shown in red on Figure 9.7, that over predict groundwater levels. These bores are within the Coggan coal seam, and indicate the model simulates mounding of groundwater under the more elevated areas of the landscape, whereas lower levels have been measured in the monitoring network

The RMS error, which is a statistic similar to standard deviation, is a measure of the variability in the observed versus simulated water level records. The model reported an RMS error calculated for the calibrated steady state model of 3.68 m when the red bores were excluded, or 11.9 m when included.

The ratio of RMS to the total head change across the calibration points (301.5 m) indicated a Scaled RMS of 1.2% and 3.9%, indicating a close match between observed and predicted water levels.

9.2.5 Water Budgets

Table 9.2 summarises the steady state model water budget.

Table 9.2: WATER BUDGET – STEADY STATE MODEL WATER BUDGETS (ML/DAY)		
Parameter	**Input**	**Output**
Rainfall recharge	30.1	-
River leakage	18.8	-
River baseflow	-	29.4
Evapotranspiration	-	19.5
General head	0.0	0.0
TOTALS	**48.9**	**48.9**

The budget indicates that water enters the model domain at a rate of:

- 30.1 ML/day from diffuse rainfall recharge; and

- 18.8 ML/day from leakage from the Goulburn River.

The model predicts water discharges at a rate of:

- 29.4 ML/day into rivers and creeks; and

- 19.5 ML/day from evapotranspiration.

The steady state model indicates that approximately 18.8 ML/day enters the model via river leakage, while a total of 29.3 ML/day leaves through baseflow. This represents a net outflow of 10.6 ML/day. A total of 3 ML/day of this outflow is from the Bylong River and Lee Creek systems.

9.3   Verification

As discussed previously, a more detailed transient calibration to time series water level measurements was not considered necessary for the Gateway assessment. Instead, a transient model run verified if the model could replicate the transient water level fluctuations measured in the monitoring bore network installed for the Project.

The model ran with daily stress periods for the period of available water level data from November 2011 to October 2013. A simple spreadsheet based soil moisture balance model estimated daily recharge to the model using daily rainfall records. The spreadsheet model assumed the soil profile requires 25 mm of rainfall to wet-up prior to deep drainage occurring. It assumed a daily evapotranspiration ratio through plants of 3.5 mm/day. The model also capped daily recharge rates at 25 mm to represent run-off under extreme rainfall events.

Figure 9.8 compares the simulated and observed transient groundwater levels.
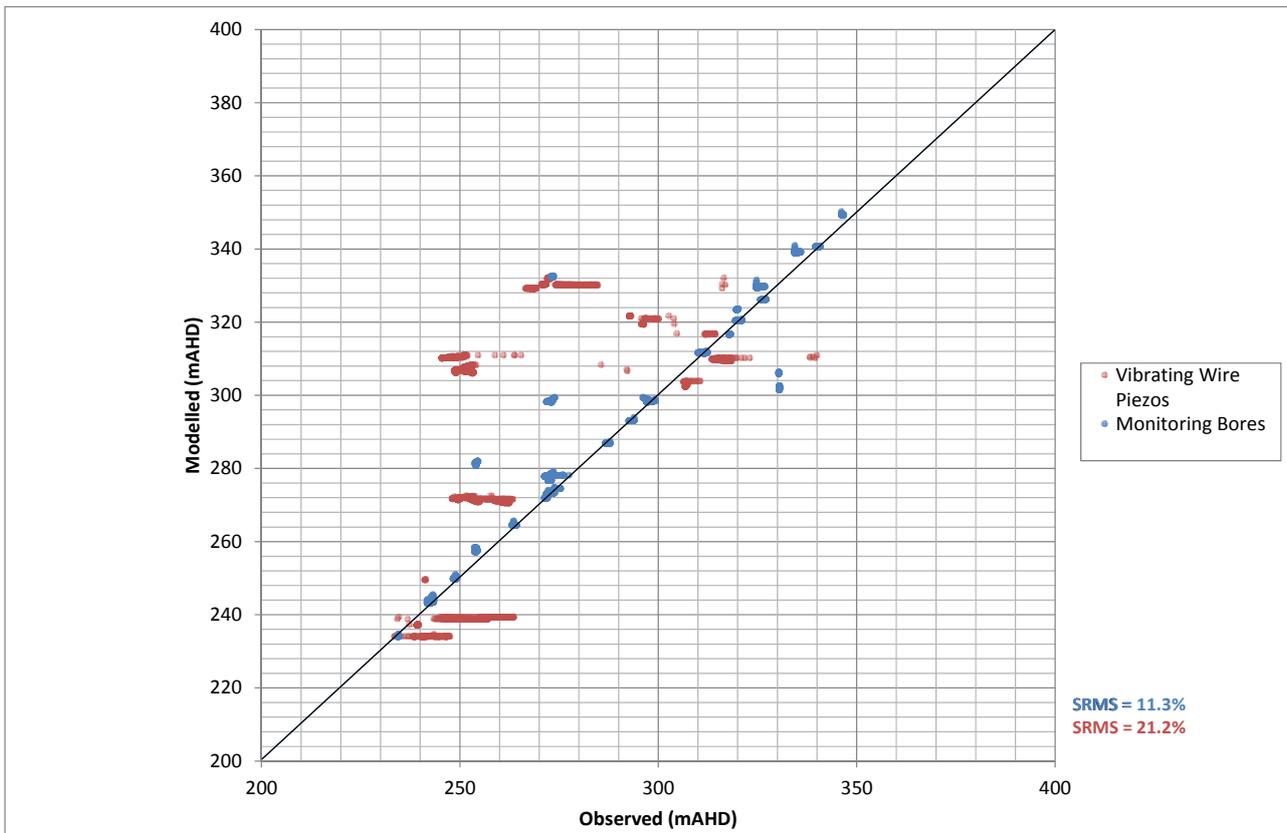
Figure 9.8: Modelled and observed transient water levels

Figure 9.8 shows the correlation between the observed and simulated transient water levels. The model replicates the measured water levels in the alluvium well. The model over predicts groundwater levels measured by the VWPs, which are installed under the more elevated areas of the landscape and indicates mounding of groundwater is not as significant as simulated by the current version of the model.

Appendix C contains hydrographs showing the measured and simulated water levels for each of the 84 bores and vibrating wire sensors used for the verification. The hydrographs show that the model generally simulates the dynamics of the alluvial system and the recharge events recorded in the monitoring bores. However, the VWP hydrographs highlight how the model over predicts groundwater levels in the proposed underground extraction area.

9.4   Model Confidence Level Classification

Barnett *et al* (2012) developed a system to classify the confidence-level for groundwater models. Models are classified as either Class 1, Class 2 or Class 3 in order of increasing confidence (i.e. Class 3 has the highest level of confidence). Several factors are considered in determining the model confidence level:

- available data;
- calibration procedures;
- consistency between calibration and predictive analysis; and
- level of stresses.

The model is currently considered a Class 1 model for a range or reasons including:

- a transient calibration has not been undertaken;
- transient predictions are made when calibration is in steady state only; and
- the model has not been reviewed.

The purpose of the Class 1 model is to assess the Gateway application requirement for a simple model, and to serve as a template that can be gradually refined and improved to higher classes as additional data is gathered from monitoring.

10 MODEL PREDICTIONS AND IMPACT ASSESSMENT

10.1 Mine Plan

The Project comprises of two open cut mining areas (Eastern and Western Open Cut Mining Areas), and one longwall mining area. The Mt Penny Project is located to the west of the Project Boundary and is a proposed open cut coal mine, which was included in the model to account for potential cumulative impacts.

10.2 Setup and Assumptions

10.2.1 Model Goals

The purpose of the modelling was to estimate the:

- groundwater seepage rates to the open cut and underground mining areas;
- extent of the zone of depressurisation due to mining activities,
- drawdown in private bores;
- flow from the alluvial aquifer into the underlying Permian strata;
- changes in creek base flows and/or leakages;
- areas of potential risk where groundwater impact mitigation/control measures may be necessary; and
- generate understanding of potential quality impacts.

10.2.2 Staged Timing and Stress Periods

The calibrated model was set up with 88 stages covering the proposed 29 year mine life. The model stopped at each stage and the aquifer parameters in the mined areas changed to represent the gradual growth of the spoil heaps. These changes represented the increased hydraulic conductivity, porosity and recharge rate to the spoil heaps. The model also changed the hydraulic conductivity above the longwall panels to represent the fracturing induced by subsidence after the longwall miner had passed through.

10.2.3 Recharge

The model increased the recharge rate to the spoil heaps to 5% of average annual rainfall after mining. The proposed tailings/co-disposal into the Eastern Open Cut Mining Area void was assigned a recharge rate of 1% of annual average rainfall. The Mt Penny Project incorporates a final void at the southern extent of its proposed mining area. The model applied 90% of annual average rainfall to the open void.

10.2.4 Evapotranspiration

Following the emplacement of spoil, the model altered the evapotranspiration surface to reflect the raised landform due to the bulking of the spoil pile. This allowed for any possible mounding of the water table within the spoil piles. The model increased evapotranspiration to 100% of potential evaporation rates within the Mt Penny Open void where a pit lake is predicted to form.

10.2.5 Groundwater Pumping

The model did not simulate pumping from private water bores within the surrounding alluvium.

10.2.6 Mine Water Seepage

The SURFACT Drain package (DRN) represented the drainage of groundwater into the open cut and underground extraction areas. The model installed drain cells in all cells in open cut footprints, for both the Project and the Mt Penny Project, down to the base of the deepest mined formation represented by Layer 8. For underground mining, the drains cells were in Layer 8 only, which represents the Coggan coal seam.

Once applied, a drain boundary condition remained actively dewatering for one year. The drain cells were then removed from the area where mining had been completed after one year, and were then applied to the cells representing new strips of mining. Drain cells remained active in each longwall mining panel until the entire panel was completed.

The model gradually introduced the main roads and gate roads according to the proposed underground mine plan. The model dewatered these roads until the end of the proposed mine life.

10.2.7 Overburden/Tailings Backfilling

Table 10.1 shows the aquifer parameters adopted for the spoil and tailings in the open cut mining areas. These parameters were based on work in the Hunter Valley by Mackie (2009).

Table 10.1: HYDRAULIC PARAMETERS OF SPOIL		
Geology Type	**Parameter**	**Value**
Spoil	Horizontal Hydraulic Conductivity kh	1 m/day
	Vertical Hydraulic Conductivity kv	0.1 m/day
	Specific Yield S_y	10%
	Specific Storage S_s	$5 \times 10^{-3}\,m^{-1}$
Tailings/Co-Disposal	Horizontal Hydraulic Conductivity kh	0.01 m/day
	Vertical Hydraulic Conductivity kv	0.001 m/day
	Specific Yield Sy	5%
	Specific Storage Ss	$1 \times 10^{-4}\,m^{-1}$

10.2.8 Hydraulic Fracturing

When each longwall panel is completed, the drains were switched off and the panel was allowed to flood with groundwater. The model then applied the subsidence induced fracturing above each longwall panel. This was achieved by changing the hydraulic conductivity of the layers above the mined panels within the model to a height of 150 m.

In the underground extraction areas for the Project, the fracturing will depressurise the strata overlying the Coggan coal seam. The extent of the connective cracking typically varies depending on the coal seam thickness, the longwall panel width and the nature and strength of the overlying strata. This will be assessed in more detail in the EIS phase of the Project.

For the Gateway, the model assumed the connective fracturing above the coal seam extended to a height of 30 times the coal seam thickness, which was equivalent to a height of 150 m within these areas. The model also simulated the connective fracturing extending to a height of 60 times the coal seam thickness, which was equivalent to a height of 300 m (refer Section 11).

Table 10.2 presents the parameter changes applied to groundwater model at the start of each stage, to represent the progress of mining.

Table 10.2: HYDRAULIC PARAMETERS – SPOIL, VOID, GOAF					
Model Layers	Lithology	Horizontal Hydraulic Conductivity (m/day)	Vertical Hydraulic Conductivity (m/day)	Specific Yield – Sy (%)	Specific Storage – Ss (m^{-1})
8	Road	100	100	50	-
1 - 8	Void	100	100	100	1/Layer thickness
Goaf Height (cell centre) (m)					
0 - 5	Rubble	Background x 5	Background x 50	0.5	-
5 - 20	Goaf		Background x 20	-	-
20 - 40	Goaf	-	Background x 5	-	-
40 - 75	Fracture	-	Background x 2	-	-
75 - 90	Fracture	-	Background x 1.5	-	-

10.3 Water Budget

Figure 10.1 shows the changes in the model water budget over the proposed 29 year mine life.
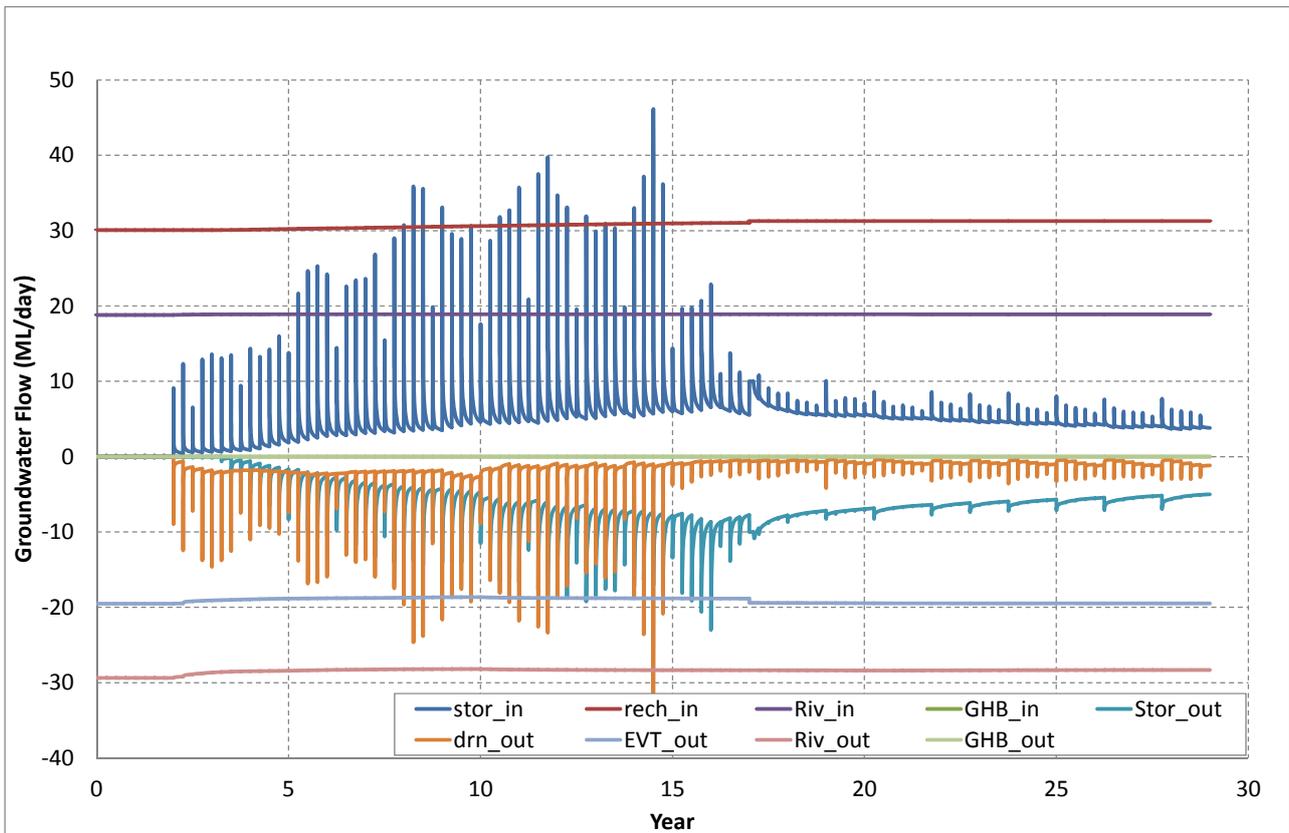
Figure 10.1: Predictive model water budget

Figure 10.1 shows that recharge dominates the inputs, averaging about 30 ML/day across the entire model domain. The recharge rate to the aquifers increases slightly over the 29-year mining period to 31 ML/day, due to the increased recharge through the overburden waste material in the backfilled mining areas. Seepage through the bed of the rivers into the underling alluvial aquifers is also a significant contributor to recharge, averaging 19 ML/day. The large spikes observed in Figure 10.1 are caused by the sudden introduction of drain cells to the model representing the progression of mining. The high rates for the peaks are generally only sustained for the first time step, being about 24 hours in duration.

River baseflow and evapotranspiration are the main mechanisms removing water from the model, which remove an average of 29 ML/day and 19 ML/day respectively.

10.4   Groundwater Seepage to Mining Areas

Figure 10.2 shows the predicted fluxes of water into the proposed mining areas.

Figure 10.2: Predicted seepage to open cut and underground mining areas

The predicted mine seepage rates vary throughout the mining period. The variability is due to the proposed mine depth, strata being mined and hydraulic gradients induced by the depressurisation.

The model predicts seepage rates to the open cut mining areas of less than 1.8 ML/day. Groundwater inflows to Western Open Cut Mining Area decrease to zero at year 7, as mining advances up-dip, above the saturated groundwater levels.
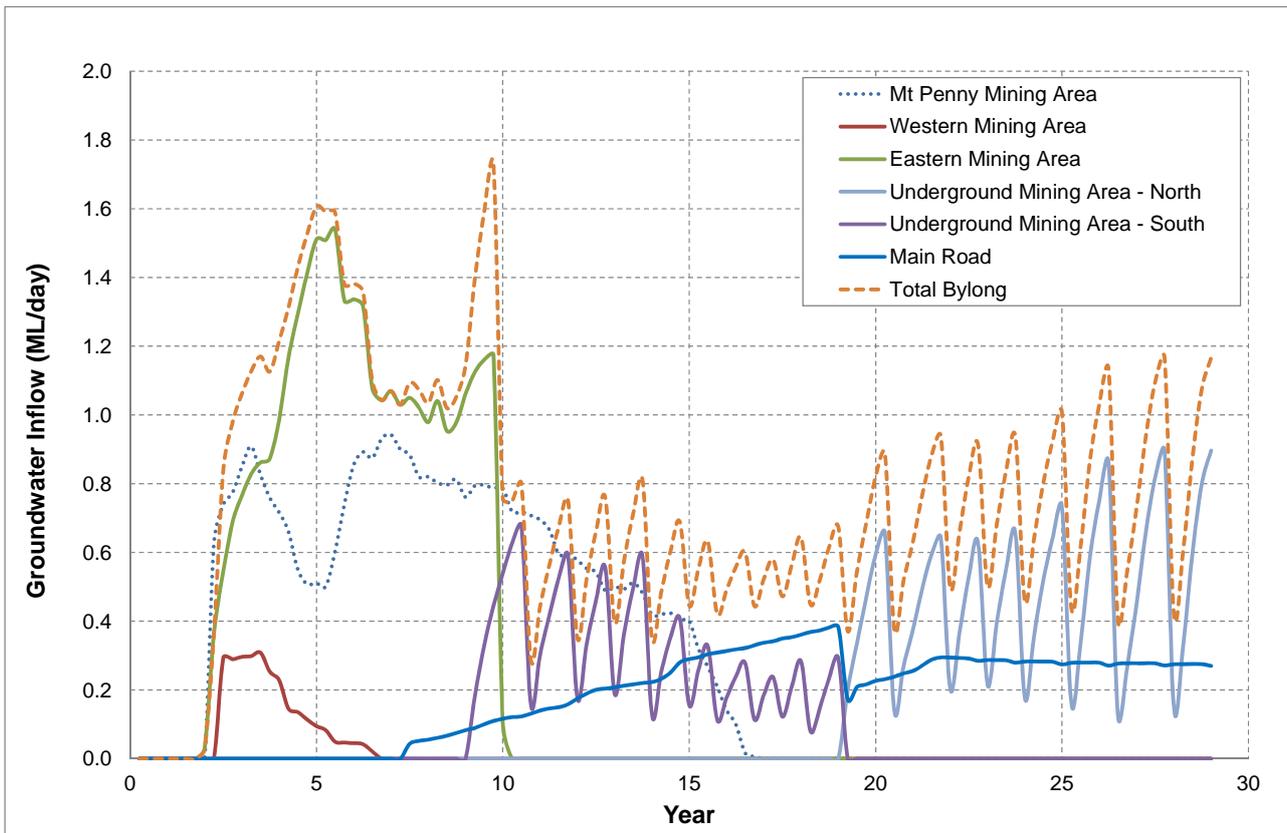
Groundwater inflow to the longwall panels and main road is lower than the open cut mining areas due to the offset distance from the alluvium. The peaks in the predicted underground inflows is due to the progress of the longwall mining, which remains active in the model until switched off when the panel is completed.

When interpreting the above results, it is important to understand the simplifying assumptions. The predicted seepage rates in Figure 10.2 represent the total groundwater loss from the groundwater systems. In reality, evaporation from the coal face exposed in the highwall and endwall would remove a proportion of the seepage predicted by the modelling and not all of the simulated seepage would flow to sumps for removal by pumping. Ventilation of the underground mine would also evaporate groundwater before it drained to the mine dewatering system.

10.5   Changes in Potentiometric Surface / Water Table Levels

10.5.1 Water levels

Figure 10.3 and Figure 10.4 present the predicted groundwater levels at the end of mining for Layer 1 (alluvium/regolith) and Layer 8 (Coggan Seam) respectively.

Figure 10.3: Groundwater levels - Layer 1 - year 29

Figure 10.4:**Groundwater levels - Layer 8 - year 29**

10.5.2 Alluvial drawdown

The process of mining reduces water pressures in surrounding aquifers. The extent of the zone affected is dependent on the properties of the coal seams and interburden units, and is referred to as the zone of depressurisation. Depressurisation of the coal formations is greatest at the working coalface, and gradually reduces with distance from the mine.

The numerical model calculated the extent of the zone of depressurisation within the Permian and alluvial groundwater systems due to mining by comparing water levels with and without the proposed mine operating. Two scenarios were simulated, firstly with all proposed mining active, and secondly with no mining at Bylong. The zone of depressurisation due to Project was determined as the difference in the potentiometric surface between these two model runs.

Layer 1 in the model represents the alluvium in the flood plains, and the weathered Permian bedrock outside these areas where alluvium is not present. The modelling indicates the proposed mining induces drawdown in the alluvium in the first 10 years of the Project life when open cut mining is active. When the open cut mine void is backfilled, the zone of influence begins to retract and groundwater levels in the alluvium start to recover. At the end of the Project life, the drawdown within the alluvium only affects the fringes of the flood plain areas.

The model did not simulate the gradual filling of the final void in the Eastern mining area with tailings, rather the model represented the final void as full of tailings at the end of Year 10. The modelling indicates the void space within the backfilled overburden in the Eastern Mining area is slow to fill with groundwater, and there is a gradual drainage of groundwater from the alluvium to the backfilled pit. Despite the slow recovery of groundwater levels within the overburden, the alluvium still recovers due to the recharge rate on the flood plain exceeding the rate of drainage of groundwater into the backfilled pit. The tailings disposal area has a relatively small footprint and therefore does not have a significant influence of recovery of groundwater levels within the alluvium.

The following figures display the drawdown over the mine life:

- Figure 10.5 shows predicted drawdown in Layer 1 at Year 10, which is when open cut mining is expected to be completed;

- Figure 10.6 shows drawdown in Year 29, which is the end of the proposed longwall mining; and

- Figure 10.7 presents a composite of the maximum drawdown in each model cell at any time throughout the entire simulation.

The figures show that drawdown within the alluvium peaks at around 5 m in the alluvium adjacent to the Eastern Open Cut Mining Area. In contrast, the longwall mining influences water levels only on the very fringes of the alluvial aquifers, and highlights that most significant impacts occur in the first 10 years of the Project life.

10.5.3 Permian Drawdown

Layer 8 represents the Coggan seam targeted for the proposed open cut and underground mining. The mining gradually depressurises the coal seams as mining advances. The following figures display the prediction drawdown in the Coggan seam over the Project life:

- Figure 10.8 shows predicted drawdown in Layer 1 at Year 10, which is when open cut mining ends;

- Figure 10.9 shows drawdown in Year 29, which is the end of the proposed longwall mining; and

- Figure 10.10 presents a composite of the maximum drawdown in each model cell at any time throughout the entire simulation.

The figures show the open cut and underground mining depressurises the water in the coal seam in a zone that extends between 1 km and 2 km from the proposed mining areas. Beyond this zone, the drawdown is predicted to be less than 1 m and would likely to be undetectable and within natural variations.

LEGEND:

Underground Extraction Area
Open Cut Mining Area
Overburden Emplacement Area
Authorisation
River
Drainage Line / Creek
Road / Track
Railway

Drawdown Contour (m)
Bore - Licenced
Bore - >2m Drawdown Predicted
Quaternary Alluvium

229000

234000

6415000

6410000

6405000

MGA 94, Zone 56

Coggan Creek

Mount Misery Creek

Dry Creek

Bylong River

1
2
5
10
20

Lee Creek

1
2

5
10

Western

1
2
5
10

Eastern

20

2

2

Growee River

Lee Creek

Cousens Creek

Bylong River

0   4
kilometres
Scale: 1:75,000

N

LEGEND:

— Underground Extraction Area
— Open Cut Mining Area
— Overburden Emplacement Area
-··- Authorisation
— River
— Drainage Line / Creek
— Road / Track
—+— Railway

—— Drawdown Contour (m)
○ Bore - Licenced
● Bore - >2m Drawdown Predicted
▨ Quaternary Alluvium

Bylong Coal Project (G1606)

**Groundwater Drawdown
Year 29 - Layer 1**

AGE

DATE:
2/12/2013

FIGURE No:
10.6

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Groundwater Drawdown
Maximum - Layer 1

Bylong Coal Project (G1606)

LEGEND:
- Underground Extraction Area
- Open Cut Mining Area
- Overburden Emplacement Area
- Authorisation
- River
- Drainage Line / Creek
- Road / Track
- Railway
- Drawdown Contour (m)
- Bore - Licenced
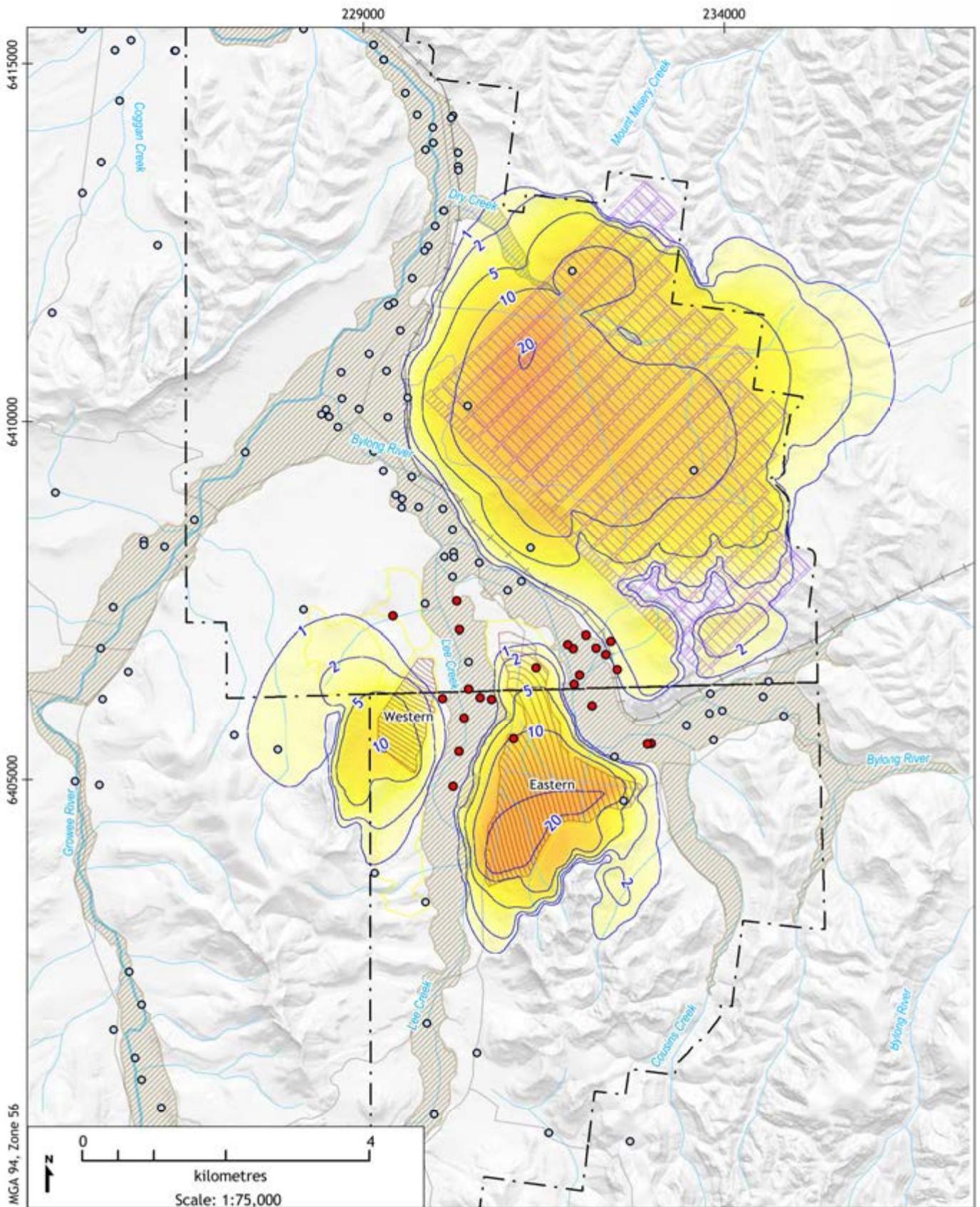- Bore - >2m Drawdown Predicted
- Quaternary Alluvium

MGA 94, Zone 56

Scale: 1:75,000

DATE: 2/12/2013

FIGURE No: 10.7

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LEGEND:

— Underground Extraction Area
— Open Cut Mining Area
— Overburden Emplacement Area

— · — · Authorisation

— River

— Drainage Line / Creek

— Road / Track

—+— Railway

— Drawdown Contour (m)

○ Bore - Licenced

● Bore - >2m Drawdown Predicted

Bylong Coal Project (G1606)

Groundwater Drawdown
Year 10 - Layer 8 - Coggan Seam

DATE: 2/12/2013

FIGURE No: **10.8**

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Groundwater Drawdown
Year 29 - Layer 8 - Coggan Seam

Bylong Coal Project (G1606)

LEGEND:
— Underground Extraction Area
— Open Cut Mining Area
— Overburden Emplacement Area

-··- Authorisation
— River
— Drainage Line / Creek
— Road / Track
—+— Railway

— Drawdown Contour (m)
○ Bore - Licenced
● Bore - >2m Drawdown Predicted

DATE: 2/12/2013
FIGURE No: 10.9

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Bylong Coal Project (G1606)

Groundwater Drawdown
Maximum - Layer 8 - Coggan Seam

LEGEND:

- Underground Extraction Area
- Open Cut Mining Area
- Overburden Emplacement Area
- Authorisation
- River
- Drainage Line / Creek
- Road / Track
- Railway
- Drawdown Contour (m)
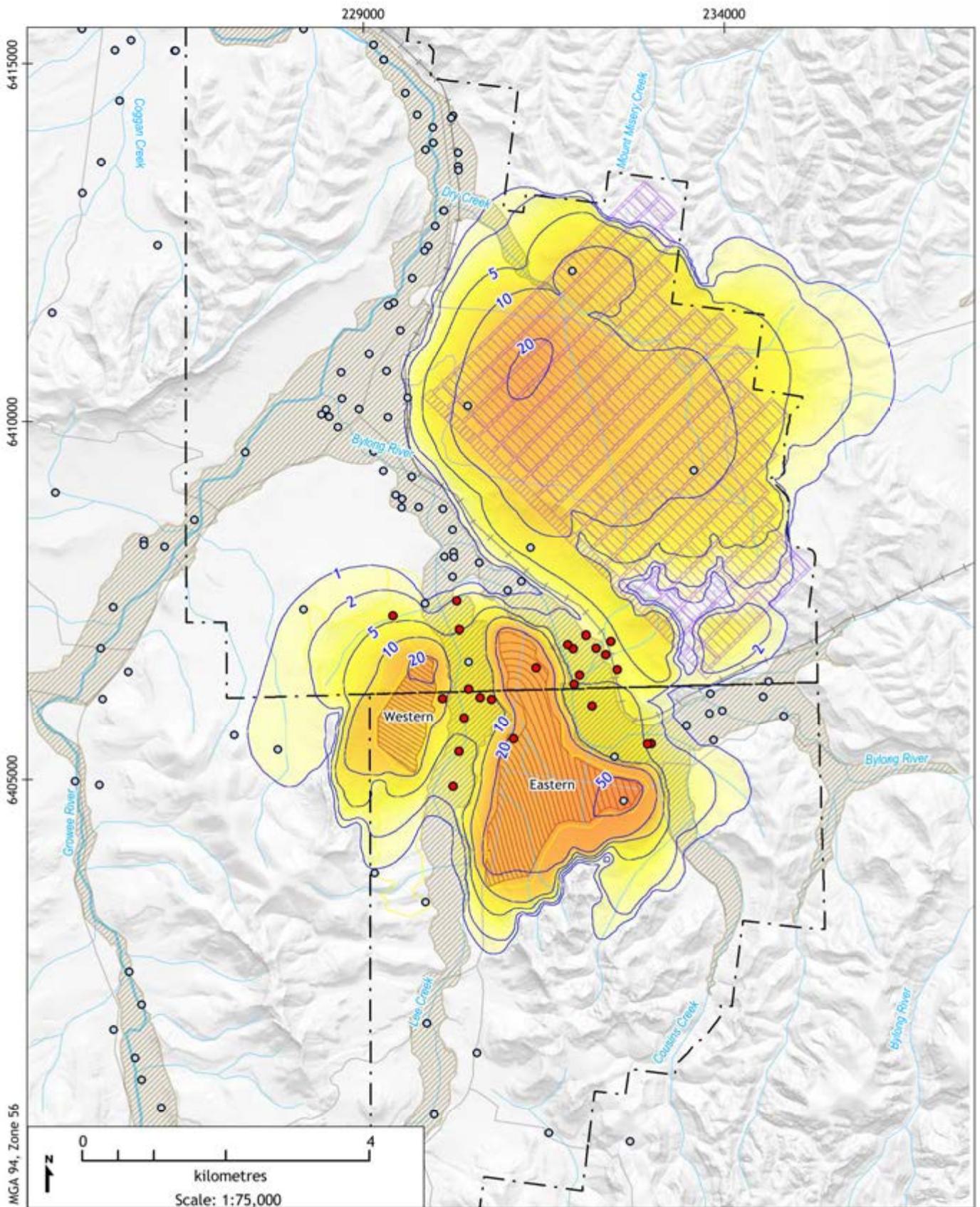- Bore - Licenced
- Bore - >2m Drawdown Predicted

MGA 94, Zone 56

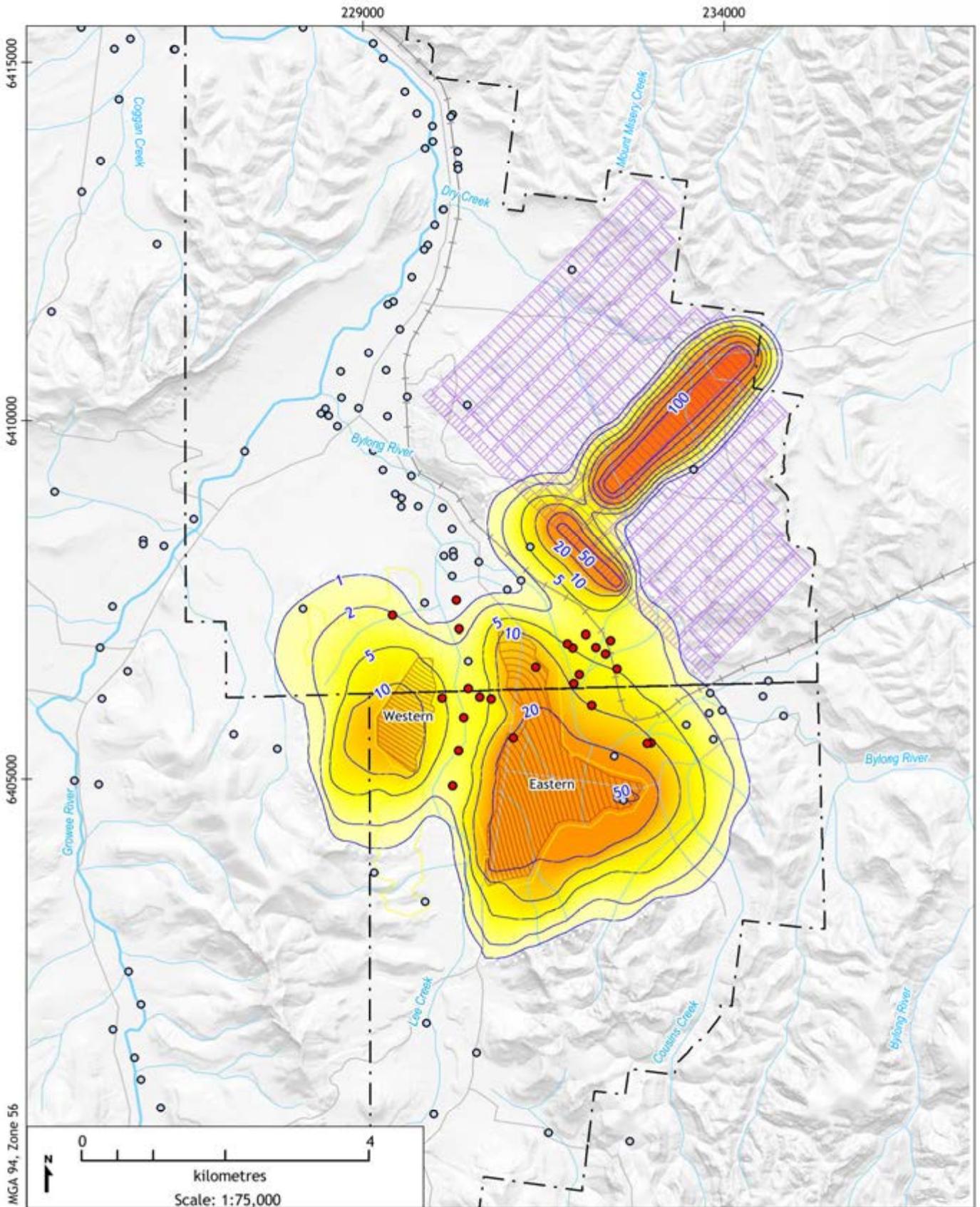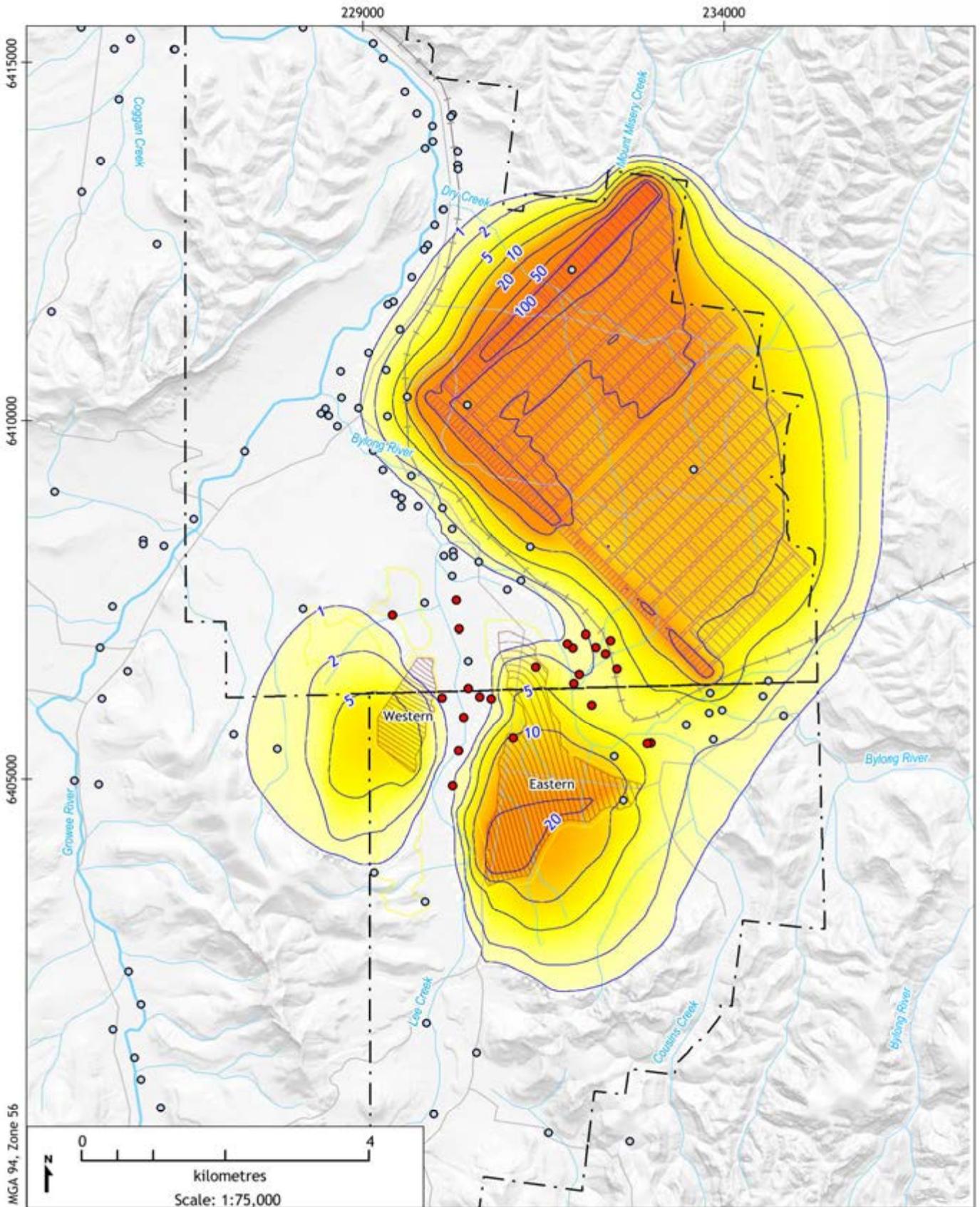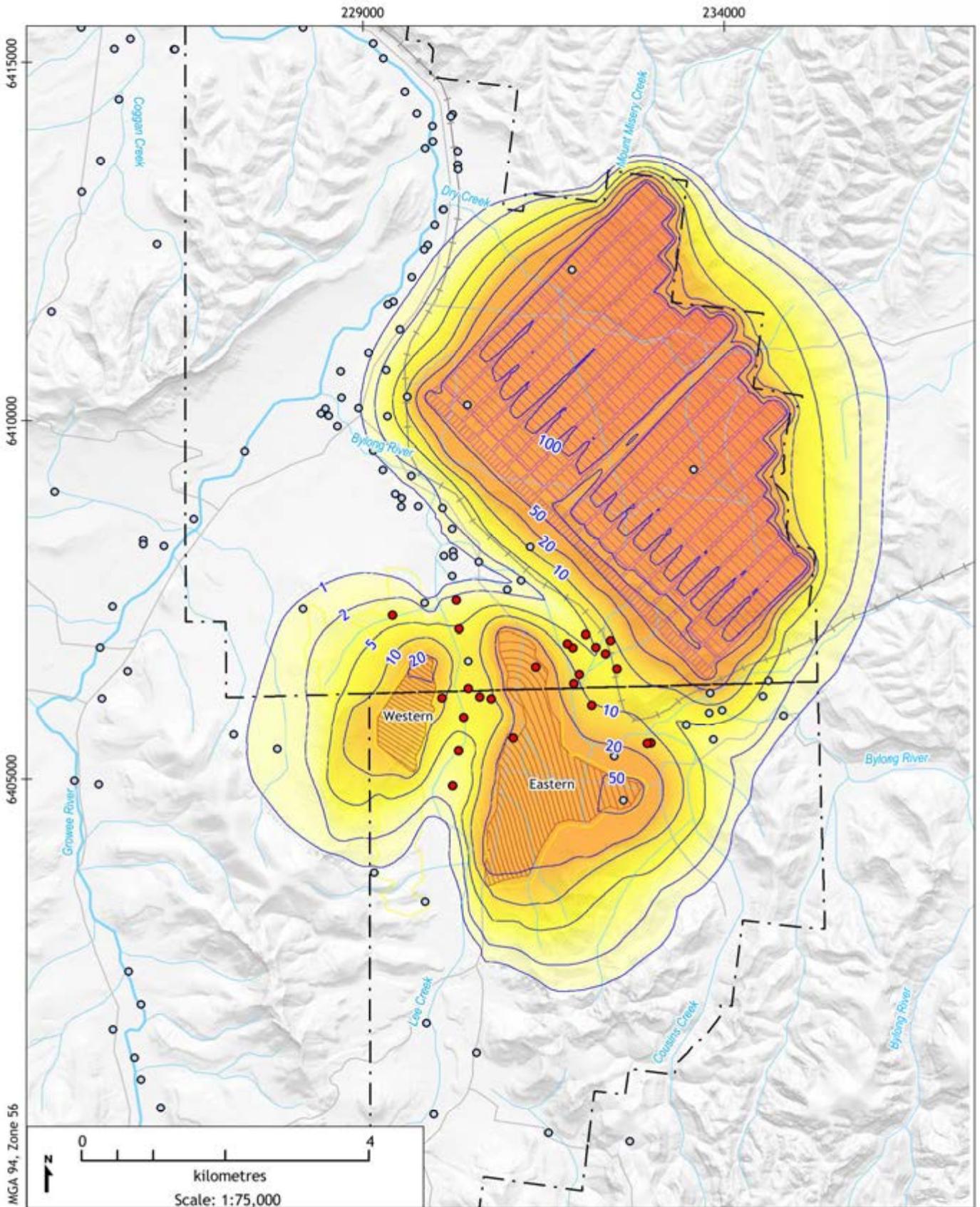Scale: 1:75,000

kilometres

DATE: 2/12/2013

FIGURE No: 10.10

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10.6   Impact on Groundwater Users

Table 10.3 presents all privately owned or government licenced bores with predicted groundwater drawdown impacts of greater than 2 m.

Table 10.3: IMPACTED LICENCED BORES				
Bore ID	Easting (m)	Northing (m)	Owner	Maximum Predicted Drawdown (m)
GW044352	231390	6406570	Private	28.47
GW030543	231077	6405575	Other Government	18.46
GW078252	230095	6406135	Unknown	12.82
GW034172	230775	6406122	Private	7.79
GW078253	230617	6406149	Unknown	7.19
GW034173	230457	6406268	Private	6.89
GW044346	232163	6406036	Private	6.25
GW078254	230390	6405865	Unknown	6.05
GW044345	231919	6406338	Private	5.13
GW027890	230330	6407097	Private	4.91
GW042936	232935	6405502	Private	4.73
GW078247	231994	6406463	Unknown	4.52
GW042935	232987	6405503	Private	4.18
GW044351	232515	6406539	Private	4.14
GW018266	229410	6407288	Private	3.99
GW044349	232426	6406937	Private	3.87
GW034171	230324	6405401	Private	3.82
GW044350	232353	6406750	Private	3.56
GW044347	231906	6406831	Private	3.49
GW078245	231826	6406890	Unknown	3.44
GW078246	232220	6406839	Unknown	3.4
GW044348	232084	6407021	Private	3.09
GW271037	230241	6404910	NSW Office of Water	2.65
GW018271	230294	6407497	Private	2.49

These bores are all in the alluvium, except GW044352, which is constructed within the Permian strata. The majority of the bores are located on private land and therefore KEPCO is currently discussing purchase of the land with the current owners (Wallings Pastoral Co Pty Ltd and Andrews Family)

Figure 10.11 shows the predicted drawdown in each bore over the mine life, and highlights the recovery in groundwater levels that occurs after open cut mining ceases.
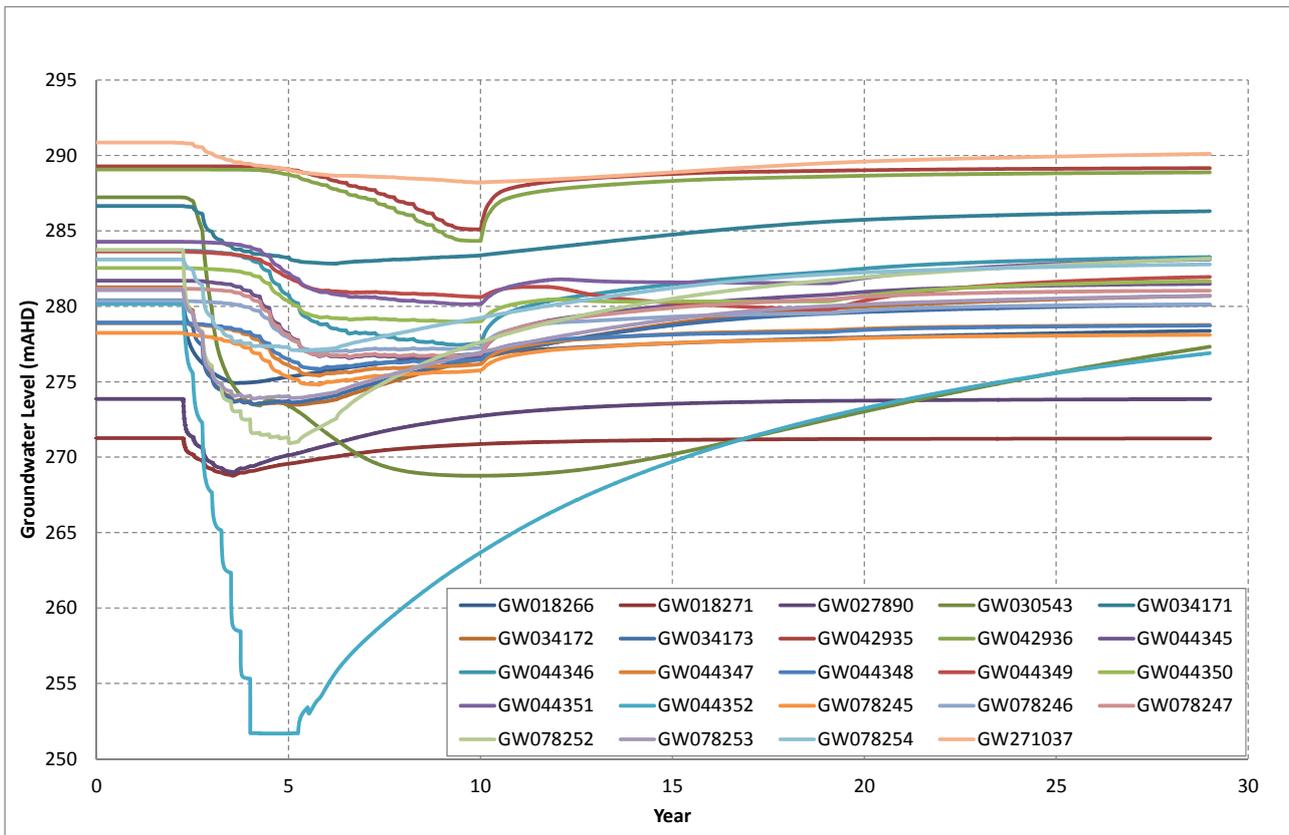
Figure 10.11: Predicted drawdown in private bores over Project life

10.7   Interaction with Alluvial Aquifers

In the absence of mining, the model predicts there is a net upward flow entering the alluvium aquifer from the underlying Permian formation of 7.8 ML/day across the whole model domain. This is comprised of 8.4 ML/day upward flow and 0.7 ML/day downward flow. This is effectively recharge to the alluvium, and is part of the alluvial system water budget.

The model predicts that once mining commences, depressurisation of the Permian strata occurs. Within the zone of influence, upward flow from the Permian to the alluvium reduces. This is due to changes in hydraulic gradients between the alluvium and Permian that reduce upward flow, and reverse the flow to downward flow in some areas adjacent to the proposed open cut mining areas.

Figure 10.12 shows the changes to the flows from the Permian to the alluvium across the Project Boundary over the course of the Project. Figure 10.13 shows the net change in the upward flow rate from the Permian to the alluvium across the model domain.

The water take from the alluvium due to mining peaks at 469 ML/year in Year 10, then gradually reduces to 285 ML/year at the end of the Project life. KEPCO has secured 1,959 units of water allocation from the Bylong Water Source under the Hunter Unregulated and Alluvial Water Sharing Plan, which is more than sufficient to license the predicted take of water from the alluvium. Further allocations are likely to be secured into the future.
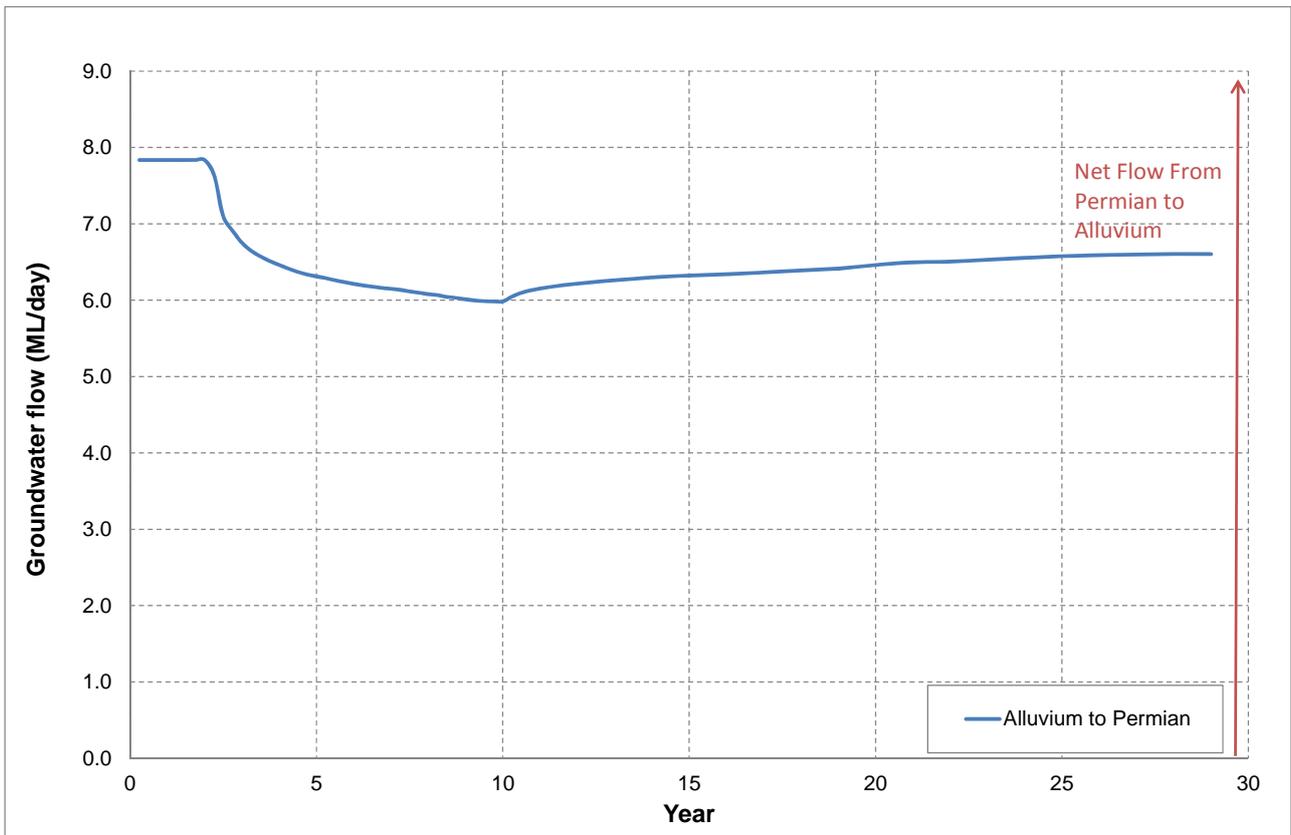
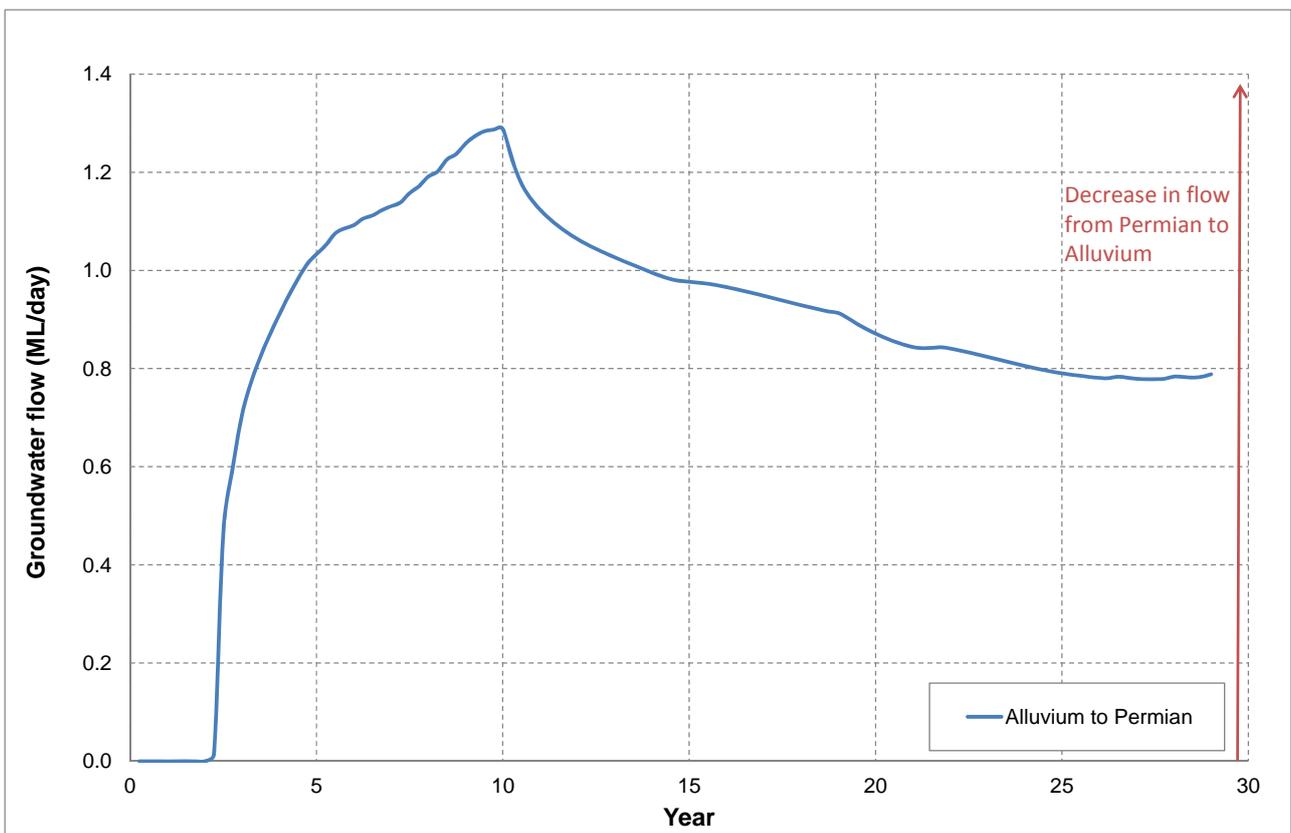**Figure 10.12: Net flow from Permian to alluvium**

Figure 10.13: Net change in flow from Permian to alluvium due to mining

10.8   Changes to Surface Water Flow

Figure 10.14 shows the model predicted river baseflow over the proposed 29 year Project life.
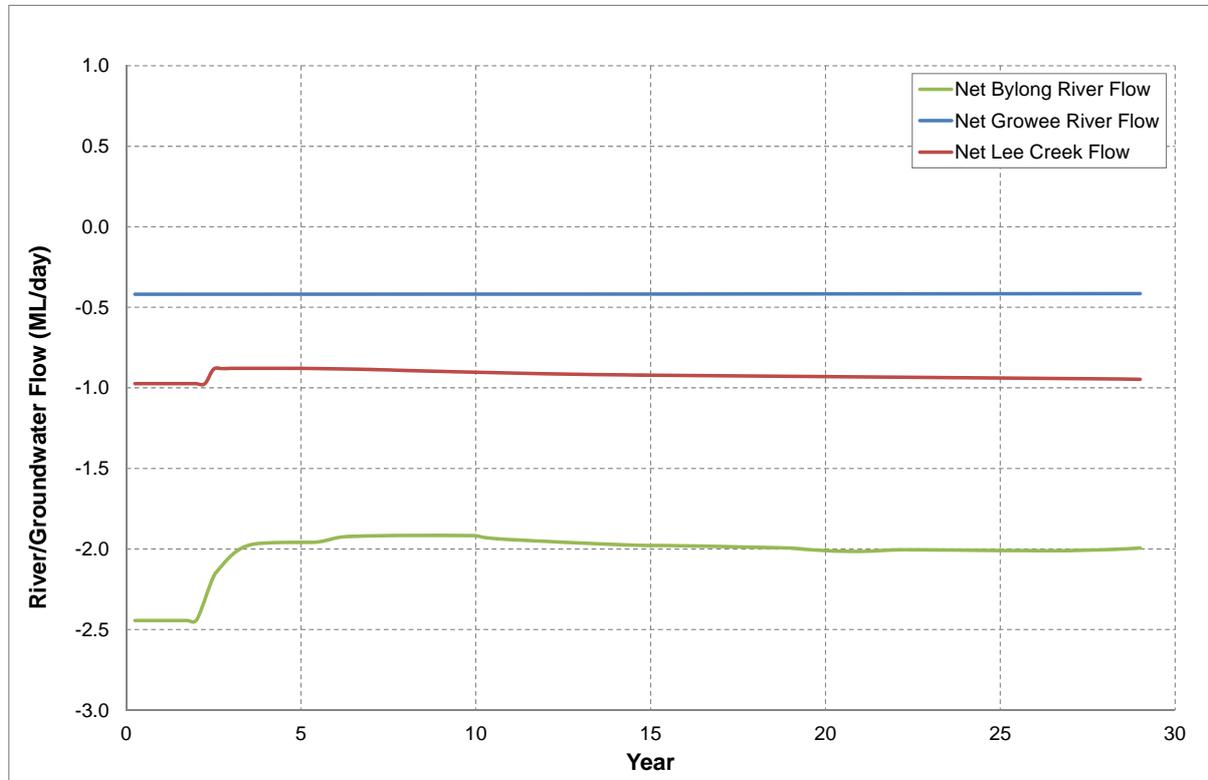

**Figure 10.14: River baseflow during mining**

Once mining commences, the Permian strata become depressurised, and within the zone of influence, upward flow from the Permian to the alluvium reduces. The resultant lowering of groundwater levels in the alluvium, although very small, reduces the hydraulic gradient between the bed of the river and the underlying aquifer, reducing the baseflow. It is important to note that Figure 10.14 presents the cumulative impact on the river systems due to the cumulative impact of both the Project and the proposed Mt Penny Project. The graphs indicate mining baseflow reduces the baseflow, in Lee Creek and the Bylong River but does not impact on flows in the Growee River. The Goulburn River, not shown above, was not predicted to be impacted within the current modelling.

KEPCO has secured 1,959 units of water allocation from the Bylong Water Source under the Hunter Unregulated and Alluvial Water Sharing Plan. Further allocations are likely to be secured into the future and will be sufficient to license the estimated water take.

10.9   Post Mining Impacts

Post mining impacts were investigated with a recovery model, commencing from the end of mining and run for 1,000 years. The model used the final end of mining groundwater levels as the starting heads, and removed all drain cells simulating the proposed mining areas to allow groundwater levels to equilibrate. At the end of mining, the last longwall panel was converted to goafed material, and the main road drain cells removed.

Figure 10.15 shows the changes in groundwater levels at equilibrium conditions 1,000 years post mining. The figure indicates mining results in a permanent change in shape of the water table surface, with a water levels mounding and falling within the spoil areas due to the change in hydraulic properties and recharge rates.
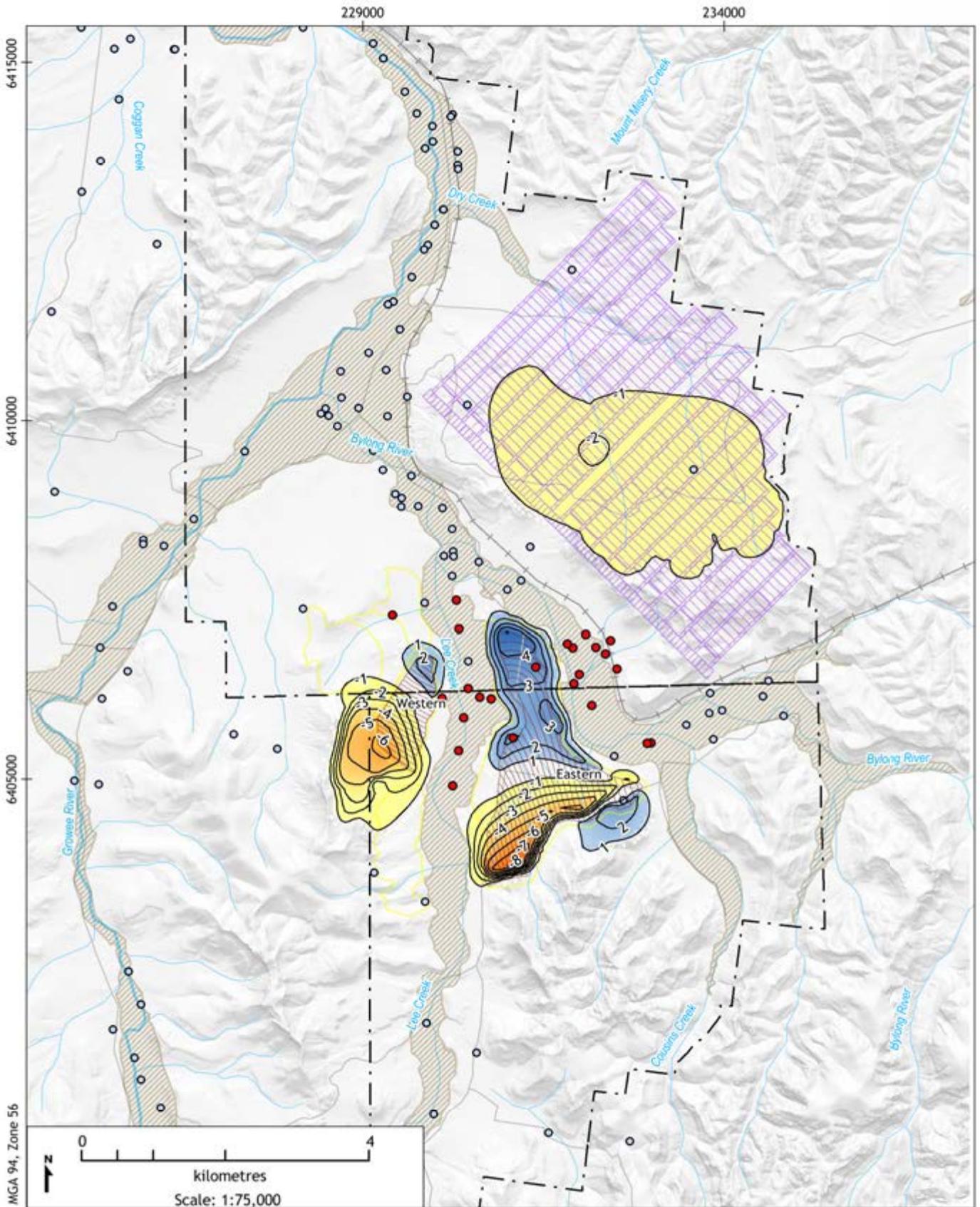
229000

234000

6415000

6410000

6405000

0   4

kilometres

Scale: 1:75,000

LEGEND:

— Underground Extraction Area
— Open Cut Mining Area
— Overburden Emplacement Area

▪▪▪ Authorisation
— River
— Drainage Line / Creek
— Road / Track
+ Railway

— Head Change Contour (m)
○ Bore - Licenced
● Bore - >2m Drawdown Predicted During
First 24 yrs of Mining
▨ Quaternary Alluvium

Bylong Coal Project (G1606)

**Change in Groundwater Levels
1000 Years Post Mining**

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GROUNDWATER & ENVIRONMENTAL

DATE:
2/12/2013

FIGURE No:
10.15

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It is proposed to co-dispose of partially dried tailings and reject materials into the Western and Eastern Open Cut Mining Areas during the years of open cut mining operations. Additionally, tailings and reject materials generated during the longer term underground mining operations are proposed to be disposed into the remaining Eastern open cut void for the remainder of the Project life following open cut mining operations.

In order to understand the potential for the leachate from the tailings to impact on surrounding water quality, it is important to understand both the tailings and rejects geochemistry and the rate of groundwater flow through the tailings and rejects and spoil materials. Geochemical studies are being undertaken to characterise the quality of water that flows through these materials for inclusion within the EIS for the Project. The model provides an indication of the fluxes of water from the spoil and tailings into the surrounding environment.

Figure 10.16 shows the groundwater levels and flow directions 1,000 years post mining. The water levels indicate groundwater flow is through the proposed tailings material, into the spoil and then into the neighbouring alluvium and streams.
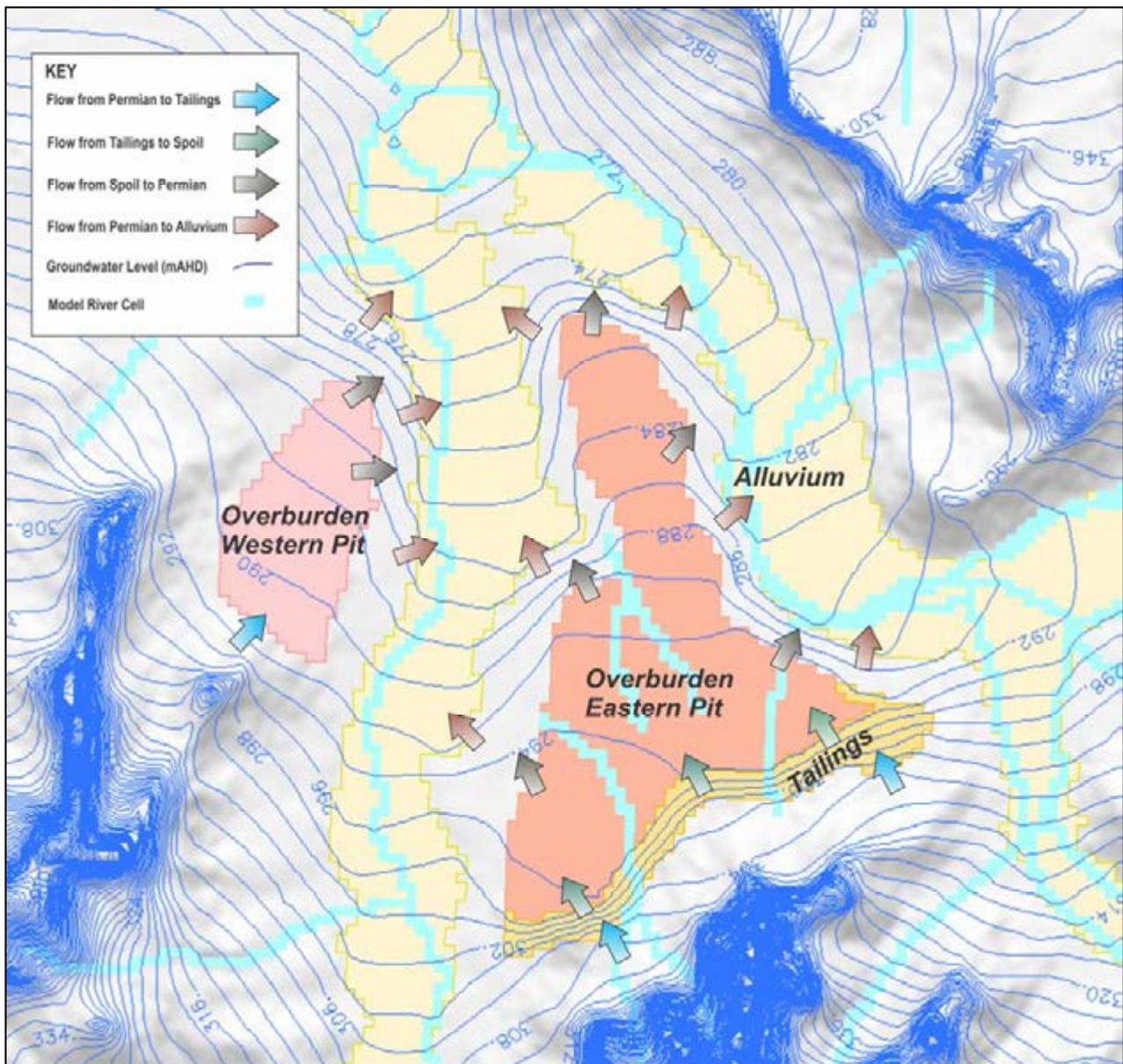

Figure 10.16: Groundwater levels and flow directions – 1000 years post mining

Figure 10.17 shows the volumes of groundwater flowing from the Open Cut Mining Areas to the surrounding Permian aquifer, and flow through the tailings within the remaining void of the eastern mining area into the adjacent backfilled Open Cut Mining Area.
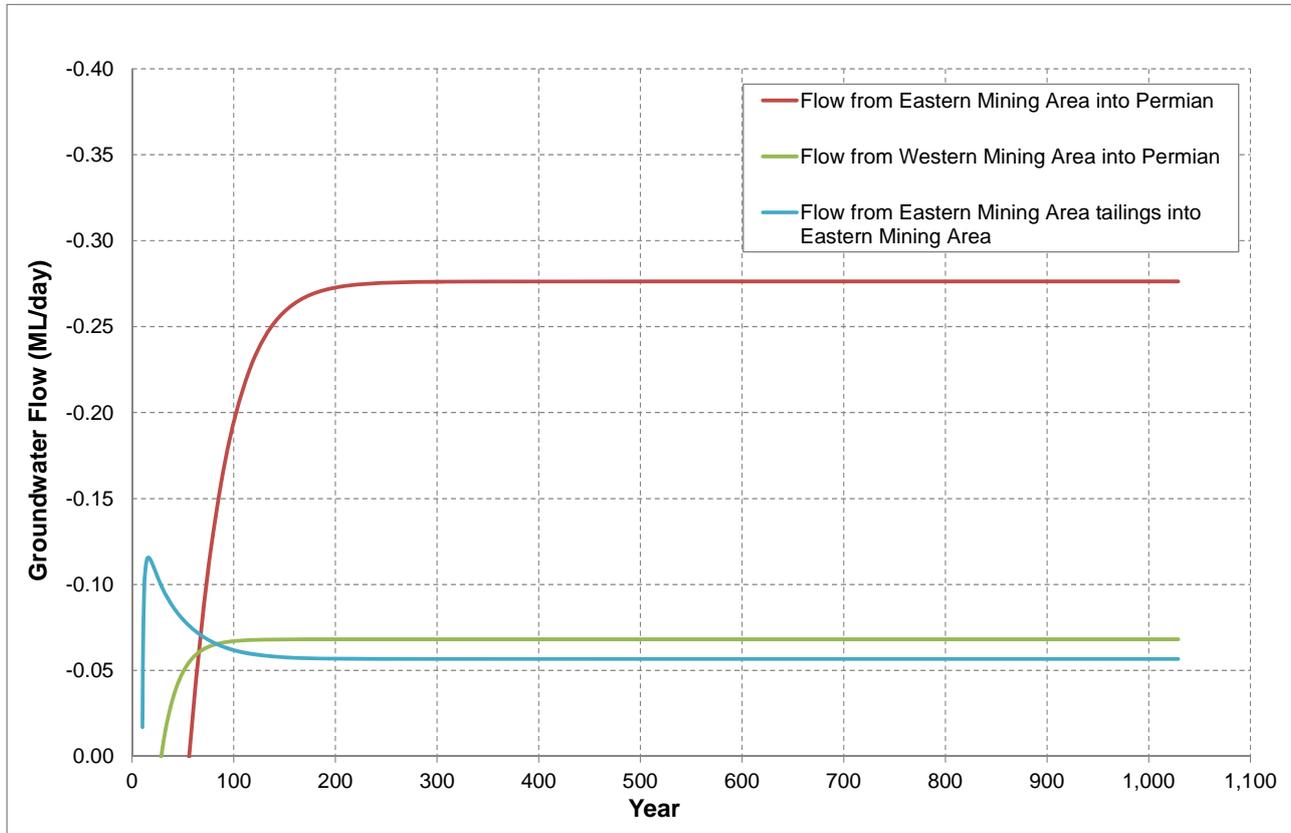

Figure 10.17: Spoil / tailings water budgets – during and post mining

The results show the flow of groundwater from Eastern Open Cut Mining Area to the surrounding strata stabilises at about 0.27 ML/day. The model indicates the flow from the remaining Eastern Open Cut Void and the proposed disposal of tailings stabilises at about 0.06 ML/day. The tailings water flows into the spoil, and then out into the surrounding alluvium.

Figure 10.18 presents the groundwater flow budgets within the predicted areas of impact, separated into the eastern (Bylong River) and western (Lee Creek) margins of the alluvium, either side of the Eastern Open Cut Mining Area.

Figure 10.18 indicates that approximately 0.8 ML/day flows from the Permian to the alluvial system. After equilibrium conditions are reached post mining, the rate of flow from the Permian to the alluvium increases to 1.0 ML/day, indicating an increase of 0.2 ML/day entering the alluvium from the post mining situation.

The flow through the tailings accounts for about 6% of groundwater flowing from the Permian into the alluvium. As stated previously, the potential for this water to impact on the water quality in the alluvium and the connected streams depends on the geochemistry of the spoil and tailings. At the time of writing no data was available for the Project site, although a geochemical study had been commissioned. Testing by EGI (2006) at the Moolarben Project analysed the chemical composition of water extracts of overburden and floor samples, which is mining in the same geological units. The testing indicated a relatively low EC of water extracts from the overburden/ interburden lithological units averaging 119 µS/cm. If the salinity of the spoil and tailings is similar to this for the Project, no significant impacts on aquifer or stream water quality are considered likely.
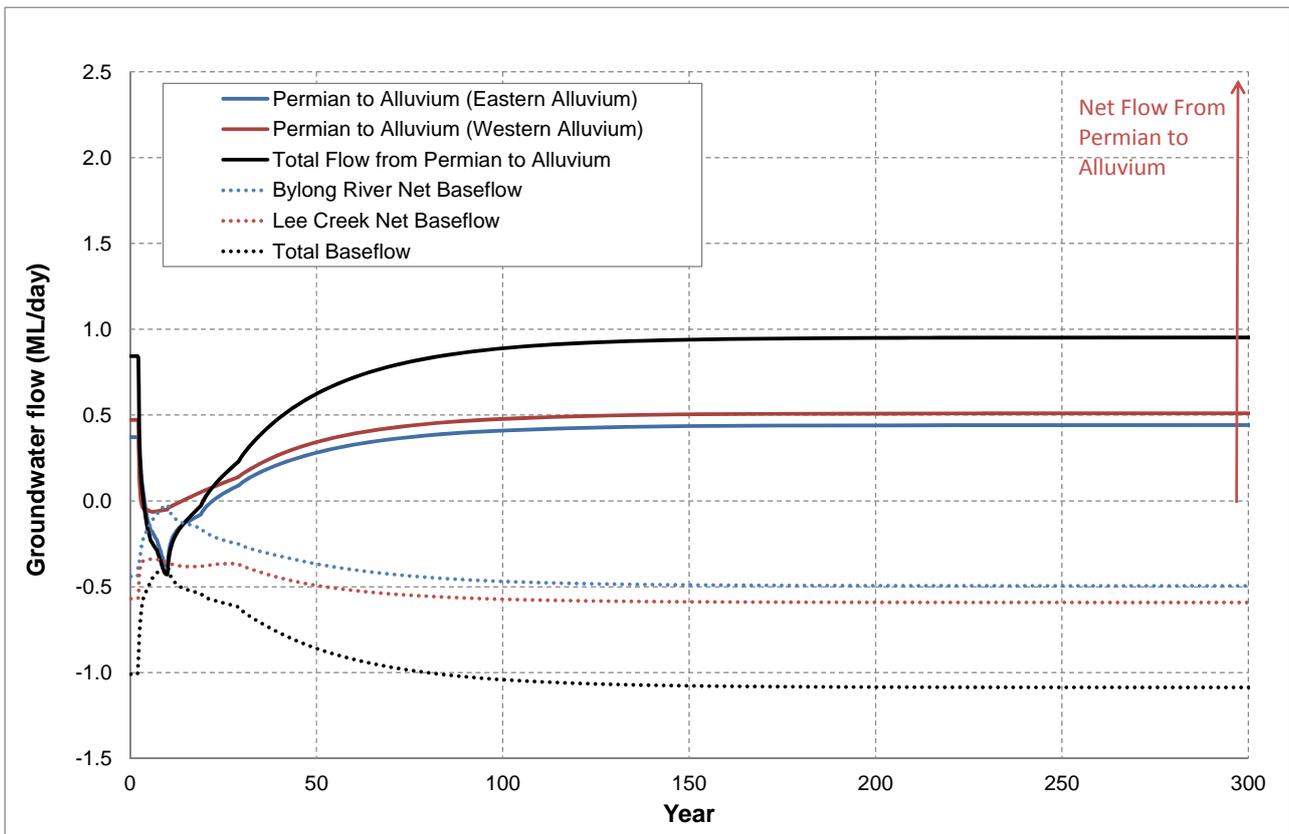
Figure 10.18: Groundwater and baseflow surrounding open cut mining areas

11 PREDICTIVE SENSITIVITY ANALYSIS

A sensitivity analysis assessed the response of the model predictions to changes in the model input parameters. The objective of the sensitivity analysis was to rank the input parameters in terms of their influence on the predicted results. The sensitivity analysis assessed the impact of:

- increasing/decreasing the horizontal and vertical hydraulic conductivity of the Permian layers by a factor of ±10;

- assuming a constant 0.3 m of water is present in the Bylong River;

- reducing the riverbed conductance in the Bylong River by a factor of 10 (at a constant stage height of 0.3 m);

- increasing the specific storage in all model layers by a factor of 10;

- decreasing the specific storage of the spoil by 50%; and

- increasing the connective cracking height by 50% above the goaf zone.

11.1 Proposed Mining Area Seepage Sensitivity

Figure 11.1 shows the sensitivity of the predicted seepage rate to changing the parameters in the model.
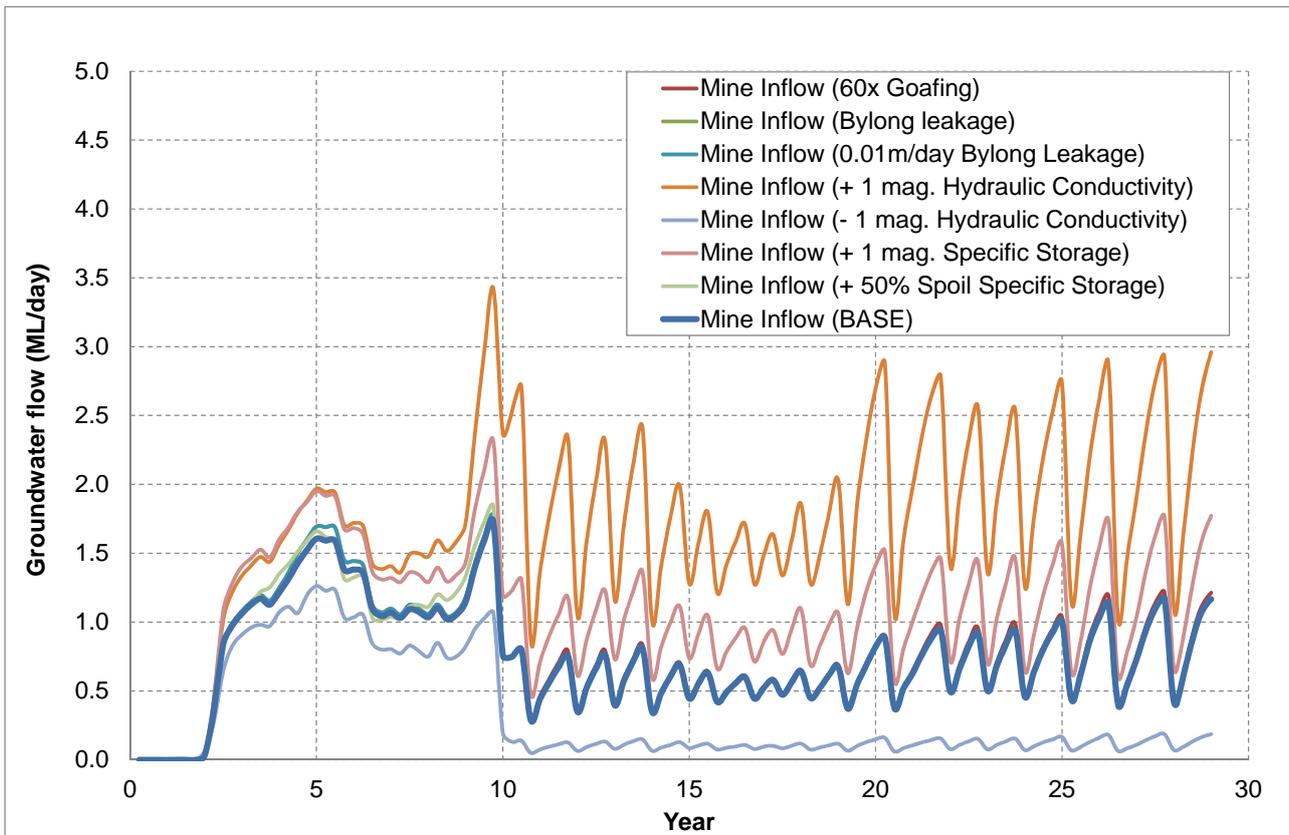
Figure 11.1: Sensitivity of Mining Area inflow

The predicted seepage is most sensitive to changes in the Permian hydraulic conductivity. Increasing the Permian hydraulic conductivity by an order of magnitude increases the predicted underground seepage peaks by an additional 1.5 ML/day to 2.5 ML/day. Reducing the hydraulic conductivity by an order of magnitude has a similar effect.

Specific storage was the second most sensitive parameter to mining area seepage, with an order of magnitude increase, resulting in an increase above the base seepage rate of about 0.5 ML/day.

Changes to the spoil parameters had a minor impact to the open cut mining seepage rates, increasing inflows by a maximum of 0.2 ML/day. A similar response occurred when changing the conditions of the Bylong River.

Changing the connective cracking height of the goaf had minimal impact on predicted mine seepage rates (~0.1 ML/day). This is because the majority of the Permian higher than 150 m above the Coggan seam is unsaturated.

11.2   Interaction with Alluvial Aquifer System

Another key model prediction is the change to the transfer rate of water from the Permian units to the overlying alluvial aquifers. Figure 11.2 presents the changes to the rate of groundwater entering the alluvium from the adjacent Permian formation.
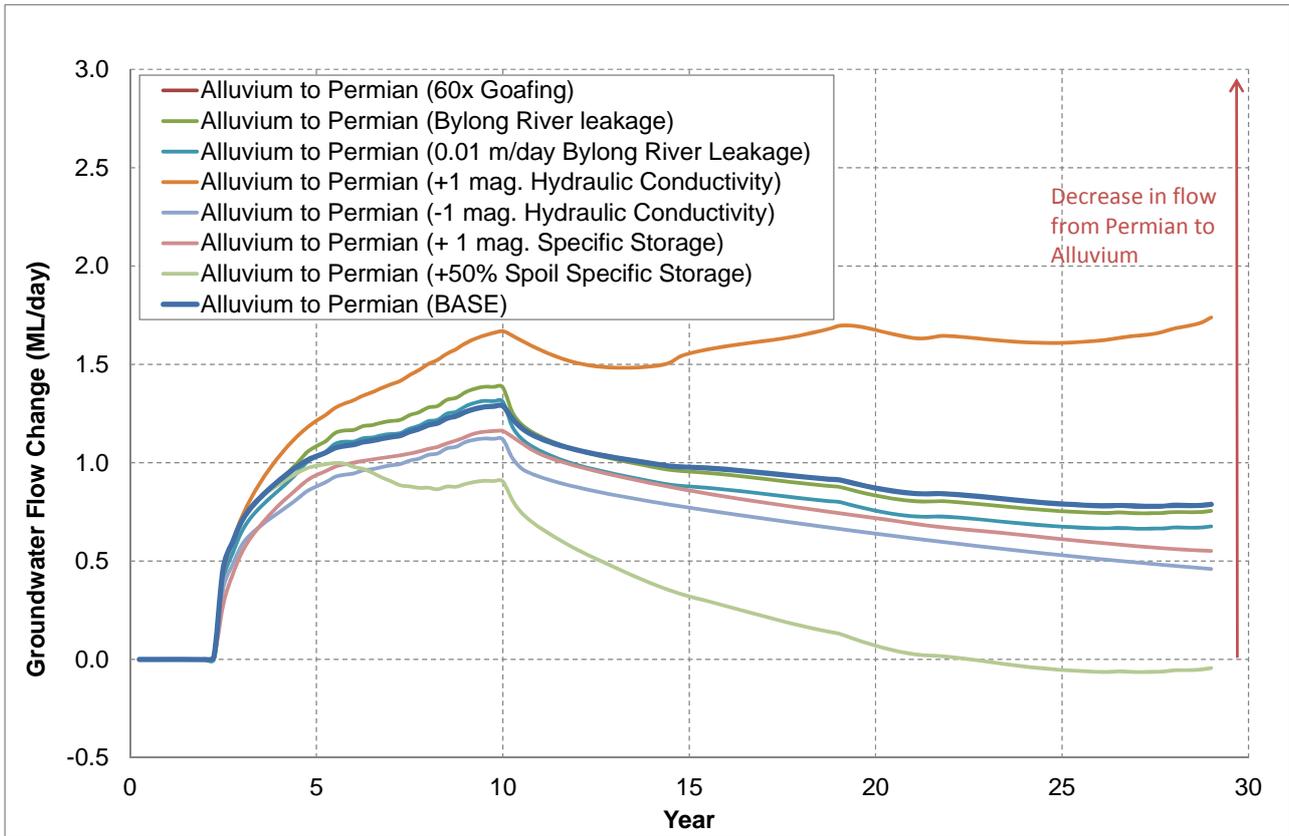
Figure 11.2: Sensitivity of Permian to alluvial flow change

Figure 11.2 demonstrates that the reduced transfer from the Permian to the alluvium is most sensitive to hydraulic conductivity, and relatively insensitive to changes in the Bylong River stage height.

Decreasing the specific storage properties of the spoil resulted in flow from Permian to the alluvial aquifer system increasing above pre-mining rates by year 24. This is due to the spoil aquifers ability to mound faster with lower storage, and increases groundwater levels adjacent to the alluvial aquifer system.

11.3 Zone of Depressurisation

The sensitivity analysis assessed the changes to the zone of depressurisation in the alluvium and the Coggan coal seam. Figure 11.3 and Figure 11.4 show the sensitivity of predicted maximum groundwater drawdown to changes in the model, for Layer 1 and Layer 8 respectively.

Drawdown in the alluvium is most sensitive to changes in the Permian hydraulic conductivity and specific storage. Figure 11.3 shows the 2 m drawdown contour extends from a distance of 0.8 km for the base case, to 1.1 km when the Permian hydraulic conductivity increases by an order of magnitude. Bylong River leakage is the most sensitive parameter to groundwater drawdown in the alluvium. Applying a constant influx along the Bylong River buffers groundwater drawdown such that most bores in the alluvium north of the Eastern Open Cut Mining Area are unaffected by mining.

Figure 11.4 shows that the 2 m drawdown contour in the Permian extends from a distance of 1.1 km in the base case, to 3.1 km when the Permian hydraulic conductivity increases by an order of magnitude.

LEGEND:

Underground Extraction Area
Open Cut Mining Area
Overburden Emplacement Area
○ Bore - Licenced
● Bore - >2m Drawdown Predicted
Authorisation
River
Road / Track
Quaternary Alluvium
Drainage Line / Creek
Railway

2 m Drawdown Contours:
Hydraulic Conductivity +10m
Hydraulic Conductivity -10m
Bylong River Leakage 0.01 m/day
Bylong River Leakage 0.1 m/day
60x Goafing
Basecase

Bylong Coal Project (G1606)

Sensitivity of Maximum Drawdown Layer 1

DATE: 2/12/2013

FIGURE No: **11.3**

MGA 94, Zone 56

0   4
kilometres
Scale: 1:75,000

Bylong Coal Project (G1606)

Sensitivity of Maximum Drawdown Layer 8

LEGEND:

— Underground Extraction Area
— Open Cut Mining Area
— Overburden Emplacement Area
○ Bore - Licenced
● Bore - >2m Drawdown Predicted
Authorisation   Quaternary Alluvium
— River   — Drainage Line / Creek
— Road / Track   —+— Railway

2 m Drawdown Contours:
- - - Hydraulic Conductivity +10m
- - - Hydraulic Conductivity -10m
- - - Bylong River Leakage 0.01 m/day
- - - Bylong River Leakage 0.1 m/day
- - - 60x Goafing
—— Basecase

MGA 94, Zone 56

0   4
kilometres
Scale: 1:75,000

DATE: 2/12/2013

FIGURE No: **11.4**

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12 AQUIFER INTERFERENCE POLICY

The tables below compare the preliminary groundwater impact predictions for the Project against the requirements under the NSW AIP (NOW, 2012).

Table 12.1: ACCOUNTING FOR OR PREVENTING THE TAKE OF WATER		
	AIP requirement	**Proponent response**
1	Described the water source (s) the activity will take water from?	Based on the AIP, the groundwater system impacted by the Project can be separated into two systems, as follows: • porous and/or fractured consolidated sedimentary rock of the Permian coal measures; and • groundwater within alluvium associated with the Bylong River and Lee Creek alluvium Water quality and yields for the coal measures and Permian coal measures is considered a less productive aquifer according to the AIP because yields >5L/sec are considered unlikely and salinity <1500 mg/L is not common, while the Bylong River and Lee Creek alluvium is considered a highly productive aquifer as yields >5L/sec are considered achievable and salinity <1500 mg/L occurs in some areas.
2	Predicted the total amount of water that will be taken from each connected groundwater or surface water source on an annual basis as a result of the activity?	Predicted take based on this preliminary modelling for the Project include: • Permian coal measures: 536 ML/year at peak – 300 ML/year average • Quaternary alluvium: 469 ML/year at peak 320 ML/year at average
3	Predicted the total amount of water that will be taken from each connected groundwater or surface water source after the closure of the activity?	• Gradual recovery to pre-mining conditions, and no greater than that predicted during mining operations
4	Made these predictions in accordance with Section 3.2.3 of the AIP? (page 27)	• Based on 3D numerical modelling.
5	Described how and in what proportions this take will be assigned to the affected aquifers and connected surface water sources?	Predicted takes based on the preliminary modelling for the Project include: • Permian coal measures – 536 ML/year at peak, 300 ML/year average • Quaternary alluvium – 469 ML/year at peak, 320 ML/year at average • Bylong River baseflow – 180 ML/year peak, 54 ML/year average • Lee Creek baseflow – 35 ML/year peak, 21 ML/year average
6	Described how any licence exemptions might apply?	• Not necessary.
7	Described the characteristics of the water requirements?	Initial estimates: • Mine Industrial Areas – 90 ML/year • Opencut – 500 ML/year • Underground – 500 ML/year • CHPP – 368 ML/year • Temporary Workers Accommodation – 50 ML/year
8	Determined if there are sufficient water entitlements and water allocations that are able to be obtained for the activity?	KEPCO has secured approximately 2,000 units of water allocation from the Bylong Water Source under the Hunter Unregulated and Alluvial Water Sharing Plan. Further allocations are likely to be secured into the future.
9	Considered the rules of the relevant water sharing plan and if it can meet these rules?	
10	Determined how it will obtain the	Via seepage to the mine face – a portion will likely evaporate or be removed as

Table 12.1: ACCOUNTING FOR OR PREVENTING THE TAKE OF WATER		
	AIP requirement	**Proponent response**
	required water?	moisture in coal and will not enter the site water circuit. Potential need for a supplementary borefield.
11	Considered the effect that activation of existing entitlement may have on future available water determinations?	Current groundwater entitlement for Bylong River is 5,843 ML/year – predicted impacts based on the preliminary modelling are considered negligible against existing entitlements.
12	Considered actions required both during and post-closure to minimise the risk of inflows to a mine void as a result of flooding?	Open cut mine plans have been designed to be located outside of the flood limits of Bylong River and Lee Creek. Further modelling and assessment will be completed within the EIS to confirm that the mine plans are located outside of this flood plain. Further, the Open Cut Mining Void is proposed to be backfilled, and will therefore not obtain a mining void post mining activities.
13	Developed a strategy to account for any water taken beyond the life of the operation of the project?	Allocate existing and future water entitlements to the Project water takes to license take of water as necessary.
	Will uncertainty in the predicted inflows have a significant impact on the environment or other authorised water users? *Items 14-16 must be addressed if so.*	Yes, modelling indicates supply of adjacent private bores could be affected when open cut mining is active for a period of approximately 9 years. While modelling did not indicate significant impact due to underground mining, the sensitivity analysis indicated increasing the hydraulic conductivity of the aquifer units could increase the number of private bores affected by mining.
14	Considered any potential for causing or enhancing hydraulic connections, and quantified the risk?	Mine plan has been designed to remain outside of the 150 m from the edge of the neighbouring alluvium to ensure that impacts to the alluvial system are minimised as far as possible. Underground mine will fracture overlying strata, but this will not result in any direct connection to the alluvial aquifer. Designs have incorporated angle of draw to stay outside 40 m stand off from alluvials.
15	Quantified any other uncertainties in the groundwater or surface water impact modelling conducted for the activity?	Yes – work plan to reduce uncertainty of modelling provided. Completed a sensitivity analysis of the modelling to identify parameters that demonstrate most substantial changes in the predictions. These parameters will be further investigated during the preparation of the EIS.
16	Considered strategies for monitoring actual and reassessing any predicted take of water throughout the life of the project, and how these requirements will be accounted for?	Ongoing monitoring and verification of modelling.

Table 12.2: DETERMINING WATER PREDICTIONS		
	AIP requirement	**Proponent response**
1	Addressed the minimum requirements found on page 27 of the AIP for the estimation of water quantities both during and following cessation of the proposed activity?	Based on modelling

Table 12.3: OTHER REQUIREMENTS		
	AIP requirement	**Proponent response**
1	Establishment of baseline groundwater conditions?	Refer Section 7
2	A strategy for complying with any water access rules?	Water licenses held by proponent

Table 12.3: OTHER REQUIREMENTS		
	AIP requirement	**Proponent response**
3	Potential water level, quality or pressure drawdown impacts on nearby basic landholder rights water users?	Yes predicted to occur – proponent will purchase land or 'make good'
4	Potential water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources?	Yes predicted to occur – proponent will purchase land or 'make good'
5	Potential water level, quality or pressure drawdown impacts on groundwater dependent ecosystems?	Will be assessed during EIS
6	Potential for increased saline or contaminated water inflows to aquifers and highly connected river systems?	Yes - will be assessed further during EIS
7	Potential to cause or enhance hydraulic connection between aquifers?	No - underground mine will fracture overlying strata, but this will not result in any direct connection to the alluvial aquifer
8	Potential for river bank instability, or high wall instability or failure to occur?	
9	Details of the method for disposing of extracted activities (for CSG activities)?	N/A

There are two levels of minimal impact considerations specified in the AIP. If the predicted impacts are less than the Level 1 minimal impact considerations, then these impacts will be considered as acceptable. Where the predicted impacts are greater than the Level 1 minimal impact considerations then the AIP requires additional studies to fully assess these predicted impacts. If this assessment shows that the predicted impacts do not prevent the long-term viability of the relevant water-dependent asset, then the impacts will be considered to be acceptable.

The modelling indicates potential for drawdown in a number of private bores to exceed the Level 1 minimal impact considerations. Further studies will be undertaken during the EIS phase of the Project to improve the accuracy of the model predictions. If predictions are shown to be valid, KEPCO will consider purchasing the land or entering into a 'make good agreement' with landowners.

13 SUMMARY AND CONCLUSIONS

The proponents recognised from an early stage the importance of obtaining baseline data and characterising the groundwater regime in the lease area. They have integrated the collection of hydrogeology data into the exploration program. They have evaluated mineral exploration drill holes for use as a potential groundwater monitoring bores, or for installing vibrating wire piezometers.

This approach resulted in bores gradually being built up as the mineral exploration proceeded. Groundwater monitoring bores were not restricted to areas of coal occurrence only, with a program of drilling undertaken for groundwater data only in key areas, for example the buffer zone between the proposed open cut mining areas and the alluvium. The monitoring bore network comprises 70 monitoring bores and 10 vibrating wire piezometers arrays and is well advanced considering the Project is only in the early stages of the approvals process.

Cockatoo Coal contracted DP to manage the installation and sampling of the groundwater and surface water monitoring network. DP have tested the permeability around each monitoring bore with falling/rising head tests (known collectively as slug tests) then implemented a program of routine monitoring. Selected monitoring bores have been equipped with down-hole data loggers recording groundwater levels on a daily basis.

Routine monitoring commenced after the first monitoring bores were installed over two years ago and is still ongoing. The oldest bores have a data set that spans over more than two years, with the majority of the bores having between one and two years data, meaning the Project satisfies the requirement of the Aquifer Interference Policy to have a minimum two years baseline data.

DP have also installed three stream flow gauges and a site rainfall gauge. The routine monitoring program has allowed the significance of external influences on the groundwater regime such as rainfall recharge and groundwater / surface water interaction.

The data collected from the field investigation allowed the development of a conceptual model and simple groundwater model to assess the impact of the proposed mining on the groundwater aquifers, particularly the alluvial aquifers. The modelling indicated that the mining within the proposed Eastern Open Cut Mining Area has the potential to lower groundwater levels in the adjacent Lee Creek and Bylong River alluvium. The predicted zone of drawdown within the alluvium is largely confined to the alluvium adjacent to the Eastern and Western Open Cut Mining Areas. The model predicts water levels in private bores within this zone could fall by more than 2 m. This however is considered temporary, and when the proposed open cut areas are completed and are progressively backfilled with rejects and tailings materials after 10 years, the water levels within the alluvium begin to recover, and approach pre-mining levels by the end of mining in Year 29. At this point, no significant impact on the alluvial water levels is evident.

The modelling indicates the impact due to the proposed underground mining is much less significant than the proposed open cut, with no notable drawdown within the alluvium.

The proposed open cut mining areas will be backfilled with spoil, and the final void will progressively be filled with tailings and reject materials from the processing of coal extracted by underground methods within the CHPP. The tailings are expected to have a texture similar to silt/clay and therefore have limited permeability. When mining of the open cut mining areas is complete, the voids within the spoil heaps slowly saturate from rainfall recharge, seepage from tailings and seepage from the walls and floor of the mining area. Post mining the water levels equilibrates and there is a net outflow of groundwater from the spoil and tailings to the adjacent alluvial aquifer. The quality of the outflow will depend on the geochemistry of the spoil and tailings material, which are currently being investigated for inclusion within the EIS.

KEPCO has secured 1,959 units of water allocation from the Bylong Water Source under the Hunter Unregulated and Alluvial Water Sharing Plan, and further allocations are likely to be secured into the future. These volumes are well in excess of the volume of water predicted to be taken from the groundwater sources and therefore are sufficient to account for the impact of mining.

14 EIS WORK PROGRAM

The main hazard/risks the project poses to agriculture is the potential to impact on bore yield and flow/salinity in connected streams. Further work is planned to better understand the groundwater regime and improve the predictive capability of the groundwater model during the EIS phase of the approvals process, so the magnitude of the risks can be better understood. The work planned in the field and for the groundwater model is outlined below.

14.1   Field Investigations

An extensive network of monitoring bores already exists in the Project area, and routine monitoring is building an excellent baseline dataset. During the EIS the following issues will be further investigated with the ultimate objective of providing further data to the groundwater model:

- potential for perched water systems to be present in the basalt capping and Permian overburden in the proposed longwall mining area;
- physical and chemical properties of the spoil and tailings;
- temporal diffuse recharge to the alluvium and recharge from the creek systems;
- usage of water from private bore / landholder bore survey
- presence of any springs or GDEs;

Two of the VWP arrays recorded a high pore pressure at shallow depth overlying the longwall mining area. This may have been due to perched water at the base of the basalt cap in this area. Alternatively perching may occur due to low permeability layer with the Permian overburden sequence. Further investigation will be undertaken to determine if perched water is present in this area, as it could influence inflows to the proposed underground mine. Perching if present, also presents suitable conceptual data that represents limited recharge through the thick Permian profile above underground mine area. The work program will consider installing further bores in this area.

The physical and chemical properties of the backfilled overburden and tailings disposed in the open cut pit voids control the rate of groundwater recovery and the quality of groundwater that will flow to the alluvial aquifer post mining. Geochemical studies will include static and kinetic leaching of ground spoil and tailings samples to determine the concentrations of salts and trace elements likely to emanate from these areas. The potential physical properties of the spoils and tailings, including porosity and hydraulic conductivity will also be further investigated to provide input to the groundwater model.

The recharge rate to the alluvium will control the drawdown and recovery in private bores induced by mining. A high recharge rate will buffer the drawdown in private bores, and promote rapid recovery post mining, whilst a lower recharge rate will allow great drawdown and slower recovery. The recharge rates will be further investigated by a number of methods including:

- water table fluctuation method – the water level records from the monitoring bores in the alluvium will be used to estimate recharge rates;
- environmental isotopes and age dating – selected groundwater and surface water samples will be analysed for environmental isotopes and water age to determine recharge sources;
- soil water balance – weather station data, couple with data from a soil moisture sensor will be used to further estimate deep drainage through the soil profile; and
- working with the surface water consultants to cross check the estimated stream flow, runoff and deep drainage proportions.

The work to date has included conducting a Freedom of Information search to obtain the locations of private water bores within the region. The next important step is to obtain data on the construction of each bore and the water usage. Whilst the groundwater model currently predicts there is potential for drawdown to exceed 2 m in some private bores, this does not necessarily mean the viability of water supplies will impacted by the project. The bore census will determine the depth of the bore, depth to water and pump setting within the bore, and therefore the available

column of water. Water quality and yield will also be determined as part of the bore census. This data will allow the impacts from the predicted drawdown on bore yields to be better understood.

The alignment of Bylong River and Lee Creek is characterised by shallow water tables that could have the potential to support groundwater dependent ecosystems. Ecosystems in areas with high water tables will be surveyed to determine the potential for vegetation to be dependent on underlying groundwater. Prominent seeps or springs will also be surveyed and water quality samples collected.

14.2 Numerical Modelling

Further work will be undertaken to improve the calibration and predictive capability of the groundwater model. This includes:

- calibrating the model to transient water level records collected from the monitoring bores and VWP network;
- representing the measured stage heights in the creek systems in the model;
- updating the geological surfaces with any updated exploration data;
- representing pumping from private bores in the model;
- simulating progressive backfilling of tailings during mining;
- analysing the sensitivity of the predictions to model parameters;
- increasing the model confidence class from Level 1 to Level 2 as described in the Australian Groundwater Modelling Guidelines; and
- having the model peer reviewed.

The model will be rigorously calibrated within the bounds of the field data using both manual and automated parameter estimation software (PEST). Field observations from the monitoring bores and stream gauges will be used in the calibration, which will reduce the non-uniqueness of the solution. Both steady state and transient calibration will be undertaken.

Transient calibration will utilise the data collected at the site including rainfall, recharge, groundwater levels, pumping, stream levels and estimates of pumping from private bores. A portion of the dataset will be held aside to verify the model can reproduce the water level fluctuations and flows beyond the calibrated period. The transient calibration will aim to remove the mounding that occurs in the current version of the model in the proposed underground extraction area. Data from vibrating wire piezometers will be used in the calibration process to ensure vertical hydraulic gradients are replicated where significant.

The current version of the model represents gradual backfilling of spoil, but not tailings. The model will be updated to replicate the gradual filling of the open void in the Eastern Mining Area with tailings over the mine life. It is not proposed to numerically model the transport of salts from the backfilled spoils and tailings in the groundwater model, rather use predicted fluxes of groundwater from the mined area to the alluvium and geochemistry data to quantify the impact using simple water budget mixing methods.

The sensitivity of the model calibration and predictions will be fully assessed, so the uncertainty of the predictions understood.

The model will be peer reviewed by Dr Noel Merrick, at key stages during the EIS modelling. Comments from Dr Merrick will be incorporated.

14.3 Management / Mitigation Measures

14.3.1 Groundwater Impacts

Should the updated modelling confirm the potential for the project to impact on the yield of private bores or the quality and rate of baseflow in connected streams then mitigation measures will be assessed. The mitigation measures assessed will depend on the magnitude of the impacts, but will include purchase of affected property, drilling new deeper bores, supplementing water supplies etc.

14.3.2 Mine Water Balance

There is potential during an extended period of dry weather for the Project to have a deficit in the water balance. The Project will supplement with groundwater pumped from properties owned by the proponent, under water licenses held by the proponent.

The EIS will assess the optimal locations for extracting groundwater from the alluvial aquifer to maintain a reliable supply, and minimise the impact on existing users, and connected surface water. This will include considering the planned cease to pump provision to be included in the Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources by Year 10 of the plan. This may require water to be extracted from a number of bores or small borefield to minimise drawdown spatially.

15 REFERENCES

ANZECC (2000), "Australian and New Zealand Guidelines for Fresh and Marine Water Quality", Australian and New Zealand Environment and Conservation Council, October 2000.

Barnett et al, (2012), Australian groundwater modelling guidelines, Waterlines report, National Water Commission, Canberra, 2012.

Douglas Partners (2013), "*Preliminary Hydrogeological Assessment and Water Monitoring Plan, Proposed Coal Mine at Bylong, Mid-Western NSW*", Project 49761-1.

Douglas Partners, (2013), *"Report on Hydrogeological Investigation and Monitoring - August 2011 to October 2013 Proposed Coal Mine Bylong, Mid-Western NSW Prepared for Cockatoo Coal Limited",* Project 49761.03-07, November 2013.

Department of Planning and Infrastructure (2013) Strategic Regional Land Use Policy. Guideline for Gateway Applicants, Fact Sheet, September 2013.
http://www.mpgp.nsw.gov.au/docs/Guideline%20for%20Gateway%20Applicants.pdf

Dundon, P. (2006), *Moolarben Coal Project – Groundwater Assessment*, September 2006.

Wells Environmental Services (2011), *Mt Penny Coal Project- Preliminary Environmental Assessment,* February 2011.

EGI, (2006), *"Geochemical Assessment of the Moolarben Coal Project".*

Mackie C.D., (2009), *"Hydrogeological Characterisation of Coal Measures and Overview of Impacts of Coal Mining on Groundwater Systems in the Upper Hunter Valley of NSW",* (January 2009).

NSW Department of Primary Industries, (2012), "*NSW Aquifer Interference Policy",* September 2012.

NSW Government, (2013), *"Strategic Regional Land Use Policy – Guideline for Gateway Applicants".* Fact Sheet September 2013.

NSW Government Fact Sheet – Strategic Regional Land Use Policy, Guideline for Gateway Applicants, September 2013.
http://www.mpgp.nsw.gov.au/docs/Guideline%20for%20Gateway%20Applicants.pdf

RPS Aquaterra, (2008), *"Moolarben Stage 2 Groundwater Assessment"*, November 2008.

RPS Aquaterra, (2011), *"Moolarben Complex Stage 2 - Preferred Project Report - Groundwater Impact Assessment"*, November 2011.

16 GLOSSARY

Alluvium - Sediment (gravel, sand, silt, clay) transported by water (i.e. deposits in a stream channel or floodplain).

Aquiclude - A low-permeability unit that forms either the upper or lower boundary of a ground-water flow system.

Aquifer - Rock or sediment in a formation, group of formations, or part of a formation which is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.

Aquifer, Confined - An aquifer that is overlain by a confining bed. The confining bed has a significantly lower hydraulic conductivity than the aquifer.

Aquifer, Perched - A region in the unsaturated zone where the soil may be locally saturated because it overlies a low-permeability unit.

Aquifer, Semi-confined - An aquifer confined by a low-permeability layer that permits water to slowly flow through it. During pumping of the aquifer, recharge to the aquifer can occur across the confining layer. Also known as a leaky artesian or leaky confined aquifer.

Aquifer, Unconfined - An aquifer in which there are no confining beds between the zone of saturation and the surface. There will be a water table in an unconfined aquifer. Water-table aquifer is a synonym.

Aquitard - A low-permeability unit than can store ground water and also transmit it slowly from one aquifer to another.

Colluvium - Sediment (gravel, sand, silt, clay) transported by gravity (i.e. deposits at the base of a slope).

Cone of Depression - The depression in the water table around a well or excavation defining the area of influence of the well. Also known as cone of influence.

Drawdown - A lowering of the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer caused by pumping of ground water from wells or excavations.

Falling/Rising Head Test - A test made by the instantaneous addition, or removal, of a known volume of water to or from a well. The subsequent well recovery is measured.

Head - sum of datum level, elevation head and pressure head which in unconfined aquifers is equal to the groundwater elevation.

Hydraulic Conductivity - A measure of the rate at which water moves through a soil/rock mass. It is the volume of water that moves within a unit of time under a unit hydraulic gradient through a unit cross-sectional area that is perpendicular to the direction of flow.

Hydraulic Gradient - The change in total head with a change in distance in a given direction. The direction is that which yields a maximum rate of decrease in head.

Infiltration - The flow of water downward from the land surface into and through the upper soil layers.

Model Calibration - The process by which the independent variables of a digital computer model are varied in order to calibrate a dependent variable such as a head against a known value such as a water-table map.

Packer Test - An aquifer test performed in an open borehole to determine rock permeability; the segment of the borehole to be tested is sealed off from the rest of the borehole by inflating seals, called packers, both above and below the segment.

Piezometer - A non-pumping well, generally of small diameter, that is used to measure the elevation of the water table or potentiometric surface. A piezometer generally has a short well screen through which water can enter.

Porosity - The ratio of the volume of void spaces in a rock or sediment to the total volume of the rock or sediment.

Potentiometric Surface - A surface that represents the level to which water will rise in tightly cased wells. If the head varies significantly with depth in the aquifer, then there may be more than one potentiometric surface. The water table is a particular potentiometric surface for an unconfined aquifer.

Pumping Test - A test made by pumping a well for a period of time and observing the response/change in hydraulic head in the aquifer in order to determine aquifer hydraulic characteristics.

Slug Test - A test made by the instantaneous addition, or removal, of a known volume of water to or from a well. The subsequent well recovery is measured and analysed to provide a permeability value.

Specific Yield - The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil. Gravity drainage may take many months to occur.

Storativity - The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer, per unit change in head.

Transmissivity - A measure of the rate at which water moves through an aquifer of unit width under a unit hydraulic gradient.

Unsaturated Zone - The zone between the land surface and the water table. It includes the root zone, intermediate zone, and capillary fringe. The pore spaces contain water at less than atmospheric pressure, as well as air and other gases. Saturated bodies, such as perched ground water, may exist in the unsaturated zone. Also called zone of aeration and vadose zone.

Water Budget - An evaluation of all the sources of supply and the corresponding discharges with respect to an aquifer or a drainage basin.

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LIMITATIONS OF REPORT

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) has prepared this report for the use of Hansen Bailey Pty Ltd in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposals dated 16 May 2012.

The methodology adopted and sources of information used by AGE are outlined in this report. AGE has made no independent verification of this information beyond the agreed scope of works and AGE assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to AGE was false.

This study was undertaken between 25 June 2012 and 3 December 2013 and is based on the conditions encountered and the information available at the time of preparation of the report. AGE disclaims responsibility for any changes that may occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. It may not contain sufficient information for the purposes of other parties or other users. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

This report contains information obtained by inspection, sampling, testing and other means of investigation. This information is directly relevant only to the points in the ground where they were obtained at the time of the assessment. Where borehole logs are provided they indicate the inferred ground conditions only at the specific locations tested. The precision with which conditions are indicated depends largely on the frequency and method of sampling, and the uniformity of the site, as constrained by the project budget limitations. The behaviour of groundwater is complex. Our conclusions are based upon the analytical data presented in this report and our experience.

Where conditions encountered at the site are subsequently found to differ significantly from those anticipated in this report, AGE must be notified of any such findings and be provided with an opportunity to review the recommendations of this report.

Whilst to the best of our knowledge, information contained in this report is accurate at the date of issue, subsurface conditions, including groundwater levels can change in a limited time. Therefore this document and the information contained herein should only be regarded as valid at the time of the investigation unless otherwise explicitly stated in this report.