WILPINJONG COAL PROJECT

APPENDIX B

Groundwater Impact Assessment

Australasian Groundwater & Environmental

REPORT on

WILPINJONG COAL PROJECT

GROUNDWATER IMPACT ASSESSMENT

prepared for
WILPINJONG COAL PTY LIMITED

Project Number G1245
April 2005

ABN:64 080 238 642

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1.0 INTRODUCTION

Wilpinjong Coal Pty Limited (WCPL), a wholly owned subsidiary of Excel Coal Limited, is the proponent for the development of the Wilpinjong Coal Project (the Project) located some 40 kilometres (km) north-east of Mudgee in New South Wales (NSW) (**Drawing No 1**).

The Project would involve open cut mining of coal from the Ulan Seam in six pits. The Project coal deposit is estimated to contain a total open cut reserve of approximately 251 million tonnes (Mt) and has a planned Project life of 21 years. The maximum planned mining rate is 13 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal.

This groundwater impact assessment report has been prepared as part of the Environmental Impact Statement (EIS) for the Project. The report describes the potential impact of the Project on the hydrogeological (groundwater) regime of the Project area and surrounds and provides groundwater impact mitigation options where adverse impacts may occur. The report was prepared by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) for WCPL.

The scope of this groundwater impact assessment comprises:

- assessment of the potential yield from a series of groundwater supply bores to be developed across the northern limit of the Project area;
- assessment of the potential rate of groundwater inflow to the open cut mine over the life of the Project;
- assessment of the impact of the Project on the local and regional groundwater regime, including other groundwater users;
- assessment of the potential change in the rate of groundwater discharge to local creeks;
- identification of groundwater management measures; and
- a recommended groundwater quality and quantity monitoring programme.

2.0 REGIONAL SETTINGS

2.1 Project Location

The Project is located some 40 km north-east of Mudgee in the upper Hunter Valley of NSW as shown on **Drawing No 1**. The mining lease application (MLA1) boundary for the Project is also shown on **Drawing No 1**.

The Project is located at the western edge of the Western Coalfield approximately 11 km south-east of the Ulan Coal Mines within the valleys of Wilpinjong and Cumbo Creeks. The eastern boundary of MLA1 is about 3 km west of the village of Wollar (**Drawing No 1**).

The Goulburn River National Park is to the north of the Project area and the elevated uplands of the Munghorn Gap Nature Reserve are to the south and west. The Gulgong-Sandy Hollow Railway and Ulan-Wollar Road are on the northern boundary of MLA1. Wilpinjong Creek flows between the northern boundary of MLA1 and the Goulburn River National Park (**Drawing No 1**).

2.2 Topography and Drainage

Topographically, the Project area and its immediate environs can be divided into two terrain types, *viz.*:

1. Rugged upland areas bordering the Project area. These areas consist of ridges, valleys and dissected plateau remnants rising some 100 metres (m) to 150 m above the Wilpinjong Creek valley floor. These areas have generally not been cleared and are mostly densely vegetated with scrub woodlands and dry sclerophyll forest. Most of the land north of the Project area (i.e. Goulburn River National Park) and to the south within the Munghorn Gap Nature Reserve is included in this terrain type. The vegetated ridgeline to the east of the Project area is also included in this terrain type.

2. Undulating lowland consisting of broad valleys of Wilpinjong, Moolarben, Wollar and Cumbo Creeks and their major tributaries. These valleys have been cleared for cattle and sheep grazing with only scattered trees and minor remnant forest remaining. The majority of the Project area is included in this terrain type.

The elevation of the Project area ranges between 350 m and 440 m Australian Height Datum (AHD) along the valleys floors of Wollar, Wilpinjong and Cumbo Creeks, 400 m and 600 m AHD in the upland areas of the Goulburn River National Park, and 510 m to 745 m AHD in the upland areas of the Munghorn Gap Nature Reserve. Steep gorges, incised typically between 10 m and 30 m, and occasionally up to 60 m, intersect the upland areas of the Goulburn River National Park and Munghorn Gap Nature Reserve.

The Project area lies within the catchment of the Goulburn River which flows from west to east encircling the Project area to the north at a distance of between approximately 8 km and 12 km from the MLA1 boundary (**Drawing No 1**). The Goulburn River joins the Hunter River near Denman (**Drawing No 2 – Refer to Inset**).

At a local level, the Project lies in the Wilpinjong Creek catchment and is drained by a number of local tributary watercourses of Wilpinjong Creek including Cumbo Creek, Planters Creek, Spring Creek, Narrow Creek and Bens Creek. Wilpinjong Creek flows into Wollar Creek approximately 4 km downstream of the confluence of Cumbo and Wilpinjong Creeks. Wollar Creek drains to the Goulburn River approximately 12 km to the north-east of the Project area (**Drawing No 2**).

Fresh water springs occur in the headwaters of the creeks within the Wollar Creek catchment. Springs with steady flow can be found at Cumbo Creek, Back Flat Gully and Barigan Creek (DIPNR, 2003) (**Drawing No 2**).

2.3 Climate

The climate in the Project area is typical of temperate areas and is characterised by hot dry summers featuring thunderstorms and cold winters with frequent frosts.

Based on the Bureau of Meteorology (BOM) climate monitoring data collected at Wollar Station No. 62032 (Barigan Street), between 1901 and 2004, the average annual rainfall recorded is 591 millimetres (mm) (**Table 1**), while the maximum and minimum total annual rainfall for the period is 1,205 mm (1950) and 129 mm (1922), respectively.

Table 1: Average Rainfall Data (BOM Wollar Station No. 62032)												
Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Rainfall (mm)	68.2	63.0	51.7	39.7	39.0	43.1	41.3	42.4	39.5	54.2	52.2	56.6	590.7

Source: BOM (2005)

Most rainfall occurs in summer with the highest measured monthly rainfall at 391.5 mm recorded in February 1955. The lowest rainfall occurs in winter averaging approximately 140 mm. On average the distribution of the rainfall throughout the year is relatively uniform. Further discussion on climate is provided in Appendix A.

Average annual potential evapotranspiration for the Project area is 1,728 mm (refer Appendix A of the EIS).

2.4 Land Use

The majority of the land in the valleys within and around the Project area is cleared agricultural land that has primarily been used for cattle and sheep grazing with some cropping. As discussed in Section 2.2, most of the land in the elevated uplands of Goulburn River National Park to the north and Munghorn Gap Nature Reserve to the south is densely vegetated.

3.0 PREVIOUS HYDROGEOLOGICAL STUDIES

A hydrogeological study within the Project area was undertaken in 2004 by GeoTerra Pty Ltd (GeoTerra). The study collated available groundwater data and carried out a preliminary investigation of the hydrogeological characteristics of the Project area. Test bores were drilled, pumping tests undertaken and the data interpreted to provide hydraulic parameters.

A dryland salinity investigation within the Wollar Creek catchment was conducted in 2003 by the Department of Infrastructure, Planning and Natural Resources (DIPNR). The study described the geology and hydrogeology of the Wollar Creek catchment area.

Exploration drilling for resource delineation has been conducted within and around the Project area by the Department of Primary Industries – Mineral Resources (formerly the Department of Mineral Resources) (DPI-MR) and private enterprise. These investigations, while not designed to collect hydrogeological data, described the geology of the area and the geometry of the Illawarra Coal Measures (including the Ulan Seam and Marrangaroo Sandstone). The investigations also provided some additional data and observations of the groundwater levels and locations for current and future monitoring.

A bore census was conducted by WCPL in February 2005 which involved advertising in the local area and requesting the participation of surrounding landholders. Twenty-one landholders participated, with a total of 22 bores/wells and seven springs inspected. Information obtained during the bore census included bore/well/spring locations, bore/well depth, depth to water, water quality, water usage and other anecdotal records. The results of the bore census are discussed in Section 6.0.

The above studies have been used in undertaking this assessment and are referenced at the end of this report. Groundwater monitoring is ongoing.

4.0 SCOPE AND METHODOLOGY

The scope of work and adopted methodology has been developed to satisfy the requirements of the Director-General of DIPNR (Attachment 1, Volume 1 of the EIS). The scope of work and methodology were staged as follows:

Stage 1 – Site Inspection

A site inspection was undertaken in July 2004 in order to develop an appreciation of the Project area and to hold discussions with the Project geologist and Mr Andrew Dawkins of GeoTerra. Mr Dawkins conducted the preliminary hydrogeological investigation, including pumping and slug tests at three sites within the Project area. This inspection also facilitated an opportunity to inspect relevant sections of drill core from the geological investigation being conducted by WCPL.

Stage 2 – Conceptual Groundwater Model Development and Predictive Numerical Modelling

A conceptual groundwater model of the Project area was developed based on the results of the site visit and review of available geological, hydrogeological and other relevant data. The conceptual groundwater model was used to develop a numerical groundwater model of the Project area which was constructed to allow simulation of mine dewatering and operation of the water supply borefield.

Stage 3 – Follow-up Site Inspection

A further site inspection was conducted by Gilbert and Associates Pty Ltd (specialist hydrologists for the EIS - Appendix A) and Dr Noel Merrick (Acting Director for the National Centre for Groundwater Management at the University of Technology, Sydney) to confirm model assumptions regarding the local hydrological/hydrogeological regime.

Stage 4 – Peer Review of Predictive Numerical Model

An iterative peer review process was undertaken by Dr Merrick whereby the groundwater model extent and geometry were expanded, various parameters were tested and modified and a sensitivity analysis was undertaken. Following this iterative process the groundwater model was finalised and this report prepared.

Stage 5 – Groundwater Monitoring Programme

A groundwater monitoring programme was developed to facilitate the ongoing collection of baseline data on the existing groundwater regime. The monitoring programme would continue throughout the Project life to provide a progressive measurement of the effects of the Project on the groundwater system.

5.0 HYDROGEOLOGICAL REGIME

5.1 Geology

The following description of the geology of the Project area and its surrounds is based primarily on reports produced by the DPI-MR and DIPNR, *viz.*:

- *Notes to Accompany the Western Coalfield Geology Maps* (Yoo, *et al*, 2001);
- *Wilpinjong-Moolarben Exploration Program - Stage 2* (Bayly, 1999); and
- *Greater Wollar Creek Catchment Dryland Salinity Groundwater Investigation* (DIPNR, 2003).

The geology of the Project area is shown on **Drawing No 3**, which was reproduced from the 1:100,000 scale geological map of the Western Coalfield Regional Geology (Northern Part), published by the Geological Survey of NSW (DMR, 1998). Geological cross sections through the Project area are shown on **Drawings No 4 and 5**.

5.1.1 Stratigraphy

The Project area is located on the western edge of the Sydney Basin which is a part of an elongated basin complex called the Sydney-Gunnedah Basin.

The stratigraphy of the Project locality is summarised in **Table 2** and is shown on **Figure 1**.

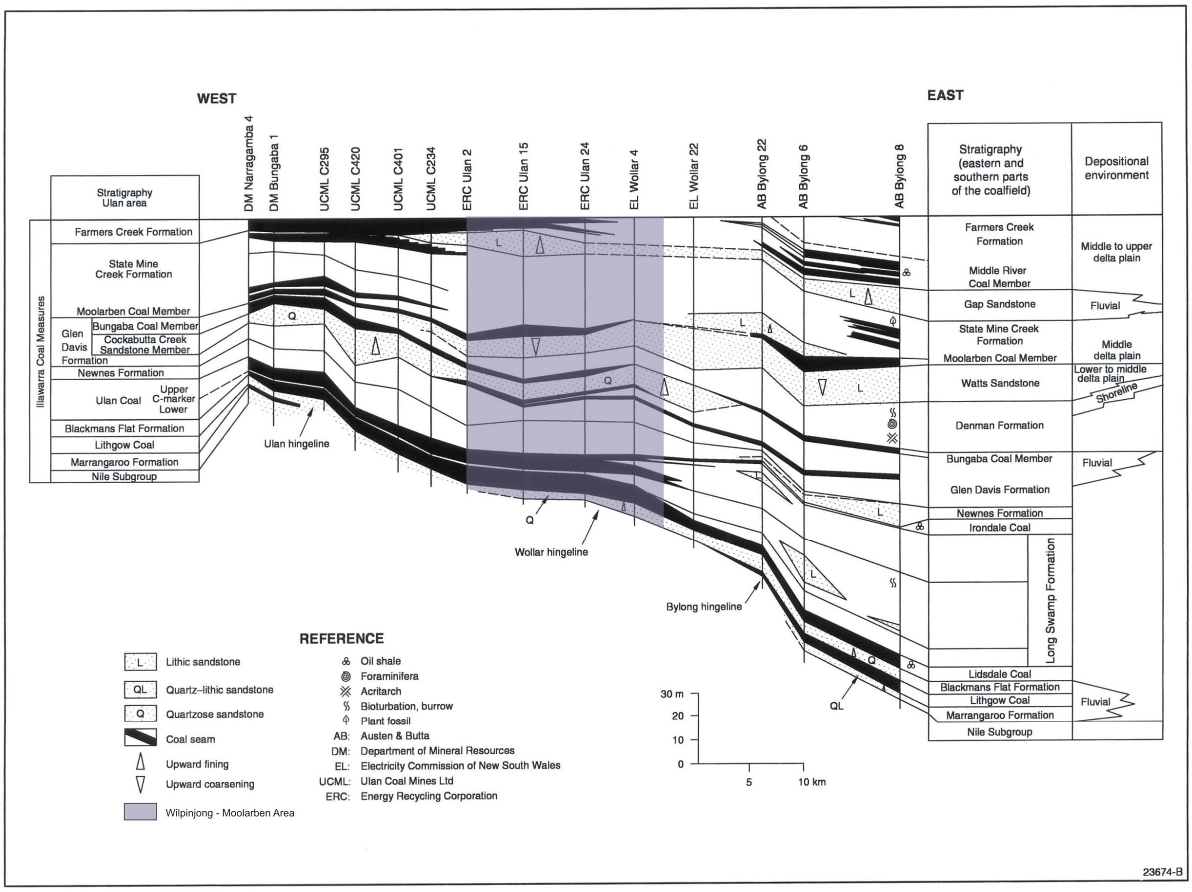

Figure 1 Stratigraphy and Coal Correlations (Yoo *et al*, 2001)

Table 2: Stratigraphy of the Project Locality

Age	Group	Formation	Rock Types	Occurrence
Quaternary	-	Alluvium	Sand, silt, clay and gravel	Lower sections of Wilpinjong and Cumbo Creeks within the Project area.
Tertiary	Extrusion and Intrusion	-	Basalt	Small area east of Cumbo Creek within the Project area. Small areas north of Wollar, in the Munghorn Gap Nature Reserve and Goulburn River National Park.
Triassic	Intrusion	Wollar Sill	Syenite	Outside of the Project area. Small areas north of Wollar and in the Goulburn River National Park.
	Narrabeen Group	Siltstone/Sandstone Quartzose Sandstone Lithic Sandstone Conglomerate	Quartz sandstone, red-brown and green mudstone and lenses of quartz conglomerate	Upland areas of the Goulburn River National Park and Munghorn Gap Nature Reserve.
Late Permian	Illawarra Coal Measures	Farmers Creek Formation State Mine Creek Formation Moolarben Coal Member Watts Sandstone Denman Formation Glen Davis Formation Bungaba Coal Member Cockabutta Creek Sandstone Member Newness Formation Ulan Coal (Ulan Seam) Blackmans Flat Formation Lithgow Coal Marrangaroo Formation (Sandstone) Nile Subgroup	Quartz lithic sandstone, mudstone, claystone, coal, torbanite, rhyolitic tuff, some lenses of polymictic conglomerate	Underlying the whole area. Variably outcropping across the Project area.
	Shoalhaven Group		Polymictic conglomerate, lithic sandstone and shale, siltstone, claystone, minor carbonate and evaporite	Subcrops south of the Project area and south of Wollar.
Early Permian	Rylstone Volcanics		Rhyolitic to dacitic pyroclastic rocks, tuffaceous sandstone, tuff, lavas	Small subcrop south of the Project area on Cumbo Creek.

Modified from: Yoo *et al*. (2001) and Department of Infrastructure, Planning and Natural Resources (November 2003).

5.1.2 Lithology

Rylstone Volcanics

The Rylstone Volcanics are the oldest geological strata within the Project locality. The Rylstone Volcanics overlie, with a distinct angular unconformity, a variety of units including Early Ordovician to Carboniferous rocks. The Rylstone Volcanics are overlain with low angular unconformity, by basal conglomerates and sandstones of the Permian Shoalhaven Group.

A small outcrop occurs along the drainage line of Cumbo Creek upstream of the Project area (**Drawing No 3**). The Rylstone Volcanics that occur in Cumbo Creek consist of rhyolitic to dacitic pyroclastic rocks including tuffaceous sandstone, tuff and lavas.

Shoalhaven Group

The Shoalhaven Group overlies Ordovician to Devonian metamorphosed sedimentary and volcanic rocks, Carboniferous granites and the Early Permian Rylstone Volcanics. The dominant lithologies are conglomerate, pebbly sandstone, and sandstone.

The Shoalhaven Group occupies the lower slopes and depressions of the drainage lines of Cumbo Creek to the south of the Project area and also on Wollar and Barigan Creeks south of the village of Wollar (**Drawing No 3**).

Illawarra Coal Measures

The Illawarra Coal Measures occupy the midslopes of the gently undulating landforms that border the drainage lines in the Project area. The measures tend to subcrop in parts of the south of the Project area. The dominant lithologies include mudstone, laminated siltstone, medium grained quartz-lithic sandstone, lenses of polymictic conglomerate, coal, carbonaceous mudstone, rhyolitic tuff and sporadic torbanite. The Illawarra Coal Measures contain the Ulan Seam to be mined by the Project. Beneath the Ulan Seam is a distinct sandstone unit called the Marrangaroo Sandstone.

Narrabeen Group

The Narrabeen Group overlies the Illawarra Coal Measures. The Narrabeen Group form cliffs, ridges and hilltops of mesa-like plateaus and pagodas and are thickest to the north of the Project area. The typical lithologies include pebbly to medium grained quartz sandstone, red-brown and green mudstone and lenses of quartz conglomerate.

The Narrabeen Group is exposed to the north and south of the Project area in the rugged upland areas of Goulburn River National Park and Munghorn Gap Nature Reserve, respectively (**Drawing No 3**).

Mesozoic Igneous Rocks

The major exposures of the Mesozoic igneous rocks in the vicinity of the Project area include the laccolith north of Wollar village and a small laccolith within the Goulburn River National Park north of Cumbo Creek (**Drawing No 3**). Their outcrops are commonly circular to elliptical, but may also form irregular shapes that later develop into rounded hills and flat topped plateaus.

Tertiary Basalts

The tertiary basalts are part of an extensive lava field, which extends from northern Queensland to Victoria. The basalts unconformably overlie and intrude all pre-Cretaceous rocks. Sills and plugs have caused contact metamorphism in the country rocks and erosion has reduced these rocks into peneplains, plateaus and valley fills.

Only small outcrops of basaltic intrusions are present in the vicinity of the Project area. The tertiary basalts are thickest to the north of the village of Wollar (**Drawing No 3**).

Quaternary Alluvium

Quaternary alluvium is found along perennial and intermittent watercourses and forms a dendritic or sinuous pattern on the ground. Quaternary alluvium conformably overlies the Cainozoic unconsolidated sediments and it unconformably overlies bedrock, saprolites or transported regoliths. The lithology generally consists of silt and clay with variable humic content. The sand content varies according to the source area and sporadic gravel deposits are also present.

Quaternary alluvium is present in the north of the Project area associated with Wilpinjong Creek and lower sections of Cumbo Creek (**Drawing No 3**). Shallow localised alluvial sediments also occur in Spring, Planters, Bens and Narrow Creeks which drain to Wilpinjong Creek (GeoTerra, 2004). Colluvium is present below escarpment areas, particularly in the north of the Project area between Wilpinjong Creek and the Goulburn River National Park.

5.1.3 Structure

The Illawarra Coal Measures together with overlying Narrabeen Group are generally gently dipping at about 1° to 2° to the north-northeast. In topographically depressed areas within Cumbo Creek and other valleys, the Illawarra Coal Measures are partially eroded and the Ulan Seam subcrops beneath Quaternary deposits.

No major faulting is indicated from available data. Faults of seam height may be present, although they are not predictable based on the current borehole spacing. Minor faults with small throws are expected.

Some areas along Cumbo Creek (south of the Project area) and Wollar Creek (south of Wollar), are incised below the base of the Illawarra Coal Measures and underlying deposits of the Shoalhaven Group and Nile Subgroup are exposed (**Drawing No 3**).

5.2 Aquifer Systems

Based on GeoTerra (2004), DIPNR (2003) and the review of borehole geological data, five aquifer[1] systems have been recognised, *viz.*:

- alluvial and colluvial deposits;
- sandstones and siltstones of the Narrabeen Group;
- Illawarra Coal Measures overlying the Ulan Seam;
- Ulan Seam; and
- Marrangaroo Sandstone.

The alluvial deposits are typically shallow and in the order of 5 m thick (GeoTerra, 2004). Most of the alluvium, particularly the basal component, contains a significant proportion of clay. The standing water level in the Wilpinjong Creek alluvium is about 3 m below ground level and in topographically elevated areas above the standing groundwater table, the alluvium is often unsaturated, except following significant rainfall.

The siltstones and sandstones of the Narrabeen Group form elevated, mesa-like and deeply incised plateaus to the north and south of the Project area. This group is likely to be moderately permeable, but due to its high elevation above the surrounding valleys is not considered to be an aquifer capable of supplying useable supplies of groundwater.

The Illawarra Coal Measures overlying the Ulan Seam are predominantly fine grained deposits however sections with over 50% sandstone are present at various locations. Standing water levels vary between 0.01 m and 7.45 m below surface (GeoTerra, 2004) whilst hydraulic conductivities range between 0.009 m/day and 0.047 m/day (GeoTerra, 2004).

[1] An aquifer is defined as a rock or sediment in a formation, which is saturated and sufficiently permeable to transmit and yield water in useable quantities.

Generally the upper sections of the Illawarra Coal Measures, above the Ulan Seam, are low yielding and are not a prospective source for groundwater supplies, however, occasional minor seepages from these units can be expected during pit excavations.

The Ulan Seam and the Marrangaroo Sandstone are the main aquifers in the Project area. Standing water levels in the Ulan Seam, within the Project area, range from 2.73 m above ground to 9.9 m below ground, with artesian levels in the north and sub-artesian levels in the topographically elevated areas to the south. Analysis of the groundwater levels indicates that along parts of the southern extent of the Project area the Ulan Seam may be dry due to its elevation being above regional groundwater levels.

The Marrangaroo Sandstone aquifer is typically separated from the overlying Ulan Seam by a relatively thin siltstone layer, but in some areas both aquifers are in direct contact. Standing water levels in the Marrangaroo Sandstone range from 0.98 m above ground to 10.46 m below ground level. Similar to the water levels in the Ulan Seam, artesian levels were identified in the north, and sub-artesian levels in the southern, topographically higher, areas. In general, groundwater levels in the Marrangaroo Sandstone appear to be at slightly higher elevations (0.05 m to 0.7 m) than those in the Ulan Seam. Pumping test results reported by GeoTerra (2004) indicate that at the test locations both aquifers are hydraulically connected.

5.2.1 Yield

Two 24-hour pumping tests were undertaken by GeoTerra (2004), in bores EW4002 and EW4003 (**Drawing No 6**). Both bores are located in the north of the Project area, just south of Wilpinjong Creek. Bore EW4002 was located at the northern limits of Pit 1 and bore EW4003 at the northern section of Pit 4, near Cumbo Creek. Bore EW4003 was screened in the Ulan Seam and was pumped at the rate of 2 L/sec. Bore EW4002 was screened in the Ulan Seam and Marrangaroo Sandstone and was pumped at a rate of 3 L/sec.

There are a number of artesian bores in the Project area, all of which are located in the vicinity of Wilpinjong Creek. Artesian bores are bores where the standing groundwater level in the bores is above the level of the ground surface. Sub-artesian bores are bores where the groundwater rises above the top of the aquifer but does not discharge to the surface. A summary of recorded flows from these bores is presented in **Table 3**.

5.2.2 Hydraulic Parameters

Various hydraulic tests including pump out and slug tests were undertaken within the Project area by GeoTerra (2004) to determine hydraulic parameters of the aquifers. A summary of the hydraulic parameters obtained from these tests is provided in **Table 4**.

Analysis of the hydraulic tests indicates similar hydraulic conductivity in the Ulan Seam and underlying Marrangaroo Sandstone.

Table 3: Artesian Flows				
Bore	**Formation**	**Depth (m)**	**SWL (magl)[1]**	**Flow Rate (L/sec)**
ERUL27	Overburden/Ulan Seam/ Marrangaroo Sandstone	45.1	0.28	< 0.25
EW1005	Overburden/Ulan Seam/ Marrangaroo Sandstone	48.9	0.98	Approx. 1
EW1021	Overburden/Ulan Seam	18.4	0.32	< 0.25
EW1020	Overburden/Ulan Seam	27.4	2.06	2
EW5001	Overburden/Ulan Seam/ Marrangaroo Sandstone	28	0.22	< 0.5
EW 2012	Overburden/Ulan Seam	22.5	0.15	< 0.5
EW1001	Overburden/Ulan Seam/ Marrangaroo Sandstone	79.4	2.73	3

Source: GeoTerra (2004)
[1] magl – metres above ground level.

Table 4: Summary of the Hydraulic Parameters of the Illawarra Coal Measures, Ulan Seam and Marrangaroo Sandstone						
Bore	**Seam/Strata**	**Depth (mbgl)[1]**	**Transmissivity T (m^2/day)**	**Hydraulic Conductivity k (m/day)**	**Storativity S (-)**	**Test Method**
EW 2012	Ulan Seam	6.5-22.1	27.9	1.8	8.1×10^{-4}	24hr pump out test at constant rate – 3L/sec
EW 5001	Marrangaroo Sandstone	23.5-28	27.9	6.2	1.3×10^{-3}	24hr pump out test at constant rate – 3L/sec
EW 2014	Ulan Seam	23-36.1	150/79*	11.5/6.0*	0.23/ 3.2×10^{-3}*	24hr pump out test at constant rate - 2L/sec
EW 2006	Coal and siltstone - Illawarra Coal Measures	0-7.9		0.01		Slug Test
EW 2011	Sandstone/siltstone/coal-Illawarra Coal Measures	0-11.7		0.05		Slug Test
EW 2013	Sandstone/siltstone/coal-Illawarra Coal Measures	0-15.2		0.09		Slug Test
EW 5052	Ulan Seam	6-12		0.01		Slug Test
EW 1005	Marrangaroo Sandstone	43-46		0.01		Slug Test
EW 5032	Marrangaroo Sandstone	18-19.7		0.01		Slug Test
EW 5049	Marrangaroo Sandstone	13-14		0.02		Slug Test
EW 5053	Marrangaroo Sandstone	10.5-13.5		0.01		Slug Test

Source: GeoTerra (2004)
[1] mbgl – metres below ground level.
* Parameters determined during drawdown/recovery.

5.2.3 Groundwater Levels

At the time of the GeoTerra groundwater investigation in 2004, the depth to groundwater levels in the Ulan Seam/Marrangaroo Sandstone aquifers varied between 10.5 m below ground level (EW5032) and 2.7 m above ground level (EW1001). All artesian groundwater levels (i.e. levels recorded above ground elevation) were recorded along Wilpinjong Creek. The groundwater contours shown on **Drawing No 6** were drawn using water level data collected during the 2004 groundwater investigation supplemented by water level data from three DIPNR registered bores, in which water levels were recorded between 1999 and 2001. The groundwater gradient in the Ulan Seam/Marrangaroo Sandstone aquifers of about 0.006 m/m to 0.01 m/m is from west and south-west to north-northeast, as shown on **Drawing No 6**.

Fluctuations in the groundwater table result from temporal changes in rainfall recharge to the aquifers. Typically, changes in the groundwater elevation reflect the deviation between the long term monthly (or yearly) average, and the actual rainfall, usually described as the Residual Mass Curve (RMC). Normally the groundwater levels are expected to reflect the RMC curve. That is, the groundwater levels recorded during periods of rising RMC are also expected to rise while those recorded during periods of declining RMC are expected to decline. A plot of monthly excess/deficit rainfall and RMC is shown in **Figure 2**.

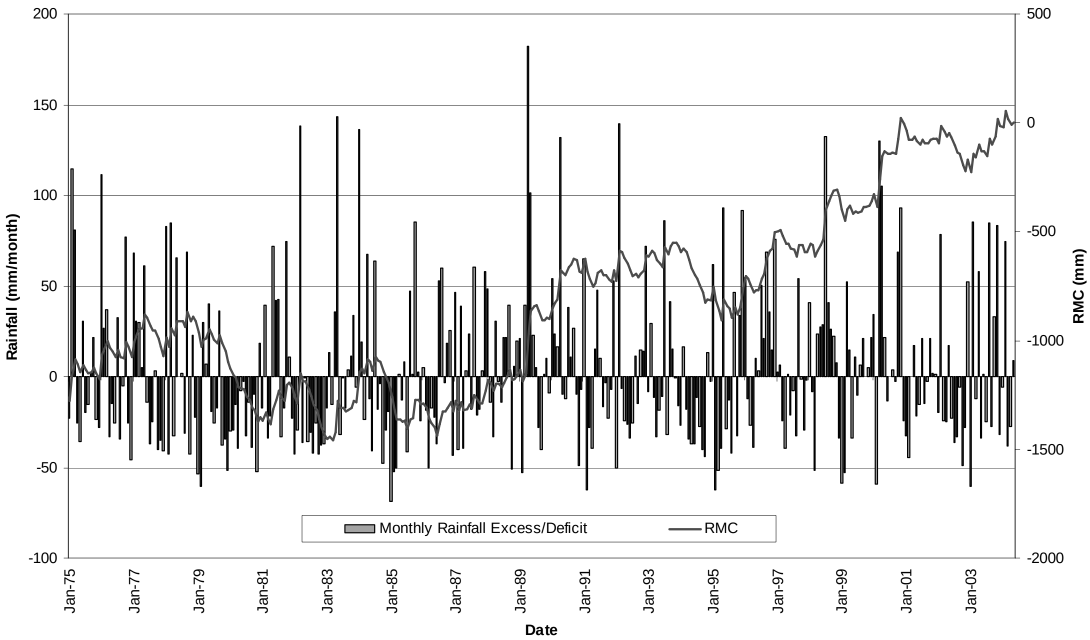

Figure 2: Monthly Rainfall Excess/Deficit

Figure 2 shows the RMC curve essentially stabilising between years 2000 and 2004, that is, at the time when groundwater levels were recorded in the Project area. This indicates that the recorded levels can be considered to represent steady state conditions for that period of time.

5.2.4 Recharge, Discharge and Surface Water Flows

Recharge (i.e. addition of water to aquifer storage from the surface by infiltration) is a function of a number of factors of which the most important are topography, rainfall rate and intensity, hydraulic conductivity of the surficial deposits, antecedent soil moisture conditions and vegetative cover. Recharge occurs across the Project area and surrounds to all aquifers outcropping and sub-cropping to the surface albeit at different rates. The rate of recharge over the alluvial and colluvial deposits and the subcrops of the Ulan Seam are likely to be higher than over the subcrops/outcrops of the Illawarra Coal Measures. The recharge over the upland areas is likely to be relatively high due to the coarse nature of the sandstones of the Narrabeen Group. The exceptions are the incised creek beds and the Goulburn River which are the main groundwater drainage zones in the region.

Discharge from the aquifers occurs to the Goulburn River and Wilpinjong, Cumbo and Wollar Creeks which are the major drainage zones in the region. Gilbert and Associates Pty Ltd (Appendix A of the EIS) have undertaken an analysis of available flow data from Wollar Creek and the Goulburn River. **Table 5** presents a summary of the relevant statistics.

Table 5: Goulburn River and Wollar Creek Flow Statistics

Station Number	Station Name	Catchment Area (km^2)	Mean Daily Flow (ML/day)	Period of Record
210082	Wollar Creek upstream of confluence with Wilpinjong Creek	258	10.6	1/5/1969 – 10/9/1997
210046	Goulburn River at Ulan	159	13.2	9/3/1956 – 31/8/1982
210006	Goulburn River at Coggan	3,340	192.2	18/10/1991 - current

After: Gilbert & Associates Pty Ltd (2005)

There are no records of flow in Wilpinjong and Cumbo Creeks. However, Gilbert and Associates Pty Ltd (Appendix A of the EIS) has developed a catchment model for Wilpinjong Creek, calibrated against the data obtained from gauging stations on Wollar Creek and the Goulburn River.

As described by Gilbert and Associates Pty Ltd (Appendix A of the EIS), the streamflow passing any point on a creek predominantly comprises drainage of water from the upstream catchment which originated as rainfall, but may also include flow derived from discharge from aquifers which extend beyond surface catchment boundaries. Streamflow can be considered as the combination of different components representing different pathways of water movement through the catchment. The dominant components are usually:

(i) *Overland flow* (or surface runoff) which is water that drains directly from the catchment surface as sheet and channel flow. Overland flow occurs during and for short periods after rainfall, as water flowing over the surface of the catchment drains off. It moves across the catchment quickly and is seen flowing in small drainage lines soon after the onset of rainfall. It can be identified on a flow hydrograph as a rapid increase in flow following the onset of rain. The point at which surface runoff ceases is less easily identified on a hydrograph but can sometimes be seen as an inflection point in the recession curve. For short duration rainfall events, overland flow tends to be generated from catchment surfaces that have low permeability or that are saturated or nearly saturated prior to the onset of rainfall and that are in close proximity to drainage lines. During longer events, larger proportions of the catchment contribute to overland flow.

(ii) *Baseflow* is water that discharges from subsurface storage into a stream. This subsurface storage may comprise interflow/underflow (see below) as well as deeper groundwater aquifer systems. Baseflow is the mechanism responsible for the low flow persistence observed during periods of low or no rainfall. Baseflow is predominantly derived from subsurface water storage with a pressure head above the streambed level. It varies over time, increasing during and after rainfall events due to recharge of the subsurface storage and persisting for relatively long periods after rainfall events as this subsurface storage discharges into the creek. It declines slowly during dry periods as the storage is depleted. Baseflow recession tends to follow an exponential decay curve.

(iii) *Interflow/Underflow* is water that infiltrates and moves rapidly through the soil mantle and other permeable strata near or beneath the stream (ie. bank flow or underflow), reappearing during and for moderate periods after a rainfall event. Interflow is often sourced from areas of temporary perched groundwater systems which form in the near surface profile near the stream channels. Interflow/underflow can be distinguished conceptually from baseflow derived from deeper groundwater storage by the fact that it moves more rapidly and because it is derived from shallow, relatively fast flowing groundwater in direct connection with the creek and its banks. There is however often no clear distinction between the components of baseflow evident in streamflow hydrographs, rather a transition from interflow/underflow as drainage from the storage of water held in the stream banks recedes and drainage from deeper groundwater system is left as the sole contributor to flow. Interflow/underflow is considered to be a component of baseflow in most catchment modelling studies.

Under pre-mine conditions, the long term average baseflow in Wilpinjong Creek has been estimated by catchment modelling to average 2,500 m^3/day (Appendix A of the EIS). Section 11.0 of this report provides a separate and supportive estimate of long term average baseflow derived from groundwater modelling. As explained in Appendix A, interflow/underflow would be expected to be the dominant contributor to the long term average baseflow, particularly following rainfall events.

5.2.5 Groundwater and Surface Water Quality

Groundwater quality in the Project area varies from fresh to brackish. Typically, the quality of water declines with the depth and age of the strata in which the groundwater occurs. The better quality groundwater is likely to be encountered in the alluvial deposits. The quality of groundwater in the Ulan Seam is reasonable with groundwater electrical conductivity (EC) varying between 1,020 µS/cm (ERUL27) and 3,390 µS/cm (DMCM12), as shown in **Table 6**.

Table 6: Groundwater Quality – Exploration Bores (June/July 2004)

Bore	Easting (m)	Northing (m)	Aquifer	pH	EC (µS/cm)	TDS (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	Cl (mg/L)	Fe (mg/L)	Mn (mg/L)	Zn (mg/L)
ERUL27	768820	6421125	Ulan Seam	8.0	1020	665	39.1	30	177.9	10.2	463.7	139.8	40.1	-	-	-
ERUL59	769774	6421126	Ulan Seam	7.5	1550	1021	43.9	27.5	307.6	15.6	781	32.2	209.9	-	-	-
ERUL67	770747	6419708	Ulan Seam	7.4	2330	1516	72.5	85.3	350.1	27	449.7	419.8	340	-	-	-
ERUL72	771904	6419933	Ulan Seam	6.6	1380	897	28.6	56.5	219.8	15.6	295.3	249.8	181.9	-	-	-
ERUL77	772903	6420064	Ulan Seam	7.6	2630	1712	53.3	35.5	560	23.1	1246.6	264.6	162	-	-	-
DMCM12	773650	6420091	Ulan Seam	6.6	3390	2200	100	70	565	31	825	685	330	0.2	<0.2	0.035

Source: Geoterra (2004)

The highest groundwater EC recorded in the Illawarra Coal Measures (below the Ulan Seam) in the Project area was measured at 4,200 µS/cm in bore GW080405, as shown in **Table 7**.

Table 7: Groundwater Quality – DIPNR Registered Bores

Borehole RN	Easting (m)	Northing (m)	Depth (m)		Formation	Standing Water Level (mbgl)[1]	Yield (L/sec)	Salinity
			from	to				
GW011258	777037	6414094	7.3	7.4	Nile Subgroup	6.4	0.252	Brackish
GW013368	761064	6413399	-	-	Illawarra Coal Measures (below Ulan Seam)	-	2.399	Brackish
GW034640	765059	6422109	15.2	18.2	Illawarra Coal Measures	-	0.53	Slightly Brackish
			21	22.2		-	0.663	Slightly Brackish
			48.7	51.7		-	2.273	Slightly Brackish
			53.3	54.8		-	1.515	Slightly Brackish
			57.9	60.9		7	2.09	Slightly Brackish
GW051150	778750	6416130	20.6	21.2	Illawarra Coal Measures	7.3	2.25	Fresh
GW051252	777355	6415774	31.1	31.4	Illawarra Coal Measures	6.1	0.25	Fresh
GW051430	769410	6417510	10.1	10.7	Illawarra Coal Measures	7.4	0.375	Brackish
			42.1	42.4		7.4	0.75	Brackish
GW052223	767660	6421210	36.6	37.8	Illawarra Coal Measures	4.6	0.63	Fresh
			46.6	47.8		4.6	0.5	Fresh
GW052937	777610	6416668	36.6	36.9	Illawarra Coal Measures	7.6	0.23	Fresh
GW053859	769590	6419785	19.2	23.8	Illawarra Coal Measures	1.2	0.88	Fresh
GW065948	760750	6428725	45	46.5	Illawarra Coal Measures	-	0.5	Fresh
			92	94		-	3.75	Fresh
GW065949	760740	6427000	7	8	Illawarra Coal Measures		0.25	Fresh
			11	13			1.3	Fresh
GW066420	779320	6416330	12	13	Illawarra Coal Measures	9	0.23	Fresh
GW078373	760668	6429449	3	5	Illawarra Coal Measures	-	-	-
GW080401	772895	6415995	2.5	4	Nile Subgroup	2.63	-	3700µS/cm
GW080403	772752	6416278	1.8	2	Nile Subgroup	1.35	-	3600µS/cm
GW080404	772334	6417282	2.5	3	Cumbo Creek Alluvium	1.58	-	2100µS/cm
GW080405	770593	6417807	2.3	3	Illawarra Coal Measures (below Ulan Seam)	2.48	-	4200µS/cm
GW080408	769551	6420978	3	4	Alluvium (Wilpinjong Creek)	0.61	-	2600µS/cm
GW080410	769811	6420808	3	4.5	Alluvium (Wilpinjong Creek)	2.6	-	1000µS/cm
GW080411	770522	6419618	3	3.5	Illawarra Coal Measures	2.62	-	3400µS/cm
GW080413	778096	6417643	5	7	Mesozoic Laccolith Intrusion	5.6	-	1300µS/cm

Source: GeoTerra (2004)
[1] mbgl – metres below ground level.

The groundwater in the underlying Nile Subgroup is of poorer quality with EC measurements of 3,600 and 3,700 µS/cm (GW080401 and GW080403), **Table 7.** Surface water samples taken from a Nile Subgroup discharge area registered EC values of 11,000 and 12,000 µS/cm (Appendix A of the EIS). The difference in EC between the groundwater in the Nile Subgroup and the overlying formations indicates hydraulic separation of the Nile Subgroup.

6.0 EXISTING GROUNDWATER USERS

A search of the DIPNR database was undertaken to identify registered bores and wells in the Project locality. The records indicate that there are 68 registered bores and wells within a 10 km radius of the Project area as shown on **Drawing No 3**.

Details of the registered bores are presented in **Attachment 1.** Of the 68 registered bores and wells there are 13 bores and 12 wells used for extraction of groundwater, 18 bores and 2 wells with unknown status, 3 abandoned bores, one collapsed bore and one test bore. The bores are installed in the Illawarra Coal Measures (37 bores), Nile Subgroup (7 bores), Wilpinjong Creek alluvium (5 bores), Cumbo Creek alluvium (one bore), and in a volcanic intrusion north of Wollar village (3 bores). Wells are installed in Wollar Creek and Cumbo Creek alluvium (6 wells each), Murragamba Creek alluvium (one well), and in the Illawarra Coal Measures (one well).

In addition to the above, a bore census was conducted by WCPL in February 2005. The census identified 10 bores (of which four were DIPNR registered), 12 wells (of which five were DIPNR registered) and seven springs. The locations of all known bores, wells and springs are shown on **Drawing No 3**.

7.0 MINE DEVELOPMENT

The Project would involve mining the Ulan Seam in 70 m wide strips in six (6) delineated pits. Mining in up to three pits at any one time and in different directions is planned in order to maintain the quality of the product coal.

Mining would commence in a box-cut in Pit 1 in Year 1 before transferring to the northern limit of Pit 1 and advancing south. Mining in Pit 2 would commence in Year 3 and progress from north to south. The corridor for the Cumbo Creek diversion would be excavated in Year 8 prior to mining in Pits 3 and 4. Mining in Pits 5 and 6 would commence in Years 13 and 14, respectively and progress from north to south. A description of the mining method and sequence is provided in Section 2 of Volume 1 of the EIS. The Project planned mining sequence is also shown on **Drawing No 7**. Mining in southerly and northerly directions would proceed up-dip and down-dip, respectively (Section 5.1.3).

Mine waste rock would be placed behind the advancing open cut in the mined out strips. The conceptual final landform would approximate the pre-mining topography.

During the 21 year planned Project life, completed open cut voids at the northern and southern limits of Pits 1 and 2 and the northern limit of Pit 4 would be progressively filled with tailings (i.e. fine rejects and slimes) from the CHPP. At the completion of mining, final voids would remain at the northern and southern limit of Pits 3 and 6, respectively. Further discussion on the long term characteristics and function of the final voids is provided in Section 12.4 of this report and the surface water assessment (Appendix A of the EIS).

8.0 PROJECT BOREFIELD

The Project includes the development of a series of water supply bores across the northern extent of the Project area. Project water supply requirements and prioritised utilisation of water resources are described in the surface water assessment (Appendix A of the EIS).

Projected demand for groundwater from the borefield was estimated by Gilbert and Associates Pty Ltd (Appendix A of the EIS) based on life of Project water balance modelling. Results of the modelling indicate borefield demand would increase in the early years as production increases, but would reduce later as predicted pit inflows increase. It is anticipated that there would be no requirement for borefield extraction in the latter part of the Project life.

Production bores would extract groundwater from the two main aquifers in the Project area (i.e. Ulan Seam and the Marrangaroo Sandstone). Proposed water supply bores have been positioned at a location where the depth of the aquifers is greatest allowing extraction rates to be maximised (**Drawing No 7**).

Based on the results of field investigations to date, it is expected that individual production bores would be capable of producing between 1 L/sec and 3 L/sec on a long term basis, depending on local hydraulic conditions and the depth of the aquifers. With yields in this range, it is envisaged that up to 19 production bores would be required.

Final bore locations would be determined following the completion of further detailed groundwater testwork. As a result, the final installed bore locations may vary from those proposed on **Drawing No 7**.

9.0 CONCEPTUAL GROUNDWATER MODEL

Based on the review of existing data, a conceptual model of the hydrogeological regime has been developed. This section of the report discusses the conceptualisation and the data used to develop the model.

The conceptual groundwater model of the Project area, illustrated in **Figure 3**, was developed based on geological and topographical maps of the Project area, geological information from about 300 coal exploration bores drilled across the Wilpinjong and Moolarben exploration areas, hydrogeological reports presented by GeoTerra (2004) and DIPNR (2003) and relevant data from the DIPNR groundwater database.

In addition it contains some elements of linkage to the stream baseflow mechanism described above and in Appendix A of the EIS (i.e. alluvium/colluvium and deeper groundwater drainage components).

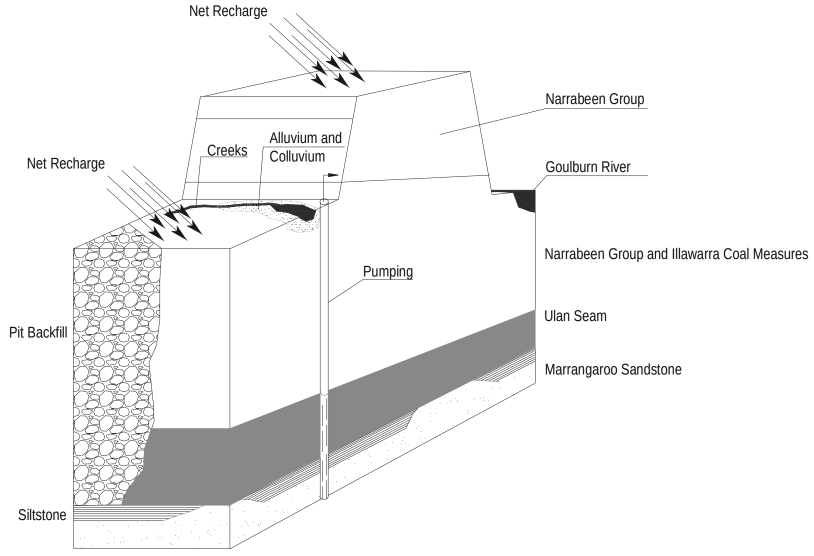

Figure 3: Conceptual Model

The conceptual model of the region encompasses the area between the Goulburn River, which flows from west to east encircling the Project area to the north at a distance of between approximately 8 km and 12 km from the MLA1 boundary (**Drawing No 8**), and outcrops/subcrops of the Ulan Seam and Marrangaroo Sandstone to the south-west, south and south-east. The areas of significant thinning of the Ulan Seam to the south of the Project area are also considered to be limits of the conceptual groundwater model.

Two alluvial deposits are present within the model. One area is associated with Wilpinjong and Cumbo Creeks in the Project area and another, some 4 km to the south-west of the Project area, with Moolarben Creek. Colluvial deposits are also present within the model between Wilpinjong Creek and the Goulburn River National Park.

Neither the Illawarra Coal Measures nor the sandstones of the Narrabeen Group are considered to be significant aquifers. The Illawarra Coal Measures contain a large proportion of mudstones and siltstones and typically have very low intrinsic hydraulic conductivity. The sandstones of the Narrabeen Group are elevated high above the valley floors with discharge occurring as lateral drainage to the valleys below and as limited seepage to deeper aquifers.

The two main aquifers in the Project area are associated with the Ulan Seam and Marrangaroo Sandstone. Both aquifers are usually separated by a relatively thin siltstone layer but are in direct contact in some locations.

Based on the above, from a conceptual groundwater model perspective, the groundwater system in the Project area is considered to consist of five aquifer systems, *viz.*:

- elevated sandstones of the Narrabeen Group;
- alluvium/colluvium along Wilpinjong Creek and alluvium along Cumbo Creek;
- overburden, encompassing Illawarra Coal Measures and lower sections of the Narrabeen Group;
- Ulan Seam; and
- Marrangaroo Sandstone.

Recharge to the aquifers is assumed to occur over the entire model area. The rate of recharge over the alluvial and colluvial deposits and areas of subcrop of the Ulan Seam is considered to be higher than over areas of outcrop/subcrop of the Illawarra Coal Measures. Recharge over the upland areas is likely to be relatively high due to the coarse grained nature of the Narrabeen Group deposits.

Layering, particularly of the Illawarra Coal Measures but also within the Narrabeen Group with mudstones and siltstones, reduces the vertical hydraulic conductivity of the aquifers and restricts the vertical movement of groundwater. Thin layers of mudstone and siltstone in the Narrabeen Group are likely to restrict the vertical movement of groundwater to such a degree that perched, or semi-perched aquifers are developed within the Group.

In sections of aquifers where groundwater levels approach the ground surface or where there are artesian groundwater levels, such as along the central reach of the Wilpinjong Creek, groundwater would be removed from the aquifer as a discharge to creeks or by evapotranspiration to the atmosphere.

10.0 NUMERICAL GROUNDWATER MODEL

The United States Geological Survey three-dimensional, finite-difference, modular, groundwater flow model MODFLOW (McDonald and Harbaugh, 1988), in conjunction with the PMWIN (Chiang and Kinzelbach, 1996), pre- and post processing package, was used to simulate the impact of open cut mining and operation of the borefield on the groundwater regime. The MODFLOW code is the most widely used code for groundwater modelling and is presently considered an industry standard.

10.1 Model Geometry

The model domain is discretised into 142,085 cells arranged into five layers comprising 157 rows and 181 columns. The dimensions of the model cells vary from 70 m by 70 m within the Project area to 500 m by 1050 m at the extremities of the model, as shown on **Drawing No 8**. The model extent is approximately 27 km from west to east and 26.5 km from south to north, covering an area of approximately 450 km^2.

The model grid (**Drawing No 8**) was rotated clockwise by 40° in order to align it with the geometry of the aquifer and the model boundaries.

The uppermost model layer (Layer 1), represents the sandstones of the Narrabeen Group, the underlying Layer 2 represents the sandstones of the Narrabeen Group except along Wilpinjong Creek where Layer 2 represents an area of alluvium/colluvium connected to the creek (Section 9.0), and the middle layer (Layer 3) represents a mixture of the Narrabeen Group and the Illawarra Coal Measures. The two lowest layers (Layers 4 and 5) represent the Ulan Seam and the underlying Marrangaroo Sandstone, respectively.

The base of Layer 1 was set 180 m above the top of the Ulan Seam. The base of Layer 2 was set 100 m above the top of the Ulan Seam except in the area of the Wilpinjong Creek alluvium and colluvium where it was set 5 m below the ground surface elevation. The top and base of Layer 4 were set to coincide with the top and base of the Ulan Seam and the thickness of the lowermost layer (Layer 5) was set to correspond with the interpolated thickness of the Marrangaroo Sandstone.

10.2 Model Boundary Conditions

In agreement with the conceptual model, the numerical groundwater model is surrounded by "no flow" boundaries to the south, south-west and south-east (**Drawing No 8**). In these areas both the Ulan Seam and the Marrangaroo Sandstone either subcrop, abut granite intrusions, or are believed to thin to less than 2 m thickness (**Drawing No 3**). "No flow" boundaries do not permit exchange of water across the model boundaries.

To the north, north-west and north-east the model domain is surrounded by "River" boundaries along the Goulburn River bed. "River" boundaries allow for losing or gaining stream/river reaches to be modelled depending on the prevailing hydraulic head in the model cell relative to the stream/river stage. The "River" boundaries can remove groundwater from the model domain as long as the simulated elevation of the groundwater in the cells surrounding the river is above the river bed. The elevation of the river bed in the "River" cells was set to coincide with the surface elevation, as determined from available topographic maps of the region.

"River" boundaries were also specified inside the model domain along major creeks, that is, Wilpinjong, Wollar and Cumbo Creeks (**Drawing No 8**). In the model, all "River" boundaries were set to remove groundwater from the model domain only and not to introduce an external groundwater supply.

Discharge from the sandstones of the Narrabeen Group was simulated by "drain" cells set along the escarpments and in the gullies in the Goulburn River National Park and in the Munghorn Gap Nature Reserve (**Drawing No 8)**. The elevation of these "drain" cells was set to the elevation of the ground surface at the respective locations.

10.3 Recharge and Evapotranspiration

Only rainfall sourced recharge was used as an external input to the model domain. Wilpinjong Creek alluvial/colluvial areas, Cumbo Creek alluvial areas, areas of known coal seam subcrop and elevated sandstones of the Narrabeen Group under the Goulburn River National Park and Munghorn Gap Nature Reserve are believed to receive more recharge than remaining areas.

Dr Noel Merrick of University of Technology, Sydney (UTS) and Mr Lindsay Gilbert of Gilbert and Associates in March 2005, during a site inspection, considered that the rate of recharge to the sandstones of the Narrabeen Group would be substantial, and that recharge to areas of alluvium and an area of colluvium between Wilpinjong Creek and the Goulburn River National Park escarpment would be marginally higher. Subsequent model calibration found the rates of recharge to be in the order of 15% (88.7 mm/year) of average annual rainfall for outcrops of the Narrabeen Group and 19% (112.3 mm/year) of average annual rainfall for the alluvium/colluvium.

It was assessed during model calibration that coal seam subcrop areas receive 5% (29.5 mm/year) as average annual rainfall as recharge. The remaining model area was assumed to receive slightly less than 1% (4 mm/year) of annual average rainfall as recharge. Distribution of recharge is shown on **Drawing No 9**.

Recharge rates and hydraulic conductivities in groundwater models are highly correlated and in the case of steady state calibration it is possible to calibrate models to a range of different hydraulic conductivity and recharge values. However, the narrow range of possible hydraulic conductivity values, limits the recharge to values considered to be representative of the aquifers, climatic conditions and topography of the Project area and surrounds.

Recharge over areas subject to open cut mining within the Project area would be affected by mining and then the backfilling of mined-out voids with mine waste rock. During predictive modelling it was assumed that there would be no recharge during the first five years across the mine waste rock emplacements after placement in the mined-out void. This was done to allow for the initial wetting-up of the mine waste rock. In subsequent years recharge was assumed to resume at an assessed rate of 5% (30 mm/year) of annual rainfall.

Evapotranspiration is a mechanism by which groundwater is removed from aquifers in areas where the water table is high, such as along the central section of Wilpinjong Creek in the Project area. The evapotranspiration extinction depth (i.e. the depth to which evapotranspiration could remove water from the aquifer) was assumed to be 3 m below ground surface.

10.4 Model Hydraulic Parameters

Hydraulic testing of the Illawarra Coal Measures conducted in 2004 by GeoTerra (2004) yielded hydraulic conductivity values varying between 0.01 m/day and 0.05 m/day. Dr Noel Merrick has previously utilised a hydraulic conductivity of 0.02 m/day for the same strata in other modelling studies. These studies were developed and calibrated utilising many years of monitoring data.

Based on these studies, a hydraulic conductivity of 0.02 m/day was adopted in the model for the overburden layers representing the Illawarra Coal Measures and Narrabeen Group over the entire model area. The exceptions were the alluvial/colluvial areas along Wilpinjong Creek and alluvial area along Cumbo Creek where the hydraulic conductivity was assumed to be 1 m/day and the uppermost layer representing the Narrabeen Group which was assumed to have an increased hydraulic conductivity of 0.1 m/day, due to constant exposure to weathering and erosional processes.

As discussed in Section 5.2.2, hydraulic tests conducted by GeoTerra (2004) in the main aquifers in the Project area (i.e. the Ulan Seam and Marrangaroo Sandstone) yielded the following hydraulic conductivity values:

Ulan Seam:

- 0.01 m/day (from a slug test);
- 1.8 m/day (from a pumping test); and
- 6.1 m/day (from a pumping test).

Marrangaroo Sandstone:

- between 0.01 and 0.02 m/day (from slug tests); and
- 4.9 m/day (from a pumping test) in a bore screened in both the Ulan Seam and Marrangaroo Sandstone.

The horizontal hydraulic conductivity of both the Ulan Seam and Marrangaroo Sandstone was set at 1.5 m/day where the elevation was above RL 290 m. The cut-off elevation of RL 290 m was selected to be about 30 m below the base of the test bores. Below an elevation of RL 290 m the hydraulic conductivity of both aquifers was assumed to decline linearly to a value of 0.4 m/day at the deepest section, that is, at an elevation of about RL 120 m, an approximate depth of 300 m below surface.

A reduction of the hydraulic conductivity of coal seam aquifers with depth is observed in many coal mines. Wold and Esterle (2000) have demonstrated a decline in the hydraulic conductivity of the Bulli Seam in the Sydney Basin with depth as shown in **Table 8**.

Table 8: Coal Permeability, Bulli Seam Sydney Basin (After Wold and Esterle, 2000)		
	Hydraulic Conductivity (m/day)	
Depth (m)	*Bright Coal*	*Dull Coal*
200	0.668	0.017
400	0.167	0.008
600	0.075	0.006

The exchange of groundwater between different model layers was controlled by the vertical conductance between these layers. The vertical conductance between layers representing the Narrabeen Group, that is Layers 1 and 2 (except where Layer 2 comprises alluvial/colluvial materials – see below), was set to between 8.4×10^{-7}day^{-1} to 1.4×10^{-6}day^{-1}, declining with depth. Vertical conductance between Layers 3 and 4, the layers representing the Narrabeen Group/Illawarra Coal Measures and the Ulan Seam, was set to 4.0×10^{-5}day^{-1} above RL 290m, declining to 2.3×10^{-5}day^{-1} at the deepest section of the model. Similarly, the vertical conductance between Layers 4 and 5 (the Ulan Seam and the Marrangaroo Sandstone) was set to 4.0×10^{-5}day^{-1} above RL 290m, declining to 2.3×10^{-5}day^{-1} with depth.

Investigations by GeoTerra (2004) and subsequent geotechnical investigations undertaken by WCPL found that alluvium associated with Wilpinjong and Cumbo Creeks generally included a significant basal clay component (possibly resulting from old fluvial processes, *in-situ* weathering of alluvium and/or the underlying bedrock or a combination of these mechanisms). GeoTerra (2004) further observed no response to pump tests in the groundwater level in nearby Cumbo Creek alluvium and concluded that there is limited to no hydraulic connection between the Wilpinjong Creek alluvium and the underlying stratum. Based on these observations, the vertical conductance between the area of Layer 2 representing alluvium/colluvium along Wilpinjong and Cumbo Creeks and Layer 3 was set to 1×10^{-8} day^{-1}. A sensitivity analysis of this parameter was undertaken and is discussed in Section 11 of this report.

GeoTerra (2004) also noted that "*Wilpinjong Creek has a variable depth of alluvium of up to approximately 5m, with the deeper sections on the south bank located where tributaries deposit transported sediment at their confluence with Wilpinjong Creek. In areas where tributaries do not flow into the creek, the south bank of Wilpinjong Creek has generally thin alluvium (<1m) that overlies weathered bedrock, with the creek bed flowing directly over bedrock and no alluvium in sections*." Upward leakage from those areas where alluvium was not present on the creek bed would be controlled by the vertical conductance of the Illawarra Coal Measures layer (model Layer 3) (**Table 9**).

Aquifer storativity of the Ulan Seam was determined by GeoTerra (2004) to vary between 2.3×10^{-4} and 3.2×10^{-3}, which for the average thickness of the coal seam of 15 m gives a specific storage value of between 1.5×10^{-5} m^{-1} and 2.1×10^{-4} m^{-1}. The storativity of the Marrangaroo Sandstone was determined from the pumping tests to be 1.3×10^{-3}. In the model, a uniform specific storage of 1×10^{-4} m^{-1} was adopted for all five model layers.

A uniform specific yield of 0.1 was specified for all five model layers. The adopted values are consistent with the hydraulic test results and with published values (Spitz and Moreno, 1996) for similar rock types.

A summary of the calibrated hydraulic parameters specified in the model is presented in **Table 9** below.

Table 9: Summary of Groundwater Model Parameters

Model Layer	Layer Name	Feature/Parameter	Value
1	Narrabeen Group	distribution	Northern sections of the Goulburn River National Park area and peaks in the Munghorn Gap Nature Reserve.
		top	Interpolated from topographic data.
		base	180m above the top of the Ulan Seam, RL 707m to RL 308m south to north.
		horizontal hydraulic conductivity	0.1m/day
		vertical conductance	1.4×10^{-6}day^{-1} declining to 8.4×10^{-7}day^{-1} with depth
		specific yield	0.1
		specific storage	1×10^{-4}m^{-1}
		recharge	88.7 mm/year (15% of average annual rainfall).
2	Narrabeen Group or Alluvial/ Colluvial Deposits	distribution	Goulburn River National Park area north of the escarpment, Munghorn Gap Nature Reserve above the base of the surrounding valley floor, alluvium/ colluvium zone of Wilpinjong Creek and alluvium of Cumbo Creek.
		top	180 m above the top of the Ulan Seam and as interpolated from topographic data where the layer daylights at the surface. Ground surface along the alluvium/colluvium zone of Wilpinjong Creek and alluvium of Cumbo Creek.
		base	100 m above the top of the Ulan Seam, RL 630 m to RL 230 m south to north. 5 m below ground surface along the alluvium/colluvium zone of Wilpinjong Creek and alluvium of Cumbo Creek.
		horizontal hydraulic conductivity	0.02 m/day, except the alluvium/colluvium zone of Wilpinjong Creek and alluvium of Cumbo Creek where it was set to 1 m/day.
		vertical conductance	1.4×10^{-6} day^{-1} declining to 8.4×10^{-7}day^{-1} with depth. 1 $\times10^{-8}$ day^{-1} along the alluvium/colluvium zone of Wilpinjong Creek and alluvium of Cumbo Creek.
		specific yield	0.1 except the alluvium/colluvium zone of Wilpinjong Creek and alluvium of Cumbo Creek where it was set to 0.25**.**
		specific storage	1×10^{-4} m^{-1}
		recharge	88.7 mm/year (15% of average annual rainfall) and 112.3 mm/year (19% of average annual rainfall) along the alluvium/colluvium zone of Wilpinjong Creek and alluvium of Cumbo Creek.
3	Narrabeen Group and Illawarra Coal Measures	distribution	Entire model area, except in areas of known intrusions and eroded section between Pits 1 and 2.
		top	100 m above the top of the Ulan Seam, and interpolated from topographic data where the layer is intersecting the surface.
		base	Interpolated from borehole data.
		horizontal hydraulic conductivity	0.02 m/day
		vertical conductance	4×10^{-5}day^{-1} above RL 290 m declining to 1×10^{-5}day^{-1} with depth.
		specific yield	0.1
		specific storage	1×10^{-4} m^{-1}
		recharge	4.0 mm/year (0.68% of average annual rainfall) over valley floors except for Ulan Seam subcrops. 30 mm/year (5% of average annual rainfall) over Ulan Seam subcrops, and over backfill mine waste rock emplacement areas 5 years after placement.

Table 9 (Continued): Summary of Groundwater Model Parameters			
Model Layer	**Layer Name**	**Feature/Parameter**	**Value**
4	Ulan Seam	distribution	Entire model area, except in areas of known intrusions and eroded section between Pits 1 and 2.
		top	Interpolated from borehole data.
		base	Interpolated from borehole data.
		horizontal hydraulic conductivity	1.5 m/day above RL 290 m declining to 0.4 m/day with depth.
		vertical conductance	$4x10^{-5}day^{-1}$ above RL 290 m declining to $2.3x10^{-5}day^{-1}$ with depth.
		specific yield	0.1
		specific storage	$1 \times 10^{-4}m^{-1}$
		recharge	0
5	Marrangaroo Sandstone	distribution	Entire model area, except in areas of known intrusions and eroded section between Pits 1 and 2.
		base	Interpolated from the borehole data.
		thickness	Interpolated from the borehole data.
		horizontal hydraulic conductivity	1.5 m/day above RL 290 m declining to 0.4 m/day with depth.
		specific yield	0.1
		specific storage	$1 \times 10^{-4} m^{-1}$
		recharge	0

11.0 MODEL CALIBRATION

As stated in “Applied Groundwater Modeling, Simulation of Flow and Advective Transport” (Anderson & Woessner, 1992):

“Calibration of a groundwater flow model refers to a demonstration that the model is capable of producing field measured heads and flows which are the calibration values. Calibration is accomplished by finding a set of parameters, boundary conditions and stresses that produce simulated heads and fluxes that match field measured values within an acceptable range of error”.

The objective of model calibration was to reproduce the estimated steady state groundwater levels existing in the Project area and allow simulation of the impact of the Project on the groundwater regime.

The accuracy of the model calibration depends on the quality of calibration parameters and the data defining the model domain such as aquifer geometry, boundaries, hydraulic properties and stresses imposed on the aquifer. It is considered that the horizontal and vertical extent of the model and model boundaries are sufficiently well defined to calibrate the groundwater model.

The selection of calibration targets was limited to water level monitoring data collected from monitoring bores in June-July 2004 and during the bore census conducted by WCPL in February 2005. It was assumed that the water levels in monitoring bores selected for steady state calibration were representative of the long term average (steady state) groundwater levels.

The accuracy of groundwater level data in the surveyed monitoring bores installed and monitored during the 2004 investigation by GeoTerra was assessed to be ± 0.01 m, whereas the accuracy of groundwater level data in regional registered groundwater bores, where the bore collar elevation was obtained from the digital topographic map of the region (10 m contours), was estimated to be ± 5 m.

A summary of the bores used as calibration targets and the reliability of each target is presented in **Table 10**. The location of the bores is shown on **Drawing No 6**.

Table 10: Calibration Targets

Bore ID	Easting (m)	Northing (m)	Collar Elevation (m AHD)	Bore Depth (m)	Observed Water Level Elevation (m AHD)	Reliability (m)[1]	Aquifers
ERUL27	768820	6421125	389.20	45.1	389.5	±2.7	Ulan Seam
ERUL77	772903	6420064	366.70	44.4	365.9	±2.7	Ulan Seam
EW1001	773507	6419997	362.55	79.4	365.3	±2.7	Ulan Seam
EW1005	769002	6421002	388.60	49.0	389.6	±2.7	Ulan Seam
EW1006	770997	6419502	374.61	34.5	373.3	±2.7	Ulan Seam
EW1020	771210	6419752	370.74	27.4	372.8	±2.7	Ulan Seam
EW2001	772748	6419750	373.78	45.5	366.9	±2.7	Ulan Seam
EW2002	772749	6419252	372.35	39.5	367.2	±2.7	Ulan Seam
EW2003	773998	6419751	375.05	51.5	367.1	±2.7	Ulan Seam
EW2007	768998	6420751	393.31	51.5	389.6	±2.7	Marrangaroo Sandstone
EW2010	768954	6420761	393.77	41.0	389.4	±2.7	Ulan Seam
EW2012	771248	6419512	373.36	22.1	373.5	±2.7	Ulan Seam
EW2014	773194	6419766	367.54	36.3	366.9	±2.7	Ulan Seam
EW2015	773194	6419776	367.20	44.0	366.9	±2.7	Marrangaroo Sandstone
EW4001	768975	6420759	393.57	48.1	386.4	±2.7	Marrangaroo Sandstone
EW4002	771249	6419482	373.43	27.6	372.9	±2.7	Ulan Seam and Marrangaroo Sandstone
EW4003	773194	6419756	367.89	36.0	366.9	±2.7	Ulan Seam
EW5001	771248	6419502	373.47	33.5	373.7	±2.7	Marrangaroo Sandstone
EW5002	771248	6419251	376.79	23.5	374.8	±2.7	Ulan Seam
GW024776	769750	6420875	379.80	48.8	380.8	±5.0	Ulan Seam and Marrangaroo Sandstone
GW052223	767660	6421210	403.00	54.2	398.5	±5.0	Ulan Seam
GW053859	769590	6419785	389.00	30.5	388.4	±5.0	Ulan Seam

[1] Based on observed groundwater fluctuations, reliability of steady state calibration targets was assumed as ±2.7 m and ±5 m for the surveyed and registered groundwater bores, respectively.

The results of steady state calibration are summarised in **Table 11**.

Table 11: Calibration Results

Bore ID	Simulated Water Level Elevation (m AHD)	Observed Water Level Elevation (m AHD)	Difference (m)	Reliability (m)
ERUL27	392.7	389.5	3.2	±2.7
ERUL77	369.4	365.9	3.5	±2.7
EW1001	365.6	365.3	0.3	±2.7
EW1005	391.9	389.6	2.3	±2.7
EW1006	380.5	373.3	7.2	±2.7
EW1020	379.7	372.8	6.9	±2.7
EW2001	370.0	366.9	3.1	±2.7
EW2002	369.6	367.2	2.4	±2.7
EW2003	363.5	367.1	-3.6	±2.7
EW2007	391.8	389.6	2.2	±2.7
EW2010	392.0	389.4	2.6	±2.7
EW2012	379.2	373.5	5.7	±2.7
EW2014	367.2	366.9	0.3	±2.7
EW2015	367.5	366.9	0.6	±2.7
EW4001	391.9	386.4	5.5	±2.7
EW4002	379.1	372.9	6.2	±2.7
EW4003	367.2	366.9	0.3	±2.7
EW5001	379.1	373.7	5.4	±2.7
EW5002	378.9	374.8	4.1	±2.7
GW024776	388.8	380.8	8.0	±5.0
GW052223	397.7	398.5	-0.8	±5.0
GW053859	388.0	388.4	-0.4	±5.0

An objective method to evaluate the calibration of the model is to examine the statistical parameters associated with the calibration. One such method is by measurement of the error between the modelled and observed (measured) water levels. A root mean square (RMS) is expressed as:

$$RMS = \left[1/n \sum (h_o - h_m)_i^2 \right]^{0.5}$$

where: n = number of measurements

h_o = observed water level

h_m = simulated water level

is considered to be the best measure of error, if errors are normally distributed.

The RMS error calculated for the calibrated model is 3.9 m. The maximum acceptable value for the calibration criterion depends on the magnitude of the change in heads over the model domain. If the ratio of the RMS error to the total head loss in the system is small, the errors are only a small part of the overall model response (Anderson and Woessner, 1992). The total head loss in the main aquifers (Layers 4 and 5) within the model domain is 180 m, therefore the ratio of RMS to the total head loss is 2.3%.

This error is considered to be acceptably small. The mass balance error, that is the difference between calculated inflows and outflows to the model, at the completion of the calibration run, expressed as percent of discrepancy, was 0.2%.

Model simulation runs indicate steady state total groundwater discharge to Wilpinjong Creek of about 2,230 m^3/day. The losses predominantly result from drainage from the alluvium/colluvium, lateral discharge from the Narrabeen Group/Illawarra Coal Measures and lesser upward leakage from the deeper semi-confined Ulan Seam aquifer. The value derived from the model is comparable to the long term average baseflow prediction of 2,500 m^3/day estimated by surface water modelling undertaken by Gilbert and Associates Pty Ltd (Appendix A of the EIS) (Section 5.2.4).

The simulated steady state elevation of the groundwater table in Layer 3 (Illawarra Coal Measures) and Layer 4 (Ulan Seam) is shown on **Drawing No 10**.

Calibration sensitivity of the model was tested by incrementally changing individual model parameters above and below the calibrated values. Recharge and horizontal hydraulic conductivity were selected for sensitivity analysis. The selected performance measure for testing the sensitivity of the model was the RMS error.

The summary of the sensitivity analysis is presented in **Table 12**.

Table 12: Calibration Sensitivity (m)

	Multiplication Factor				
Parameter	**0.25**	**0.5**	**1**	**2**	**4**
Recharge	>16.5[a)]	>3.2 [a)]	4.1	6.5	9.9
Horizontal Hydraulic Conductivity	5.2	5.4	4.1	>3.9 [a)]	>23.8 [b)]

a) - RMS value shown in the table does not include one calibration bore that became inactive during simulation. True RMS value is higher than the one shown in the table.

b) - RMS value shown in the table does not include two calibration bores that become inactive during simulation. True RMS value is higher than the one shown in the table.

The analysis indicates that the model is more sensitive to the value of recharge than to horizontal hydraulic conductivity. In addition the sensitivity of model prediction of groundwater outputs (discharges) to Wilpinjong Creek to the vertical conductance parameter was assessed. The vertical conductance parameter between the modelled alluvial/colluvial zone along Wilpinjong Creek and alluvial zone along Cumbo Creek and the Illawarra Coal Measures (i.e. Layer 3) was increased by an order of magnitude. Results of this run showed that creek inflows were relatively insensitive to vertical conductivity with no consistent change in modelled inflows over the Project life.

The steady state water balance of the calibrated model is shown in **Table 13**.

Based on the above calibration analysis, it is considered that calibration is accomplished in that the simulated heads and fluxes match field measured values within an acceptable range of error.

Table 13: Model Steady State Water Budget		
	Inflow to Model Domain (m^3/day)	**Outflow from Model Domain (m^3/day)**
River Leakage	0	13342
Recharge	29319	0
Evapotranspiration and surface seepage losses from escarpment areas.	0	16037
Total	**29319**	**29379**
Difference between Inflow and Outflow from the Model Domain (m^3/day)	-60	
Percent Discrepancy (%)	-0.20	

The breakdown of the simulated total discharges to the different creeks and river is shown in **Table 14**.

Table 14: Simulated Steady State Total Losses to the Creeks and Goulburn River	
Creek/River	**Discharge (m^3/day)**
Wilpinjong Creek	2230
Wollar Creek	1215
Cumbo Creek	121
Goulburn River	10223

12.0 PREDICTIVE SIMULATIONS

12.1 Development of Mining

The impact of the Project on the aquifers and other groundwater users in the Project area would depend on the mining method, mining schedules and on the operation of the borefield. The mine development and Project borefield is discussed in Sections 7.0 and 8.0, respectively. The planned mining sequence is shown on **Drawing No 7**.

12.2 Modelling Strategy

The future response of the groundwater system to extractions from the Project borefield, development of the open cut mine and the predicted rate of groundwater inflow to the open cut have been assessed by running the model for a total simulation period of 21 years. Simulated steady state groundwater elevations have been used as initial conditions.

Active open cut areas were simulated using MODFLOW Drain cells. Drain cells allow water to be removed from the model domain (i.e. by drainage) if the hydraulic head in the cell is above a nominated drainage level. The drainage level specified is the level at which groundwater seepage occurs through pit walls rather than the actual base of the model cell. It was assumed that the elevation of the seepage face on pit walls would be about 1 m above the base of the model layer, that is, the base of Layer 3 representing the overburden, and the base of Layer 4 representing the Ulan Seam.

Once the water level in the surrounding cells falls below the drainage level, drainage from that cell ceases. Drain cells were progressively moved across the Project area in accordance with the mine plan. Once the open cut area was backfilled with mine waste rock the drain cell was removed from the model.

Mining and backfilling of open cut mine areas would have an impact on the rate of recharge over backfilled mine waste rock emplacement areas. It was assumed that for five years following placement of backfill there would be no recharge reporting to the model. A five year period was assumed to be necessary to establish the soil moisture profile through the mine waste rock and allow deep percolation of rainfall, with no recharge to the underlying aquifer occurring during that time. It was further assumed that once the soil moisture profile is established, the recharge over the backfilled mine waste rock emplacement area would resume at a rate of 29.5 mm/year (i.e. 5% of the average annual rainfall).

As discussed in Section 10.2, major creeks (i.e. Wollar, Wilpinjong and Cumbo Creeks) and the Goulburn River were simulated as MODFLOW "River" type boundaries which permit losing or gaining river reaches to be modelled, depending on the prevailing hydraulic head in the cell relative to the nominated river stage.

Stages and river bed elevations in major creeks within the model domain were assessed on the basis of digital topographic maps of the Project area. Where the model extended beyond the limits of the above maps stages were assigned from published 1:100,000 topographic maps. Both river stage and river bed elevations were at the same elevations. The above arrangement resulted in river cells acting as drain cells and prevented simulating recharge from major creeks and Goulburn River.

The extraction bores in the borefield were simulated using MODFLOW well cells. Well cells allow water to be removed from the model domain at a pre-determined rate. The borefield extraction rate was applied based on advice from Gilbert and Associates Pty Ltd (Appendix A of the EIS) who conducted the water balance simulation for the Project.

At the commencement of the predictive simulation, a total of 19 production bores extracting from the Ulan Seam and Marrangaroo Sandstone were simulated. All production bores were assumed to be screened in both aquifers (i.e. model Layers 4 and 5). Based on the pump tests reported in GeoTerra (2004) the extraction rates were assigned to range between 1.5 L/sec and at 2.5 L/sec.

Nine of the production bores were removed at various times from the simulation when they were assumed to have been pumped dry. As the model simulates water levels in the whole well (bore) cells rather than that of individual bores, a bore was assumed to be dry when the simulated water levels in the well cell as a whole were lowered to about 10 m above the base of the Ulan Seam aquifer (Layer 4).

The 21 year long mining period was discretised into 42 stress periods with two stress periods per year. A stress period is a period of time during which there is no change to stresses, such as pumping rates, recharge or dewatering imposed on the model.

Recovery simulation was conducted assuming that after Project closure, dewatering from the remaining open voids in Pit 3 and Pit 6 would be terminated and that groundwater in and around the voids would be allowed to recover. Appendix A of the EIS presents the results of water balance modelling of the long term behaviour of the final voids. The voids would continue to act as a groundwater sink due to continuous evaporation from the void lake surface.

12.3 Simulation Results

12.3.1 Inflow to Pits (Mine Void)

The response of the groundwater system to the proposed mining schedule and operation of the borefield has been assessed by running the model for a total simulation period of 21 years. Simulated steady state heads within model layers have been used as initial conditions.

Mining of the Ulan Seam in Years 1 to 8 progresses from north to south in an up-dip direction, with the exception of Year 1 during excavation of the box-cut. During this time, the elevation of the base of the pits (base of the Ulan Seam) increases from about RL 350 m to RL 410 m, towards and above the elevation of the groundwater level. Therefore, as the depth of the pit base below the groundwater level decreases, so does inflow to the pit. Once the direction of mining is reversed from south to north and the pits are mined at progressively lower elevations and at increasing depths below the groundwater table, more water would inflow to the pits. Consequently, more dewatering would be required.

During Years 13 and 14, mining would be conducted mostly along the northern limit of the open pits (**Drawing No 7**). At that time, mining would be conducted at the lowest elevation of the Ulan Seam and under the highest groundwater head. Inflows to the pits are expected to be the highest at this time. **Table 15** presents the average groundwater inflow rate for each of the six pits over the life of the Project. Simulated inflows to the pits represent the average estimated total groundwater inflow into each pit. Some of this groundwater would not be available as a water supply as it would either be lost from the open cut face due to evaporation and/or removed with coal/mine waste rock (Appendix A).

Table 15: Predicted Average Inflow to the Pits

Pit	Project Years	Average Inflows (m^3/day)
Pit 1 North	Years 2 to 4	1676
Pit 1 South	Years 1, 5 to 7	0
Pit 2 North	Years 3 to 5	234
Pit 2 South	Years 6 to 9	0
Pit 3	Years 8 to 21	1375
Pit 4	Years 9 to 21	2660
Pit 5	Years 13 to 21	2134
Pit 6	Years 14 to 21	3350

Dewatering of the open cut and simultaneous operation of the borefield would have an impact on some of the production bores, particularly those that are the shallowest and/or closest to the pit boundaries which would go dry during the mining period. Discontinuation of extraction from selected bores would extend the production life of the remaining bores.

Water balance modelling undertaken by Gilbert and Associates Pty Ltd (Appendix A of the EIS) indicates that at different stages of the Project there would be periods with a surplus of water. Pit dewatering from Year 14 of the Project would be sufficient to satisfy the total water supply requirement. Hence, there would be no need for the operation of the borefield from that time.

The Project water supply volumetric reliability has been assessed by Gilbert and Associates Pty Ltd (Appendix A of the EIS). This assessment included the advance dewatering from Pits 5 and 6 at a rate of up to 4 L/s. This extraction has not been included in the groundwater model as these temporary bores would be within the ultimate limit of the pits and, with exception of one Project water supply bore, would be more than 1 km from the Project borefield. These extractions would have negligible effect on the model simulations.

12.3.2 Water Table/Piezometric Surface (Cone of Depression)

Simultaneous dewatering of the open cut and extraction of groundwater from the borefield would create a cone of depression in the piezometric surface around the Project area (**Drawing No 11 and No 12**).

The cone of depression in the Ulan Seam (model Layer 4) (**Drawing No. 12**), as defined by the 1 m drawdown contour, would increase with time. The simulated extent of the cone of depression in the Illawarra Coal Measures (model Layer 3) (**Drawing No. 11**) above the Ulan Seam and the underlying Marrangaroo Sandstone (model Layer 5) is similar to that in Ulan Seam.

12.3.3 Linkage between Aquifers above the Cone of Depression

The simulated impact of open cut dewatering and extraction of groundwater from the borefield on groundwater levels in different aquifers varied depending on the hydraulic connection between these aquifers and the aquifers being dewatered. As such, the greatest simulated impact was on the main aquifers in the Project area (i.e. the Ulan Seam and the Marrangaroo Sandstone). A similar impact occurs in the Illawarra Coal Measures (model Layer 3), as this aquifer is in direct hydraulic connection with the main aquifers being dewatered and will also be dewatered by open cut mining of overburden above the Ulan Seam. Modelling showed negligible effect in the Narrabeen Group (model Layers 1 and 2). Similarly, modelling showed only a limited affect on the water levels in the alluvium/colluvium aquifer. Large sections of the alluvium remained saturated at the end of 21 year Project life.

12.4 Groundwater Recovery

On completion of mining, pit dewatering and extraction of water from the borefield would discontinue. As a result, the extent of the cone of depression would stabilise and groundwater levels in and around the Project area would be allowed to recover. However, for some time after mine closure, the cone of depression would persist until new steady state conditions are established. The rate of groundwater recovery would largely depend on climatic conditions.

Once the groundwater recovery stabilises, the overall groundwater gradient would return to the east-northeast, consistent with the existing groundwater conditions. Any tendency for development of ‘dryland salinity’ developing in the Project area would be mitigated by the proposed woodland revegetation presented in Section 5 of the EIS. In addition, due to the dominance in evaporation over rainfall in this region localised sinks (localised depression in groundwater levels towards which there is a groundwater gradient) would form around the final voids in Pits 3 and 6. Appendix A of the EIS presents the results of a final void water balance.

12.5 Groundwater Balance

The components of the model-derived groundwater balance at the end of the 21 year Project life are shown in **Table 16**.

Table 16: Groundwater Balance – End of Predictive Simulation

Model Component	Inputs (m^3/day)	Outputs (m^3/day)	Gain (+), or Loss (-) (m^3/day)
Storage	4014	1866	+2148
Bores	0.0	0.0	0.0
Discharge to cliff faces and gullies	0.0	14725	-14725
Mine dewatering	0.0	3920	-3920
Recharge	29585	0.0	29585
River Leakage	0.0	12539	-12539
Evapotranspiration	0.0	552	-552
Sum	33599	33603	-4
Discrepancy [%]			-0.01

13.0 POTENTIAL IMPACT OF THE PROJECT ON AQUIFER SYSTEMS AND MITIGATION OPTIONS

13.1 Regional and Cumulative Impacts

As discussed, extraction of groundwater by mine dewatering and operation of the borefield would lower the elevation of the local groundwater table (i.e. create a cone of depression). The model simulated the development and extent of the cone of depression in the main aquifers in the Project area (i.e. model Layers 4 and 5, the Ulan Seam and Marrangaroo Sandstone). A similar but slightly lesser cone of depression occurs in the overlying Illawarra Coal Measures (**Drawing No 11**).

The Ulan Seam and underlying Marrangaroo Sandstone provide water supplies to some domestic and farm bores in the region. The location of all known domestic bores in the vicinity of the Project area is shown on **Drawing No 11 and No 12**.

Whilst the groundwater modelling prediction include reduced piezometric pressures in parts of the coal seam aquifer underlying the Goulburn River National Park sandstone plateau, it is expected that there would no discernible effect on the groundwater and surface water regimes in the overlying sandstone units (i.e. Narrabeen Group).

Groundwater flow in the aquifers is to the Goulburn River which is a major discharge zone in the region. Modelling has shown that there is no reduction on groundwater discharge directly to the Goulburn River. The majority of the simulated drawdown within the cone of depression is within the range of natural groundwater fluctuation (i.e. less than 5 m).

The Ulan Coal Mines are located approximately 11 km to the north-west of the Project, near the village of Ulan. The Ulan Coal Mines incorporate both underground and open cut mining areas and associated surface infrastructure including a CHPP, rail loop, rail loading and administrative facilities. The Ulan Coal Mines operate under a number of consents (and associated consent modifications).

It is noted that a 2 Mtpa underground mining operation comprising Underground Mine No. 4, a new CHPP, rail loop and train loading facility was approved in October 1985 as part of Stage 2 of the Ulan Coal Mines (hereafter referred to as Ulan Stage 2). The Underground Mine No. 4 and associated surface facilities that comprised part of Ulan Stage 2 were not developed at that time. Other components of Ulan Stage 2 were however developed (i.e. the Stage 2 open cut and Underground Mine No. 3 commenced in the 1980's [Kinhill, 1998]) and form part of the existing Ulan Coal Mines development. Underground Mine No. 4 and associated surface infrastructure would be located to the immediate east of the Ulan Coal Mines.

Groundwater assessment studies undertaken for Ulan Coal Mines (including Ulan Stage 2) concluded that "*drawdown induced would tend to be confined to the general area of the mining lease*" (Kinhill Stearns Engineers, 1983). The mining lease referred to in the *Ulan Coal Mines Stage 2 – Colliery Development and Expansion Environmental Impact Statement* (Kinhill Stearns Engineers, 1983) is approximately 4 km further west than the Year 21 maximum extent of groundwater drawdown predicted for the Project. Underground mining at Ulan Coal Mines as stated in *Ulan Coal Mines Mining Lease Application No. 80, Development Application and Environmental Impact Statement* (Kinhill, 1998) is located some 10 km north of Ulan and is further north-west of the predicted cone of depression for the Project. Based on this, it is concluded that there would be no overlap in the cone of depression generated by the Ulan Coal Mines (including Ulan Stage 2) and the Project and therefore no cumulative groundwater impacts are predicted.

13.2 Impact on Existing Bores/Wells

A summary of predicted impacts on the individual bores/wells is presented in **Attachment 1**.

Of the 68 registered groundwater bores/wells and additional bores/wells identified during the bore census, 14 are located within the Year 21 cone of depression (as determined by the 1 m simulated drawdown contour on **Drawing No 12**) and the same aquifer system. Of these, with the exception of one privately owned bore GW80121 (north of Wollar village) and one bore located on land owned by Ulan Coal Mines GW034640 (west of the Project area), all of these bores/wells are currently located on land owned by WCPL. Bores located south of the approximate northing of 6416300mN (**Drawing No 12**) are either beyond the extent of the cone of depression or are located in a different aquifer system from those being dewatered by the Project and are not expected to be impacted. No bores, or wells, installed in the Wilpinjong Creek alluvium or Wollar Creek alluvium are expected to be dewatered.

All known springs on privately owned land are located beyond the extent of the cone of depression and/or in different aquifer systems from those being dewatered by the Project and are not expected to be impacted.

A groundwater monitoring programme to monitor the impact of mining on existing bores/wells is discussed in Section 15.0. Where a Project induced drawdown (i.e. as opposed to seasonal variations and the effect of other groundwater users) is measured in a privately owned existing bore/well and results in a reduction in water supply, WCPL would consult with the affected landowner and mitigate this impact by measures such as deepening of the existing bore or well, construction of a new bore/well or providing an alternative water supply.

13.3 Reduction in Groundwater Discharge to Creeks

The modelling results indicate that mine dewatering and operation of the borefield would reduce the long term average baseflow of Wilpinjong Creek due to the reduction in upward leakage from the underlying artesian aquifer formed in the Ulan Seam and underlying Marrangaroo Sandstones. The simulated average baseflow in Wilpinjong Creek declined from 2,230 m^3/day in pre-mining conditions to 1,566 m^3/day in Year 14 of the Project, at which time in the simulation the Project borefield was no longer required. The groundwater modelling indicated that the baseflow reduction was almost entirely due to a reduction in discharge from Layers 3 and 4 rather than Layer 2. Interflow/underflow associated with the alluvial and colluvial deposits adjacent to the creek and shallow seepage from the adjacent elevated Goulburn River National Park escarpment, which are the dominant contributors to the long term average baseflow of Wilpinjong Creek (Appendix A of the EIS), would remain relatively unchanged. Results of the groundwater modelling also showed that after cessation of borefield extraction gradual groundwater level recovery was accompanied by corresponding recovery of creek baseflow.

Simulation results indicated negligible impact on the rate of groundwater discharge to Wollar Creek which is at the eastern limit of the potential cone of depression and no impact on direct groundwater discharge to Goulburn River.

Further assessment of these flow changes on stream hydrology and aquatic ecosystems along these creeks is presented in Appendix A and Appendix HD of the EIS, respectively.

The groundwater in the Ulan Seam is reasonably saline as previously discussed in Section 5.2.5, therefore any reduction in discharge to the creeks from the Ulan Seam would result in a corresponding reduction in the total salt load entering the creeks. The reduced salt load discharged from the aquifer would result in overall reduced salinity in some creeks because fresher flows in the creeks associated with rainfall/runoff and alluvium would be substantially unchanged by the Project.

14.0 MODEL LIMITATIONS

Development, calibration and the results of predictive simulations from any groundwater model is based on data characterising the groundwater system under investigation. It is not possible to collect all the data characterising the whole aquifer system in detail and therefore various assumptions have to be made during development of the groundwater model. A number of assumptions were made during development of the groundwater model described in this report and these assumptions together with their impact on the simulation results are discussed below.

It was assumed that main simulated aquifers within the model domain area (Ulan Seam and Marrangaroo Sandstone) are hydraulically continuous and without internal boundaries. The impact of such an assumption on the simulation results is such that there are no impediments to the development of the cone of depression around the Project area. If there were low permeability (barrier) faults which had the effect of compartmentalising the aquifer into a number of hydraulically distinctive zones then the simulated drawdown would be different. The extent and the shape of the cone of depression would be determined by the geometry and hydraulic parameters of such faults but would in general be smaller, but deeper in the extraction area zones. In this regard it is recommended that long term pumping tests be undertaken as part of the design of the Project water supply system.

Should there be any hydraulically conductive faults intersecting the aquifers and these faults were intersected by the pit or production bores, a cone of depression may develop preferentially along the faults traces. In these circumstances the depth of the cone of depression may be smaller than simulated.

An assumption was made regarding hydraulic parameters of the overburden and in particular the vertical conductance that governs the rate of transfer of groundwater from the overburden to the Ulan Seam and Marrangaroo Sandstone aquifers. The impact of an increase or decrease in the value of this parameter would be to respectively decrease or increase the extent and depth of the cone of depression. The sensitivity analysis showed however that the model is relatively insensitive to the value of this parameter and therefore a wide range of values would calibrate the model.

15.0 GROUNDWATER MONITORING PROGRAMME

The recommended groundwater monitoring programme is as summarised in **Table 17**. It is recommended that all groundwater monitoring, water level measurements and sample collection, storage and transportation be undertaken in accordance with the procedures outlined by the Murray Darling Basin Commission (1997).

A bore licence should be obtained from DIPNR prior to the installation of any new monitoring bores. All monitoring bores should be constructed according to the Australian guidelines (Land and Water Diversity Committee, 2003) by an appropriately qualified water bore driller.

Table 17: Recommended Groundwater Monitoring Programme

Location	Parameters	Frequency
Wilpinjong Creek 4 alluvium bores/wells. 2 coal measures bores.	water level, pH, EC	monthly
	pH, EC, Na, Mg, Ca, Cl, HCO_3, SO_2, Total Fe	biannually
Cumbo Creek 2 alluvium bores/wells. 1 coal measures bore.	water level, pH, EC	monthly
	pH, EC, Na, Mg, Ca, Cl, HCO_3, SO_2, Total Fe	biannually
Wollar Creek 1 coal measures bore.	water level, pH, EC	quarterly
	pH, EC, Na, Mg, Ca, Cl, HCO_3, SO_2, Total Fe	biannually
Wollar Village 1 alluvium bore/well. 1 coal measures bore.	water level, pH, EC	quarterly
	pH, EC, Na, Mg, Ca, Cl, HCO_3, SO_2, Total Fe	biannually
Water Supply Bores	water level, volume extracted, pH and EC	monthly

It is recommended that a groundwater monitoring programme be developed and that in addition to the above, selective monitoring of existing bores in the local area be included.

16.0 REFERENCES

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17.0 GLOSSARY

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

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

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.

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.

Slug Test – A test made by the addition, or removal, of a known volume of water to or from a well. The subsequent well recovery is measured.

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.

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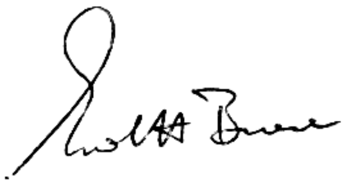
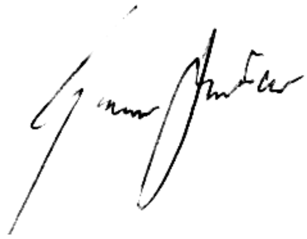
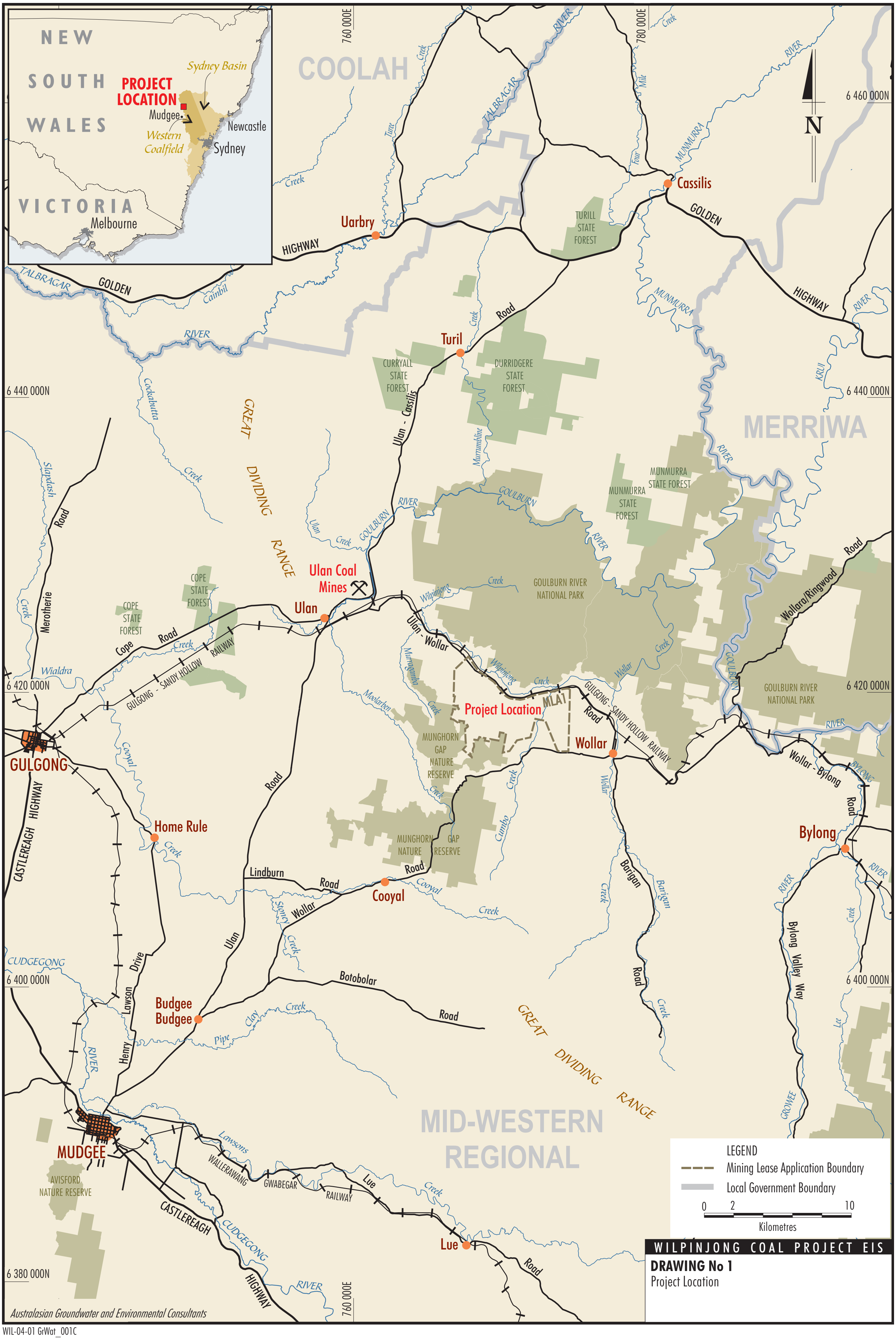




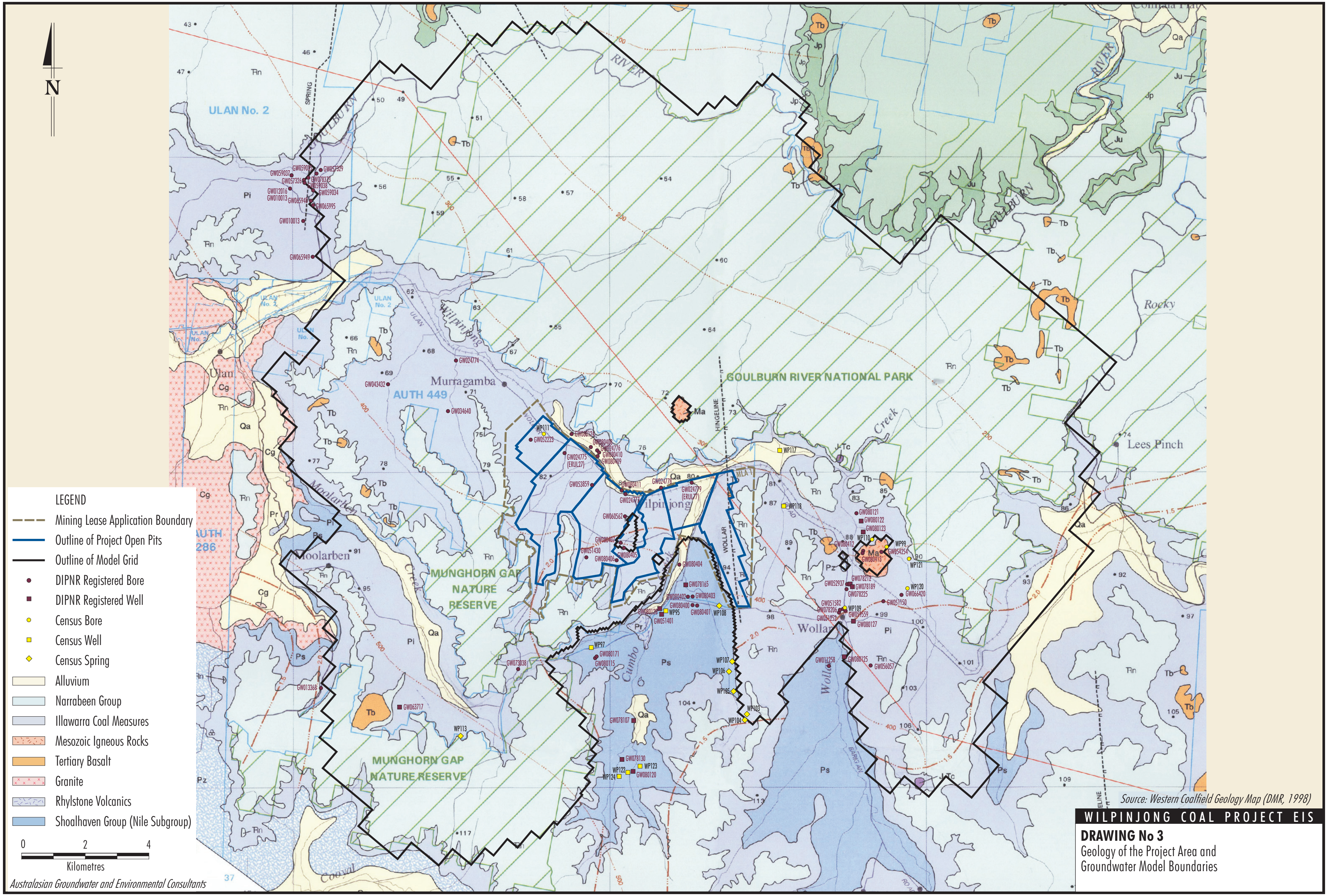
ERROL H. BRIESE
Managing Director/Principal Hydrogeologist

BRON SMOLSKI
Groundwater Modeller

DRAWINGS No 1 to No 12


NEW SOUTH WALES
VICTORIA
PROJECT LOCATION
Sydney Basin
Mudgee
Western Coalfield
Newcastle
Sydney
Melbourne
COOLAH
MERRIWA
MID-WESTERN REGIONAL
GREAT DIVIDING RANGE
Ulan Coal Mines
Ulan
Uarbry
Turil
Cassilis
Gulgong
Wollar
Bylong
Home Rule
Cooyal
Budgee Budgee
Mudgee
Lue
Project Location
MLA1
CURRYALL STATE FOREST
DURRIDGERE STATE FOREST
TURILL STATE FOREST
MUNMURRA STATE FOREST
COPE STATE FOREST
GOULBURN RIVER NATIONAL PARK
MUNGHORN GAP NATURE RESERVE
AVISFORD NATURE RESERVE
GOLDEN HIGHWAY
CASTLEREAGH HIGHWAY
GULGONG - SANDY HOLLOW RAILWAY
WALLERAWANG GWABEGAR RAILWAY
Ulan - Cassilis Road
Ulan - Wollar Road
Wollar - Bylong Road
Bylong Valley Way
Wollara/Ringwood Road
Botobolar Road
Lindburn Road
Cope Road
Merotherie Road
Henry Lawson Drive
GOULBURN RIVER
TALBRAGAR RIVER
CUDGEGONG RIVER
6 460 000N
6 440 000N
6 420 000N
6 400 000N
6 380 000N
760 000E
780 000E
N
LEGEND
Mining Lease Application Boundary
Local Government Boundary
0 2 10
Kilometres
WILPINJONG COAL PROJECT EIS
DRAWING No 1
Project Location
Australasian Groundwater and Environmental Consultants
WIL-04-01 GrWat_001C

WIL-04-01 GrWat_002F



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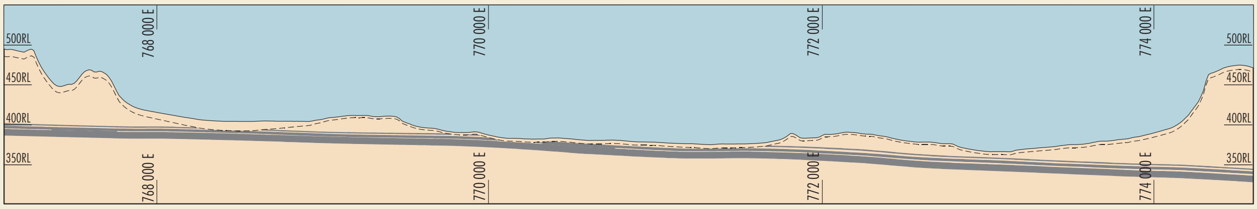

Cross Section A - A[1]

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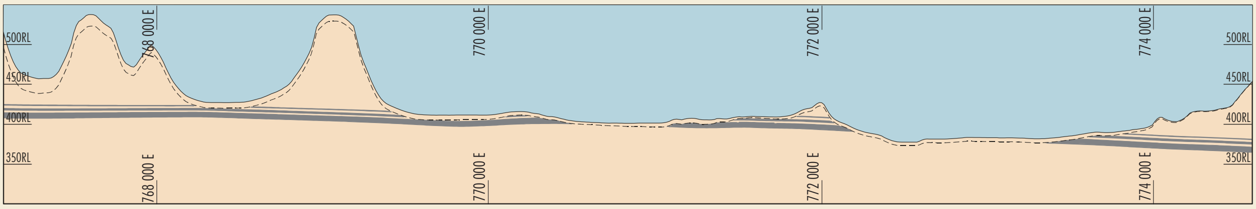
Ulan Seam



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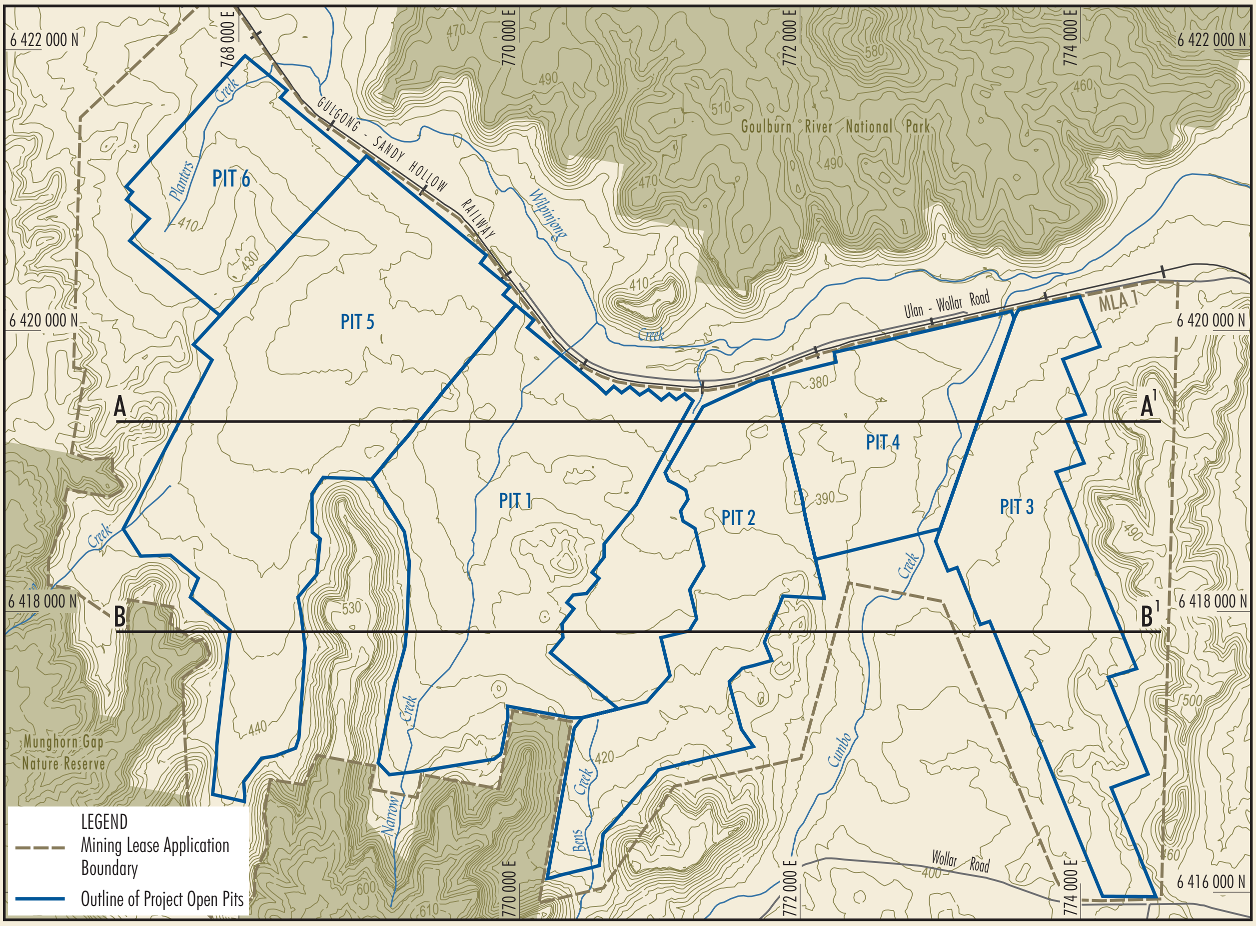

Source: WCPL (2003)

WILPINJONG COAL PROJECT EIS

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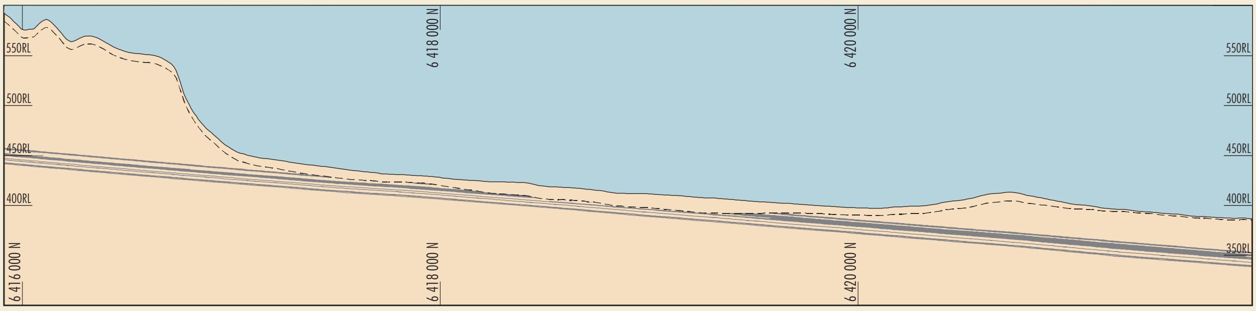
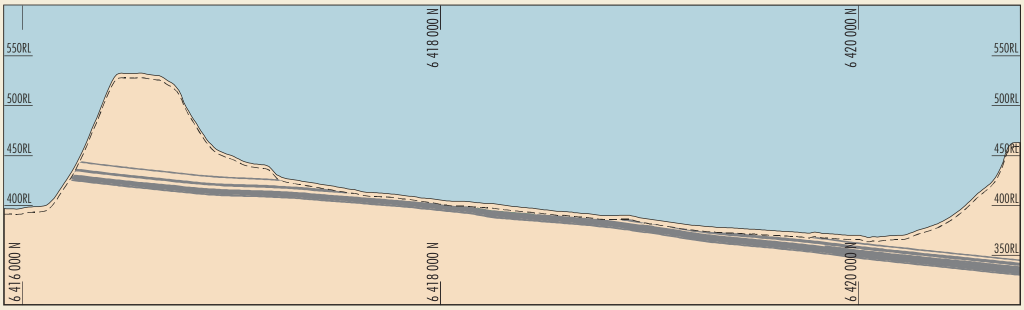
Australasian Groundwater and Environmental Consultants

WIL-04-01 GrWat_004C



LEGEND
Ulan Seam

Cross Section C - C[1]



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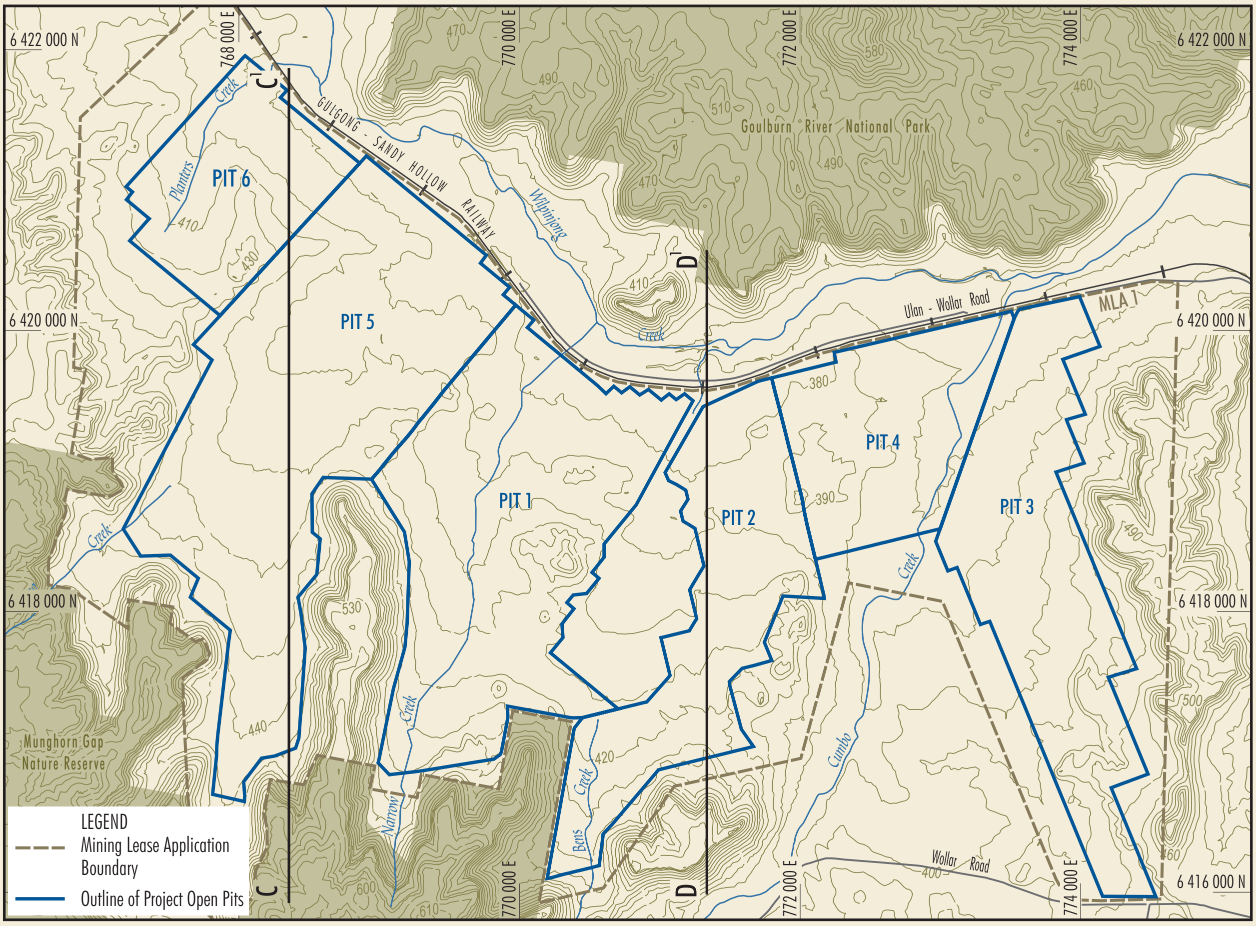

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WILPINJONG COAL PROJECT EIS

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Australasian Groundwater and Environmental Consultants

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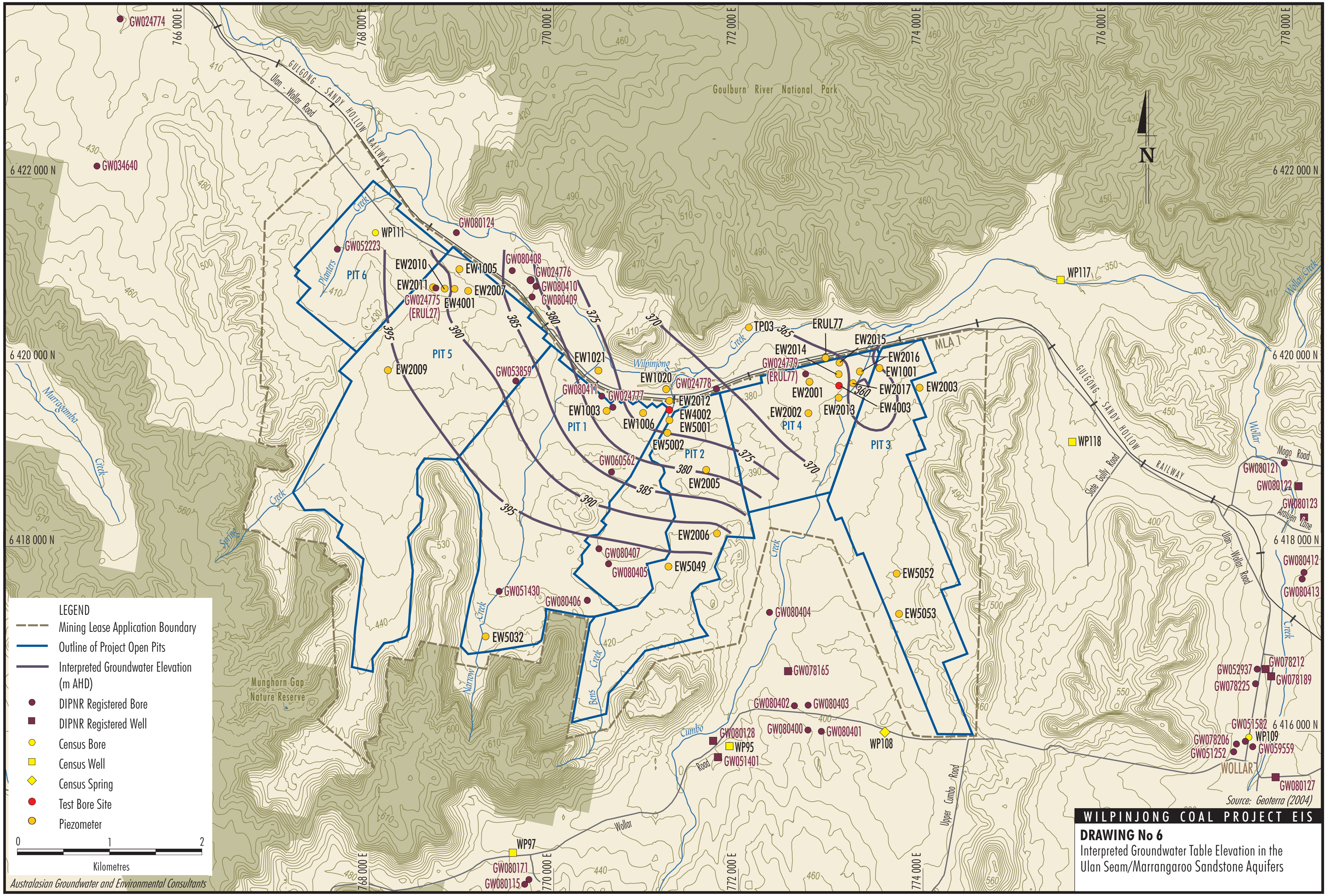

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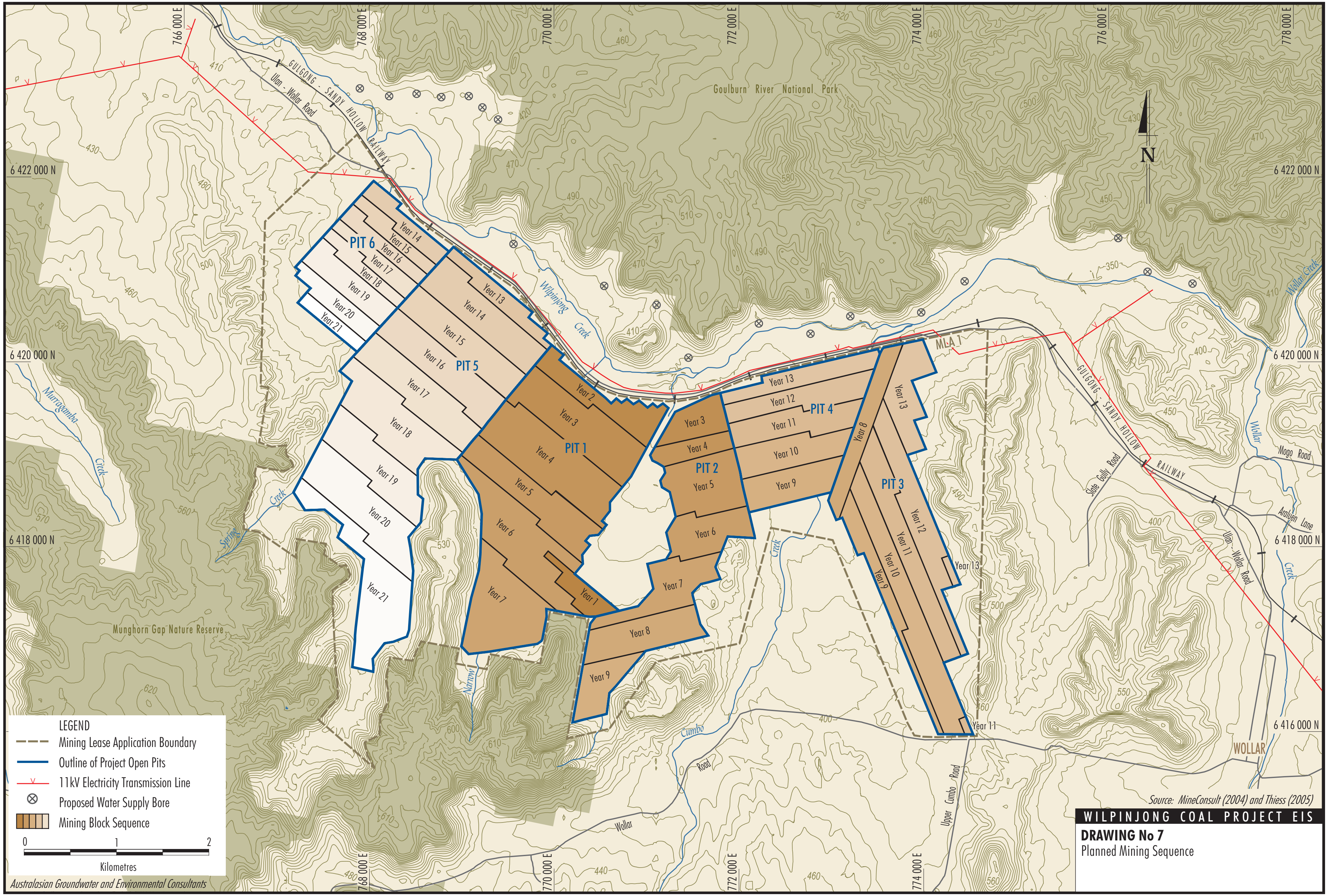

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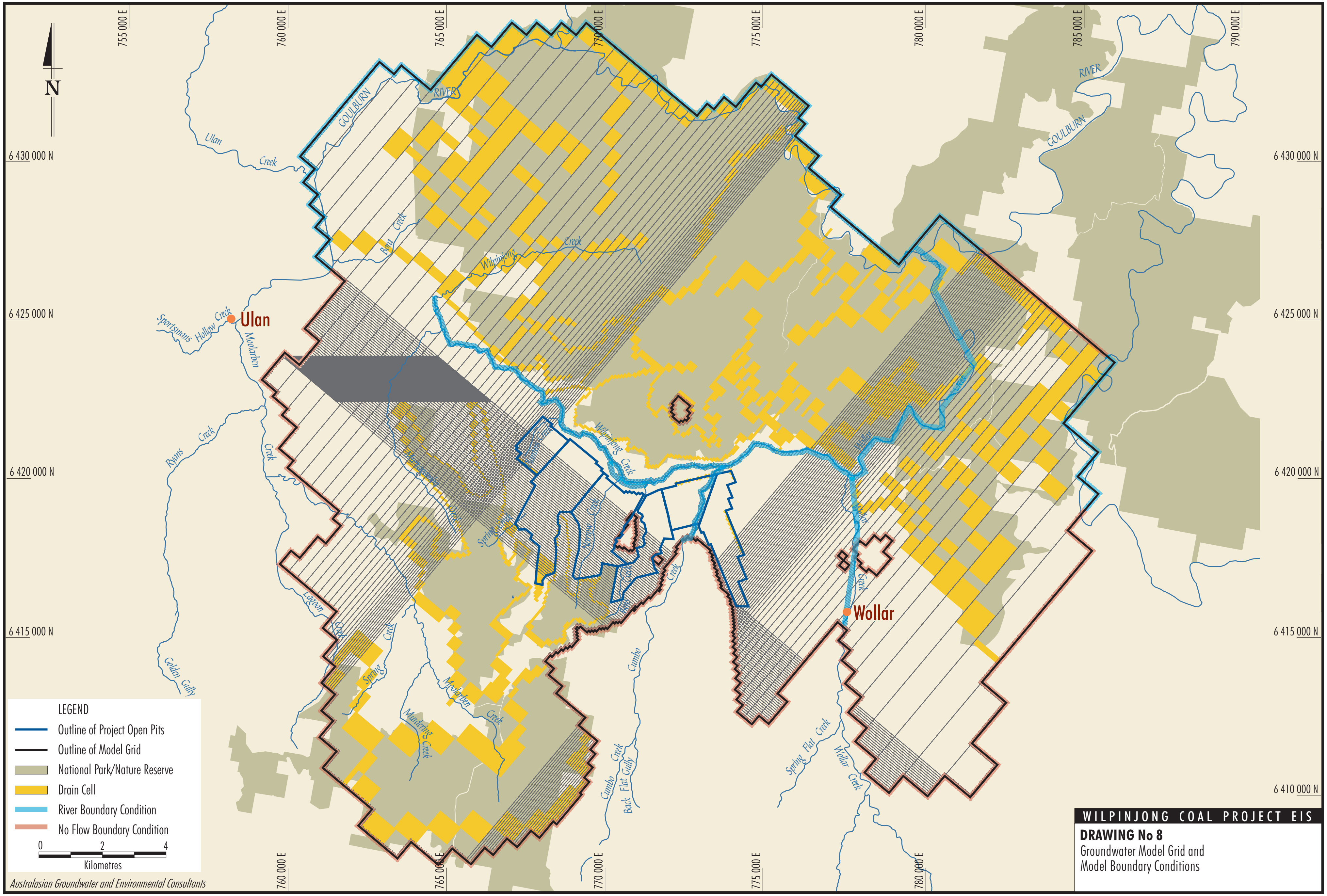

WILPINJONG COAL PROJECT EIS

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Groundwater Model Grid and Model Boundary Conditions

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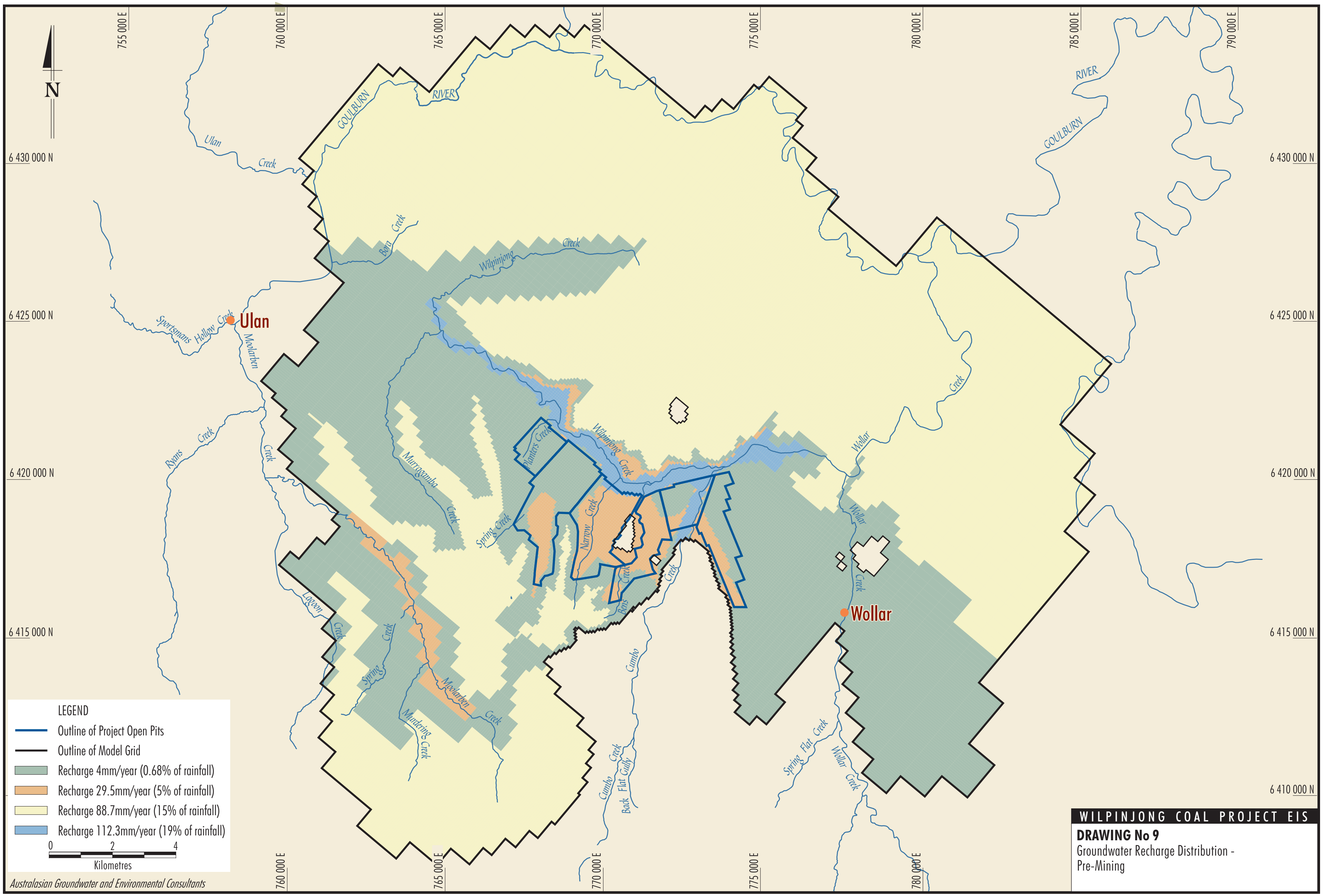

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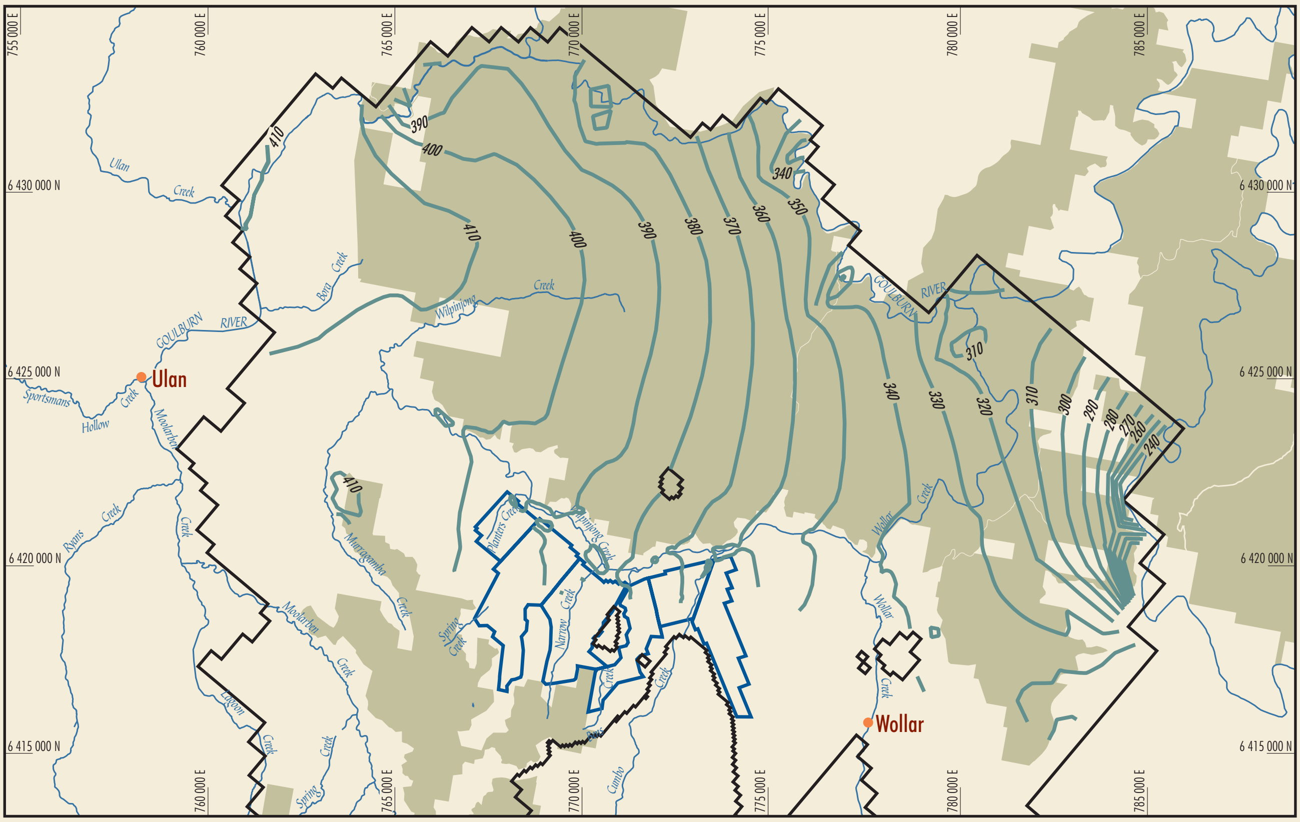
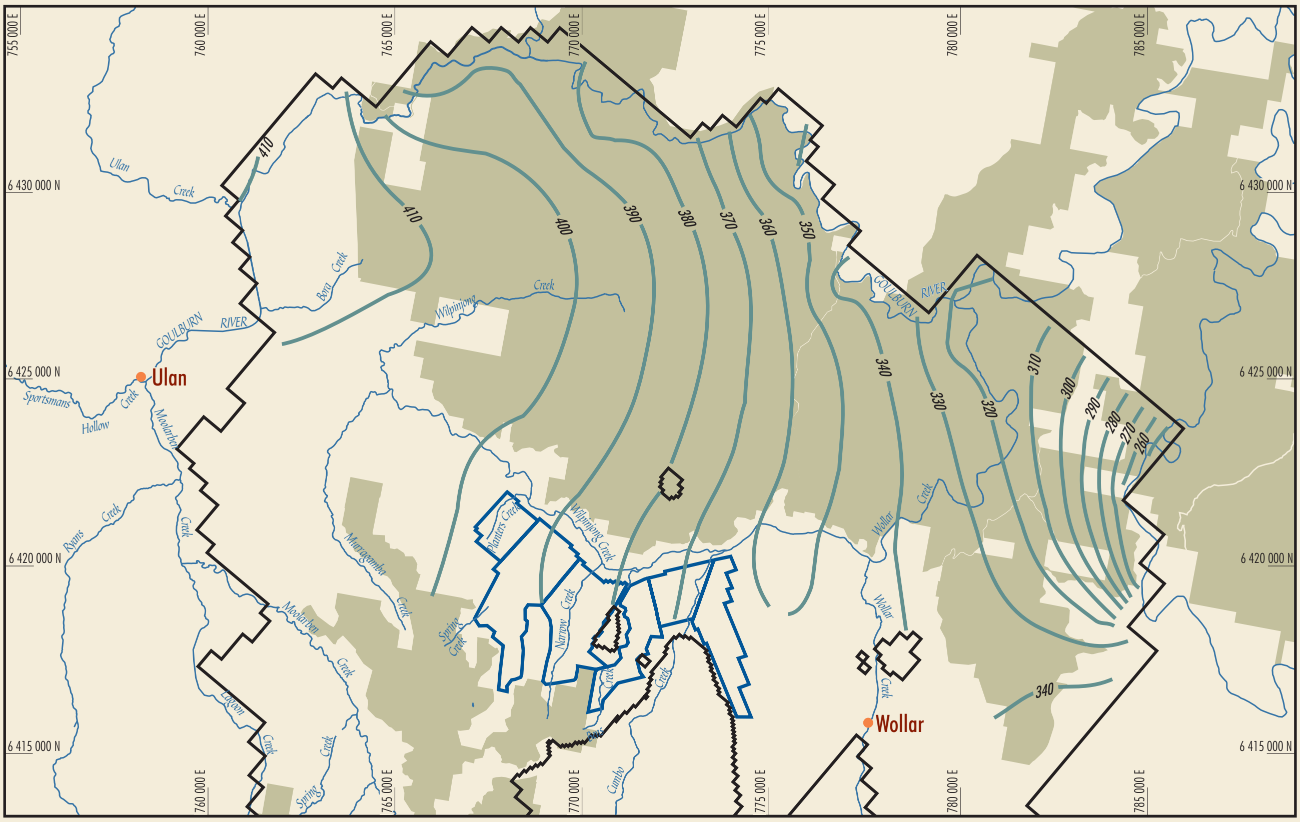


Simulated Groundwater Elevation in Layer 3 (Illawarra Coal Measures)



Simulated Groundwater Elevation in Layer 4 (Ulan Seam)

LEGEND
- Outline of Project Open Pits
- Outline of Model Grid
- National Park/Nature Reserve
- Simulated Steady State Groundwater Elevation (m AHD)

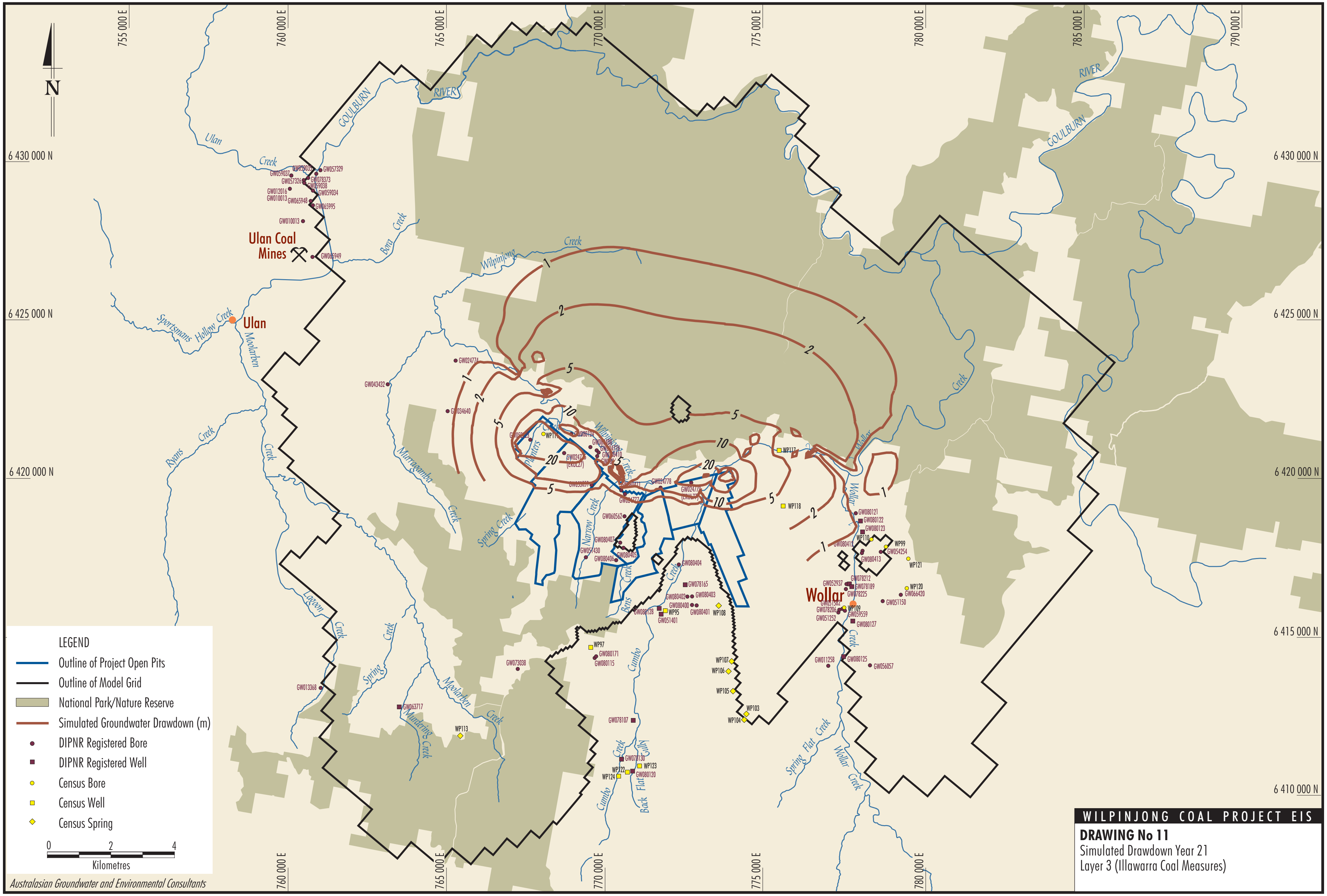
0 2 4
Kilometres

Australasian Groundwater and Environmental Consultants

WILPINJONG COAL PROJECT EIS

DRAWING No 10
Simulated Steady State Groundwater Elevation

WIL-04-01 GrWat_012D



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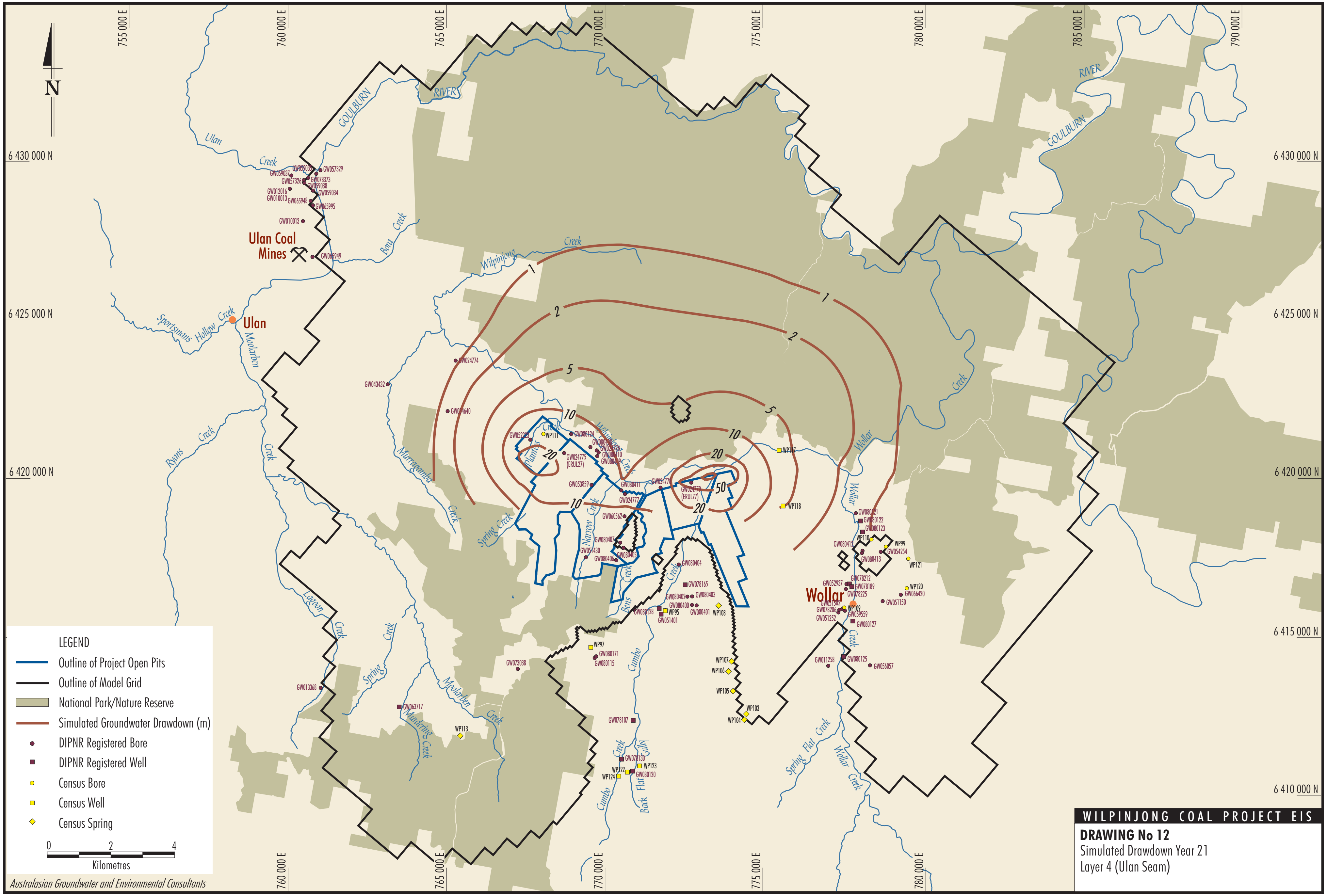

WILPINJONG COAL PROJECT EIS

DRAWING No 12

Simulated Drawdown Year 21

Layer 4 (Ulan Seam)

WIL-04-01 GrWat_013E

ATTACHMENT 1

PREDICTED IMPACTS ON INDIVIDUAL BORES/WELLS IN THE PROJECT AREA AND SURROUNDS

Groundwater Users and Summary of Predicted Impact of the Project

Borehole RN	Easting (m)	Norhing (m)	Type	Formation	Landholder	PREDICTED IMPACT OF THE PROJECT
GW010013	760497	6428105	Bore	Illawarra Coal Measures	Ulan Coal Mines	Outside the Year 21 cone of depression.
GW011258	777037	6414094	Bore	Nile Subgroup		Outside the Year 21 cone of depression Different aquifer system.
GW012016	760093	6429108	Bore	Illawarra Coal Measures	Ulan Coal Mines	Outside the Year 21 cone of depression.
GW013368	761064	6413399	Bore	Illawarra Coal Measures (below Ulan Seam)		Outside the Year 21 cone of depression. Different aquifer system.
GW024774	765310	6423700	Bore	Illawarra Coal Measures	Ulan Coal Mines	Outside the Year 21 cone of depression.
GW024775	768725	6420790	Bore	Illawarra Coal Measures	WCPL	Located in Pit area.
GW024776	769750	6420875	Bore	Alluvium (Wilpinjong Creek)	WCPL	Alluvial bore not expected to be impacted. Located immediately north of Pit 5 area.
GW024777	770640	6419500	Bore	Illawarra Coal Measures	WCPL	Located in Pit area.
GW024778	771760	6419700	Bore	Illawarra Coal Measures	WCPL	Year 21 drawdown between 10m and 20m. Located immediately north of Pit 2 area.
GW024779	772725	6419860	Bore	Illawarra Coal Measures	WCPL	Located in Pit area.
GW034640	765059	6422109	Bore	Illawarra Coal Measures	Ulan Coal Mines	Year 21 drawdown between 1m and 2m.
GW043432	763117	6423005	Well	Murragamba Creek Alluvium (Illawarra Coal Measures)		Outside the Year 21 cone of depression.
GW051150	778750	6416130	Bore	Illawarra Coal Measures		Outside the Year 21 cone of depression.
GW051252	777355	6415774	Bore	Illawarra Coal Measures		Outside the Year 21 cone of depression.
GW051401	771775	6415720	Well	Nile Subgroup (Cumbo Creek Alluvium)		Outside the Year 21 cone of depression. Different aquifer system.
GW051430	769410	6417510	Bore	Illawarra Coal Measures	WCPL	Located in Pit area.
GW051582	777481	6415887	Bore	Illawarra Coal Measures		Outside the Year 21 cone of depression.
GW052223	767660	6421210	Bore	Illawarra Coal Measures	WCPL	Located in Pit area.
GW052937*	777610	6416668	Bore	Illawarra Coal Measures	King	Outside the Year 21 cone of depression.
GW053859	769590	6419785	Bore	Illawarra Coal Measures	WCPL	Located in Pit area.
GW054254	778690	6417680	Bore	Mesozoic Laccolith Intrusion		Outside the Year 21 cone of depression.
GW056057	778350	6414110	Bore	Illawarra Coal Measures		Outside the Year 21 cone of depression.
GW057326	760530	6429380	Bore	Illawarra Coal Measures	Ulan Coal Mines	Outside the Year 21 cone of depression.
GW057329	761057	6429693	Bore	Illawarra Coal Measures	Ulan Coal Mines	Outside the Year 21 cone of depression.
GW059034	760820	6429050	Bore	Illawarra Coal Measures	Ulan Coal Mines	Outside the Year 21 cone of depression.
GW059035	760925	6429580	Bore	Illawarra Coal Measures	Ulan Coal Mines	Outside the Year 21 cone of depression.
GW059037	760140	6429525	Bore	Illawarra Coal Measures	Ulan Coal Mines	Outside the Year 21 cone of depression.
GW059038	760550	6429290	Bore	Illawarra Coal Measures	Ulan Coal Mines	Outside the Year 21 cone of depression.
GW059559	777561	6415829	Bore	Illawarra Coal Measures		Outside the Year 21 cone of depression.
GW060562	770625	6418800	Bore	Illawarra Coal Measures	WCPL	Located in Pit area.
GW063717	763540	6412800	Well	Illawarra Coal Measures (below Ulan Seam)		Outside the Year 21 cone of depression. Different aquifer system.
GW065948	760750	6428725	Bore	Illawarra Coal Measures	Ulan Coal Mines	Outside the Year 21 cone of depression.
GW065949	760740	6427000	Bore	Illawarra Coal Measures	Ulan Coal Mines	Outside the Year 21 cone of depression.
GW065995	760820	6428588	Bore	Illawarra Coal Measures	Ulan Coal Mines	Outside the Year 21 cone of depression.
GW066420	779320	6416330		Illawarra Coal Measures		Outside the Year 21 cone of depression.
GW073038*	767266	6413996	Bore	Illawarra Coal Measures (below Ulan Seam)	Batty	Outside the Year 21 cone of depression. Different aquifer system.
GW078107*	770905	6412382	Well	Cumbo Creek Alluvium (Nile Subgroup)	Conden	Outside the Year 21 cone of depression. Different aquifer system.
GW078130*	770535	6411152	Well	Nile Subgroup (Cumbo Creek Alluvium)	Parker	Outside the Year 21 cone of depression. Different aquifer system.
GW078165	772539	6416649	Well	Nile Subgroup (Cumbo Creek Alluvium)	WCPL	Outside the Year 21 cone of depression. Different aquifer system.
GW078189	777764	6416596	Well	Illawarra Coal Measures (Wollar Creek Alluvium)		Outside the Year 21 cone of depression.
GW078206	777385	6415858	Bore	Illawarra Coal Measures		Outside the Year 21 cone of depression.
GW078212	777698	6416669	Well	Illawarra Coal Measures (Wollar Creek Alluvium)		Outside the Year 21 cone of depression.
GW078225	777592	6416510	Bore	Illawarra Coal Measures		Outside the Year 21 cone of depression.

* Located and recorded during the Bore Census (February 2005)

Groundwater Users and Summary of Predicted Impact of the Project

Borehole RN	Easting (m)	Norhing (m)	Type	Formation	Landholder	PREDICTED IMPACT OF THE PROJECT
GW078373	760668	6429449	Bore	Illawarra Coal Measures	Ulan Coal Mines	Outside the Year 21 cone of depression.
GW080115*	769686	6414341	Bore	Nile Subgroup/ Shoalhaven Group	Kattau	Outside the Year 21 cone of depression. Different aquifer system.
GW080120	770880	6410781	Well	Nile Subgroup (Cumbo Creek Alluvium)		Outside the Year 21 cone of depression. Different aquifer system.
GW080121*	777903	6418897	Bore	Illawarra Coal Measures	Rheinberger	Year 21 drawdown between 1.0 and 1.5m.
GW080122*	778054	6418653	Well	Illawarra Coal Measures (Wollar Creek Alluvium)	Rheinberger	Well in Wollar Creek alluvium not expected to be impacted.
GW080123*	778115	6418310	Well	Illawarra Coal Measures (Wollar Creek Alluvium)	Rheinberger	Well in Wollar Creek alluvium not expected to be impacted.
GW080124	768947	6421389	Bore	Alluvium (Wilpinjong Creek)	WCPL	Alluvial bore not expected to be impacted. Located immediately north of Pit 5 area.
GW080125	777521	6414383	Well	Nile Subgroup (Wollar Creek Alluvium)		Outside the Year 21 cone of depression. Different aquifer system.
GW080127	777810	6415503	Well	Illawarra Coal Measures (Wollar Creek Alluvium)		Outside the Year 21 cone of depression.
GW080128*	771719	6415895	Well	Nile Subgroup (Cumbo Creek Alluvium)	Robinson	Outside the Year 21 cone of depression. Different aquifer system.
GW080171	769732	6414392	Bore	Nile Subgroup		Outside the Year 21 cone of depression. Different aquifer system.
GW080400	772750	6416009	Bore	Nile Subgroup	WCPL	Outside the Year 21 cone of depression. Different aquifer system.
GW080401	772895	6415995	Bore	Nile Subgroup	WCPL	Outside the Year 21 cone of depression. Different aquifer system.
GW080402	772604	6416272	Bore	Nile Subgroup	WCPL	Outside the Year 21 cone of depression. Different aquifer system.
GW080403	772752	6416278	Bore	Nile Subgroup	WCPL	Outside the Year 21 cone of depression. Different aquifer system.
GW080404	772334	6417282	Bore	Cumbo Creek Alluvium/Nile Subgroup	WCPL	Outside the Year 21 cone of depression. Different aquifer system.
GW080405	770593	6417807	Bore	Illawarra Coal Measures (below Ulan Seam)	WCPL	Bore located between Pits 1 and 2 in different aquifer system. No impact expected.
GW080406	770362	6417419	Bore	Illawarra Coal Measures	WCPL	Located in Pit area.
GW080407	770489	6417970	Bore	Illawarra Coal Measures (below Ulan Seam)	WCPL	Bore located between Pits 1 and 2 in different aquifer system. No impact expected.
GW080408	769551	6420978	Bore	Alluvium (Wilpinjong Creek)	WCPL	Alluvial bore not expected to be impacted. Located in Pit 5 area.
GW080409	769766	6420693	Bore	Alluvium (Wilpinjong Creek)	WCPL	Alluvial bore not expected to be impacted. Located immediately north of Pit 5 area.
GW080410	769811	6420808	Bore	Alluvium (Wilpinjong Creek)	WCPL	Alluvial bore not expected to be impacted. Located immediately north of Pit 5 area.
GW080411	770522	6419618	Bore	Illawarra Coal Measures	WCPL	Located in Pit area.
GW080412	778116	6417714	Bore	Mesozoic Laccolith Intrusion		Outside the Year 21 cone of depression.
GW080413	778096	6417643	Bore	Mesozoic Laccolith Intrusion		Outside the Year 21 cone of depression.
WP95*	-	-	Well	Nile Subgroup/ Shoalhaven Group	Robinson	Outside the Year 21 cone of depression. Different aquifer system.
WP97*	-	-	Well	Nile Subgroup/ Shoalhaven Group	Langshaw	Outside the Year 21 cone of depression. Different aquifer system.
WP99*	-	-	Bore	Mesozoic Laccolith Intrusion/ Illawarra Coal measures	Fields	Outside the Year 21 cone of depression.
WP120*	-	-	Bore	Illawarra Coal Measures	Woolford	Outside the Year 21 cone of depression.
WP121*	-	-	Bore	Illawarra Coal Measures	Andrews	Outside the Year 21 cone of depression.
WP110*	-	-	Bore	Mesozoic Laccolith Intrusion/ Illawarra Coal Measures	Batey	Outside the Year 21 cone of depression.
WP111*	-	-	Bore	Illawarra Coal Measures	WCPL	Located in Pit area.
WP117*	-	-	Well	Wilpinjong Creek Alluvium	Smith	Alluvial bore not expected to be impacted.
WP118*	-	-	Well	Illawarra Coal Measures	WCPL	Year 21 drawdown between 5.0 and 10.0m.
WP109*	-	-	Bore	Illawarra Coal Measures	McDermott	Outside the Year 21 cone of depression.
WP122*	-	-	Well	Nile Subgroup (Cumbo Creek Alluvium)	Rheinberger	Outside the Year 21 cone of depression. Different aquifer system.
WP123*	-	-	Well	Nile Subgroup (Cumbo Creek Alluvium)	Rheinberger	Outside the Year 21 cone of depression. Different aquifer system.
WP124*	-	-	Well	Nile Subgroup (Cumbo Creek Alluvium)	Seaman	Outside the Year 21 cone of depression. Different aquifer system.

* Located and recorded during the Bore Census (February 2005)

Groundwater Users and Summary of Predicted Impact of the Project

Borehole RN	Easting (m)	Norhing (m)	Type	Formation	Landholder	PREDICTED IMPACT OF THE PROJECT
WP103*	774481	6414153	Spring	Illawarra Coal Measures/ Nile Subgroup	McKenzie	Outside the Year 21 cone of depression. Different aquifer system.
WP104*	775329	6412398	Spring	Illawarra Coal Measures/ Nile Subgroup	McKenzie	Outside the Year 21 cone of depression. Different aquifer system.
WP105*	774027	6413317	Spring	Illawarra Coal Measures/ Nile Subgroup	McKenzie	Outside the Year 21 cone of depression. Different aquifer system.
WP106*	773881	6414033	Spring	Illawarra Coal Measures/ Nile Subgroup	McKenzie	Outside the Year 21 cone of depression. Different aquifer system.
WP107*	773980	6414267	Spring	Nile Subgroup	Gaffney	Outside the Year 21 cone of depression. Different aquifer system.
WP108*	773576	6416004	Spring	Nile Subgroup	Gaffney	Outside the Year 21 cone of depression. Different aquifer system.
WP113*	765420	6411650	Spring	Narrabeen Group	O'Sullivan	Outside the Year 21 cone of depression. Different aquifer system.

* Located and recorded during the Bore Census (February 2005)