Appendix

O

Groundwater Assessment

Australasian
Groundwater & Environmental
Consultants Pty Ltd

REPORT on

CONTINUATION OF BOGGABRI COAL MINE

GROUNDWATER ASSESSMENT

prepared for
BOGGABRI COAL PTY LIMITED

Project No. G1465
October 2010

ABN:64 080 238 642

Australasian
Groundwater & Environmental
Consultants Pty Ltd

REPORT on

CONTINUATION OF BOGGABRI COAL MINE

GROUNDWATER ASSESSMENT

prepared for
BOGGABRI COAL PTY LIMITED

Project No. G1465
October 2010

36 Jeays Street
Bowen Hills Qld 4006
Ph (+617) 3257 2055
Fax (+617) 3257 2088
Email: brisbane@ageconsultants.com.au
Web: www.ageconsultants.com.au

A.B.N 64 080 238 642

TABLE OF CONTENTS

Page No.

TABLE OF CONTENTS
(continued)

Page No.

Attachments:

REPORT ON

CONTINUATION OF BOGGABRI COAL MINE GROUNDWATER ASSESSMENT

1.0 INTRODUCTION

The Boggabri Coal Mine, located on lease CL368, was approved in 1990 for open cut coal mining of up to 5 Million tonnes per annum (Mtpa) for a period of 21 years. This development consent is due to expire on 15 November 2011 and as such Boggabri Coal Pty Limited (Boggabri Coal) are seeking a Project Approval under Part 3A of the *Environmental Planning & Assessment Act 1979* (EP&A Act) for continuation of its mining operations within its current mining tenements for a further 21 years (the Project). The current mining lease is shown in Drawing No. 1.

Hansen Bailey Pty Ltd (Hansen Bailey) has been commissioned by Boggabri Coal to prepare an Environmental Assessment (EA) in support of the Part 3A Project Application. This groundwater impact assessment has been completed by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) at the request of Hansen Bailey, on behalf of their client Boggabri Coal and forms part of the EA.

2.0 PROJECT OVERVIEW

The Project seeks approval for continuation of all aspects of Boggabri Coal Mine's activities including:

- Continuation of mining operations via open cut methods up to 7 Mtpa product coal to the Merriown Seam with an overburden emplacement height of approximately RL 395m,
- Open cut mining fleet including excavators and fleet of haul trucks, dozers, graders, water carts and other equipment with the flexibility to introduce a dragline as required utilising up to 500 employees,
- Modifications to existing and continuation of approved (but not yet constructed) infrastructure including:
  - Coal Handling and Preparation Plant (CPP);
  - Modifications to existing site infrastructure capacities including: Run of Mine (ROM) coal hopper, second crusher, stockpile area, coal loading facilities, water management and irrigation system;
  - Rail loop and 17km rail line across the Namoi River and floodplain including overpasses across the Kamilaroi Highway, Therribri Road and Namoi River;
  - Minor widening of the existing coal haul road;

  - Upgrading and relocating site facilities including offices, car parking and maintenance sheds as and when required;
- Closing a section of Leard Forest Road; and
- Upgrading the power supply capacity to 132 kilovolt (kV) high voltage lines suitable for dragline operations.

3.0 SCOPE OF WORK

The Director Generals Requirements for the surface and groundwater assessments provided by NSW Department of Planning are as follows:

- a detailed assessment of potential surface water and groundwater impacts (including cumulative impacts);
- a detailed site water balance, including a description of the measures to be implemented to minimise water use on site;
- a detailed assessment of the potential impacts of the project on:
  - the quality and quantity of both surface water and ground water resources;
  - water users, both in the vicinity of and downstream of the project;
  - the riparian and ecological values of the watercourses both on site and downstream of the project; and
  - environmental flows; and
- a detailed description of the proposed water management system for the project and water monitoring program.

The objective of the groundwater study was to assess the impact of the Project on the hydrogeological regime and to meet the applicable Director Generals Requirements. To achieve this objective a scope of work was developed that included:

- identification of groundwater resources in the vicinity of the site which could be impacted by the Project;
- a site visit to discuss the project with staff at the mine;
- assessment of the potential for any groundwater impacts resulting from the Project, including modelling the cumulative groundwater impacts of the Project with existing industry or approved mining projects (including groundwater impacts on each identified privately owned bore);
- an assessment of the potential for contaminant migration from co-disposed materials to enter and impact on the local and regional groundwater system;
- assessment of post-mine groundwater impacts including predicted final void water levels;
- the development of groundwater management strategies;
- identification of any groundwater impact mitigation measures necessary for the Project;
- a recommended groundwater management program.

The study area for the groundwater investigation was an approximate radius of 15km surrounding the Project Boundary, encompassing the alluvial aquifers surrounding the mine.

4.0 LEGISLATION, POLICY AND GUIDELINES

The following section outlines New South Wales State Government legislation, policy and guidelines with respect to groundwater that must be addressed in assessing a mining proposal.

4.1 Water Management Act 2000

The objective of the *Water Management Act 2000* (WM Act) is the sustainable and integrated management of the State's water for the benefit of both present and future generations. The WM Act provides clear arrangements for controlling land based activities that affect the quality and quantity of the State's water resources. It provides for four types of approval:

- water use approval – which authorise the use of water at a specified location for a particular purpose, for up to 10 years;
- water management work approval;
- controlled activity approval; and
- aquifer interference activity approval – which authorises the holder to conduct activities that affect an aquifer such as approval for activities that intersect groundwater, other than water supply bores and may be issued for up to 10 years.

For controlled activities and aquifer interference activities, the WM Act requires that the activities avoid or minimise their impact on the water resource and land degradation, and where possible the land must be rehabilitated.

The Water Management Act 2000 is progressively replacing the *Water Act 1912* but some provisions are still in force. Boggabri Coal has two groundwater licences under Part 5 of the Water Act 1912 to extract groundwater from the Gunnedah Basin (90BL255090 and 90BL253854) as part of dewatering the open cut pit with an annual limit of 142ML.

4.2 Water Sharing Plan for the Upper and Lower Namoi Groundwater Sources

The Water Sharing Plan for the Upper and Lower Namoi Groundwater Sources commenced in November 2006. The water sharing plan sets the framework for managing groundwater in the Upper and Lower Namoi alluvial aquifers until the end of the 2015/16 water year.

The Water Sharing Plan includes all water contained in the unconsolidated alluvial sediment aquifers associated with the Namoi River and its tributaries and is subdivided into 13 zones. The Boggabri Coal Mine is located in an area of outcropping bedrock surrounded by Zone 4 to the south, Zone 5 to the west and Zone 11 to the north. The location of the zones is shown in Figure 1.

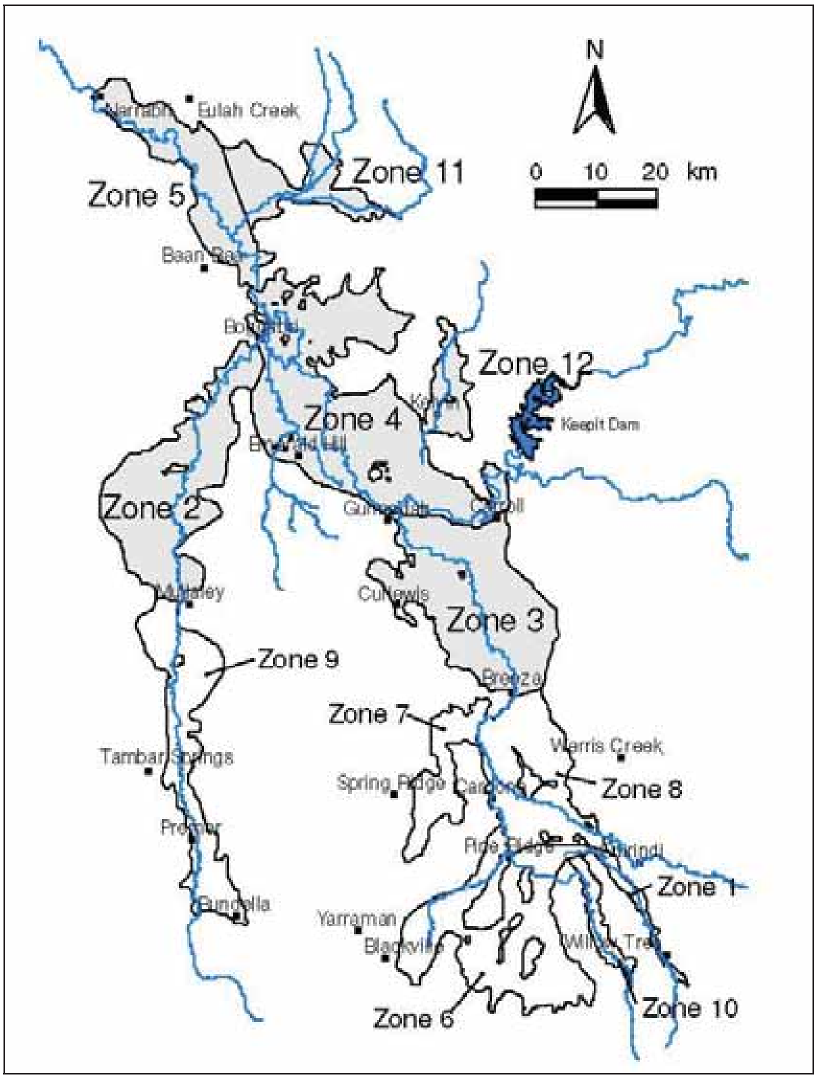


Figure 1: Upper Namoi Alluvial Aquifer Zones (after NOW 2006)

The objectives of the Water Sharing Plan are to:

"(a) protect, maintain and, where practicable, enhance ecosystems dependent on groundwater, and the cultural and spiritual values of groundwater, by minimising the impacts on these of groundwater extraction,

(b) protect the structural integrity of the aquifers and groundwater quality, by ensuring groundwater extraction does not result in any aquifer compaction, aquitard compaction, land subsidence or change in the beneficial use of the aquifer,

(c) manage access to the extraction limits to ensure there are no long-term declines in water levels,

(d) preserve basic landholder rights access to these groundwater sources and ensure the fair, equitable and reliable access to groundwater through the management of local impacts or interference effects,

(e) contribute to the protection, maintenance and enhancement of the economic viability of groundwater users and their communities in the Namoi Valley,

(f) ensure opportunities for market based trading of groundwater access licence rights within sustainability and interference constraints, and

(g) ensure sufficient flexibility in account management to encourage efficient use of these groundwater sources and to manage these groundwater sources to account for climatic variations."

A summary of the aquifer access licences presented in the Water Sharing Plan for zones surrounding Boggabri Mine are summarised in Table 1.

Table 1: SUMMARY OF AQUIFER ACCESS LICENCES

Category	Aquifer Volumetric Licence (ML/yr)			
	Zone 4	Zone 5	Zone 11	TOTAL
Domestic and Stock	667	262	210	1139
Native Title	0	0	0	0
Local Water Utility	4,660 3,900 Gunnedah 760 Boggabri	None	None	4660
Share Components	21,040	16,000	2,200	37,040
Recharge	25,700	16,000	2,200	43,900

Boggabri Mine currently holds Water Access Licence 15037 (90AL807033 90CA807034) in Zone 4, for 52 unit shares which can be extracted from a bore on the Daisymede property.

4.3 State Groundwater Policy

The NSW State Groundwater Policy (Framework Document) was adopted in 1997 and aims to manage the State's groundwater resources to sustain their environmental, social and economic uses. The policy has three components parts, namely:

- the NSW Groundwater Quality Protection Policy, adopted in December 1998;
- the NSW State Groundwater Dependent Ecosystems Policy adopted in 2002; and
- the NSW Groundwater Quantity Management Policy (undated document).

4.3.1 Groundwater Quality Protection

The NSW Groundwater Quality Protection Policy (1998), states that the objectives of the policy will be achieved by applying the management principals listed below.

1. *"All groundwater systems should be managed such that their most sensitive identified beneficial use (or environmental value) is maintained.*

2. *Town water supplies should be afforded special protection against contamination.*

3. *Groundwater pollution should be prevented so that future remediation is not required.*

4. *For new developments, the scale and scope of work required to demonstrate adequate groundwater protection shall be commensurate with the risk the development poses to a groundwater system and the value of the groundwater resource.*

5. *A groundwater pumper shall bear the responsibility for environmental damage or degradation caused by using groundwaters that are incompatible with soil, vegetation and receiving waters.*

6. *Groundwater dependent ecosystems will be afforded protection.*

7. *Groundwater quality protection should be integrated with the management of groundwater quality.*

8. *The cumulative impacts of developments on groundwater quality should be recognised by all those who manage, use, or impact on the resource.*

9. *Where possible and practical, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored."*

4.3.2 Groundwater Dependent Ecosystems

The NSW Groundwater Dependent Ecosystems Policy is specifically designed to protect valuable ecosystems which rely on groundwater for survival so that, wherever possible, the ecological processes and biodiversity of these dependent ecosystems are maintained or restored for the benefit of present and future generations. The policy defines Groundwater Dependent Ecosystems as *"communities of plants, animals and other organisms whose extent and life processes are dependent on groundwater".*

Five management principles establish a framework by which groundwater is managed in ways that ensure, whenever possible, that ecological processes in dependent ecosystems are maintained or restored. A summary of the principles follows:

- groundwater dependent ecosystems (GDEs) can have important values. Threats should be identified and action taken to protect them;
- groundwater extractions should be managed within the sustainable yield of aquifers;
- priority should be given to GDEs, such that sufficient groundwater is available at all times to meet their needs;
- where scientific knowledge is lacking, the precautionary principle should be applied to protect GDEs; and
- planning, approval and management of developments should aim to minimise adverse affects on groundwater by maintaining natural patterns, not polluting or causing changes to groundwater quality and rehabilitating degraded groundwater ecosystems where necessary.

4.3.3 Groundwater Quantity Protection

The objectives of managing groundwater quantity in New South Wales are:

- *"to achieve the efficient, equitable and sustainable use of the State's groundwater;*
- *to prevent, halt and reverse degradation of the State's groundwater and their (sic) dependent ecosystems;*
- *to provide opportunities for development which generate the most cultural, social and economic benefits to the community, region, state and nation, within the context of environmental sustainability; and*
- *to involve the community in the management of groundwater resources."*

4.4 Aquifer Risk

The "Aquifer Risk Assessment Report" of 1998[1] used a number of criteria to classify risks to various significant groundwater resources across the State. It classified the Upper Namoi Valley Alluvium as a "highest risk aquifer".

5.0 REGIONAL SETTING

5.1 Location

The Boggabri Coal Mine is located approximately 15km north-east of the township of Boggabri in the Leard State Forest. Boggabri is situated approximately 40km and 60km from the larger centres of Gunnedah and Narrabri respectively. The mine is located within the Leard State Forest on mining lease CL368 which covers an area of approximately 3,544ha (see Drawing No. 1).

The Leard State Forest covers an area of approximately 8,134ha and incorporates the Willow Tree Range that surrounds the existing mining are to the east, north and west. The Tarrawonga Mine is located adjacent to the existing Boggabri Coal Mine to the south.

The locations of the key facilities are shown in Drawing No. 2 along with the adjacent Tarrawonga Mine.

5.2 Existing Mining Operation

Boggabri Coal mine is an open cut mining operation with approval to produce up to 5 Mtpa of thermal coal. In 2009 Boggabri Coal produced 1.5 Million tons (Mt) of thermal coal for the export market.

Construction of the Boggabri Coal Mine commenced in 2005 and included: a 17km bitumen sealed private coal haul road, bridge over the Namoi River and Kamilaroi Highway, ROM coal pad, crusher, conveyors and a truck load out facility; a product stockpile, train loading facility; and the Mine Infrastructure Area including workshop and offices. The first coal was delivered to the ROM coal pad in October 2006 and the construction activities were largely completed by November

[1] NSW Department of Land and Water Conservation, (April 1998), *"Aquifer Risk Assessment Report",* HO/16/98.

2006. The current method of open cut mining allows coal extraction to occur in the uppermost seams including the Braymont, Bollol Creek, Jeralong and Merriown Coal Seams to a depth of approximately 110m.

A CPP, tailings dam, rail spur and mine site rail loop are approved but have not yet been constructed nor has a dragline been introduced.

5.3 Topography and Drainage

The topography of the area is controlled by the underlying geology that is comprised of volcanic basement overlain by sedimentary coal measures, which are inturn overlain by alluvial sediments. The alluvial lands form a relatively flat floodplain adjacent to the Namoi River and following tributaries in an easterly direction where the flood plain is broad and gently sloping. The alluvial land falls gently from about RL 340m in the east to RL 230 at the Namoi River over a distance of about 20km.

The outcrop of the basement geology is evident as upland slopes and hills that rise up to between RL 400m and RL 500m in the area of the Boggabri Coal Mine. Away from the ridgelines, the topography is gently undulating and ground slopes are principally less than 10%. The hills and slopes are drained by a series of generally westerly flowing ephemeral creeks that meander across the floodplain and discharge to the Namoi River. Nagero Creek originates within the mining lease and flows in a westerly direction. The confluence of Goonbri Creek and Bollol Creek is located about 4km to the south of the operation.

The Namoi River is the most significant water body in the Namoi Valley and flows in a north-westerly direction passing through the town of Boggabri. The Namoi River is about 10km west of the Boggabri Coal Mine.

5.4 Land Use

The predominant land uses in the EA Boundary is the existing Boggabri Coal Mine, forestry and recreational use of the state forest. Land use in the wider region also includes forestry, mining and agriculture. Forestry activities occur predominantly on the steeper slopes and poorer soils. To the south of the Boggabri Coal Mine is the fertile Namoi River alluvial floodplain as shown on Drawing No. 1 which supports an array of agricultural enterprises including cotton, wheat and cattle grazing.

5.5 Climate

The climate in the vicinity of the Project Boundary is temperate and is characterised by hot summers with regular thunderstorms and mild dry winters. Rainfall records collected by the Bureau of Meteorology (BoM) were obtained from the Boggabri Post Office which is located about 17 km to the south-west of the Project Boundary, and the Gunnedah Pool, located about 41km to the south. A summary of climate data is provided in Table 2.

Table 2: CLIMATE AVERAGES

Month	Mean Daily Temperature (°C)				Mean Monthly Rainfall (mm)		Mean Monthly Rain Days		Mean Monthly Relative Humidity (%)*		Mean Monthly Evaporation (mm)**
	Gunnedah Pool		Boggabri Met Dataset		Gunnedah Pool	Boggabri Met Dataset	Gunnedah Pool	Boggabri Met Dataset			
	Min	Max	Min	Max					9:00 AM	3:00 PM	
January	18.3	34.0	19.6	34.5	71.1	56.0	6.5	6.0	60.0	43.0	238.7
February	18.1	32.9	18.8	32.9	66.5	100.1	6.1	8.7	65.0	45.0	197.2
March	15.8	30.7	15.1	31.1	47.9	19.1	4.6	2.3	64.0	44.0	186.0
April	11.4	26.4	12.3	25.5	37.7	13.0	4.3	2.5	67.0	46.0	132.0
May	7.1	21.3	3.0	22.0	42.5	50.0	5.1	3.0	73.0	51.0	83.7
June	4.3	17.6	6.5	17.9	43.9	57.2	6.3	6.5	78.0	55.0	57.0
July	3.0	16.9	3.9	16.9	42.2	36.1	6.2	4.0	77.0	53.0	58.9
August	4.1	18.9	5.4	22.6	41.3	38.7	6.1	3.3	71.0	48.0	86.8
September	6.9	22.8	8.6	22.4	39.6	37.1	5.8	2.7	65.0	43.0	120.0
October	10.7	26.7	12.3	27.4	55.2	27.6	6.9	4.0	61.0	43.0	164.3
November	14.1	30.3	16.2	26.7	61.2	78.3	6.8	8.0	59.0	40.0	201.0
December	16.8	33.0	17.8	30.0	68.0	80.7	6.9	8.3	58.0	40.0	241.8
Annual Mean / Total	**10.9**	**26.0**	**12.4**	**26.2**	**617.1**	**593.9**	**71.6**	**59.3**	**67.0**	**46.0**	**1767.4**

The average annual rainfall at Boggabri is 594mm with February being the wettest month (101mm). Evaporation of 1,767mm/year exceeds mean rainfall throughout the year, with the highest moisture deficit occurring during summer.

Monthly rainfall records were used to calculate the Cumulative Rainfall Deficit (CRD - also referred to as the Rainfall Residual Mass) for the Boggabri Post Office (refer Figure 2). The CRD is a summation of the monthly departure of rainfall from the long-term average monthly rainfall and provides a historical record of relatively wet and dry periods. A rising trend in slope in the CRD plot indicates periods of above average rainfall, whilst a declining slope indicates periods when rainfall was below average. The CRD for Boggabri indicates a long cycle of below average rainfall from about 1910 to 1947. From 1947 to 1980 the pattern was dominated by above average falls indicated by the rising trend in the graph. Since 1980 there have been several cycles of above and below average rainfall each of about 10 years in duration.

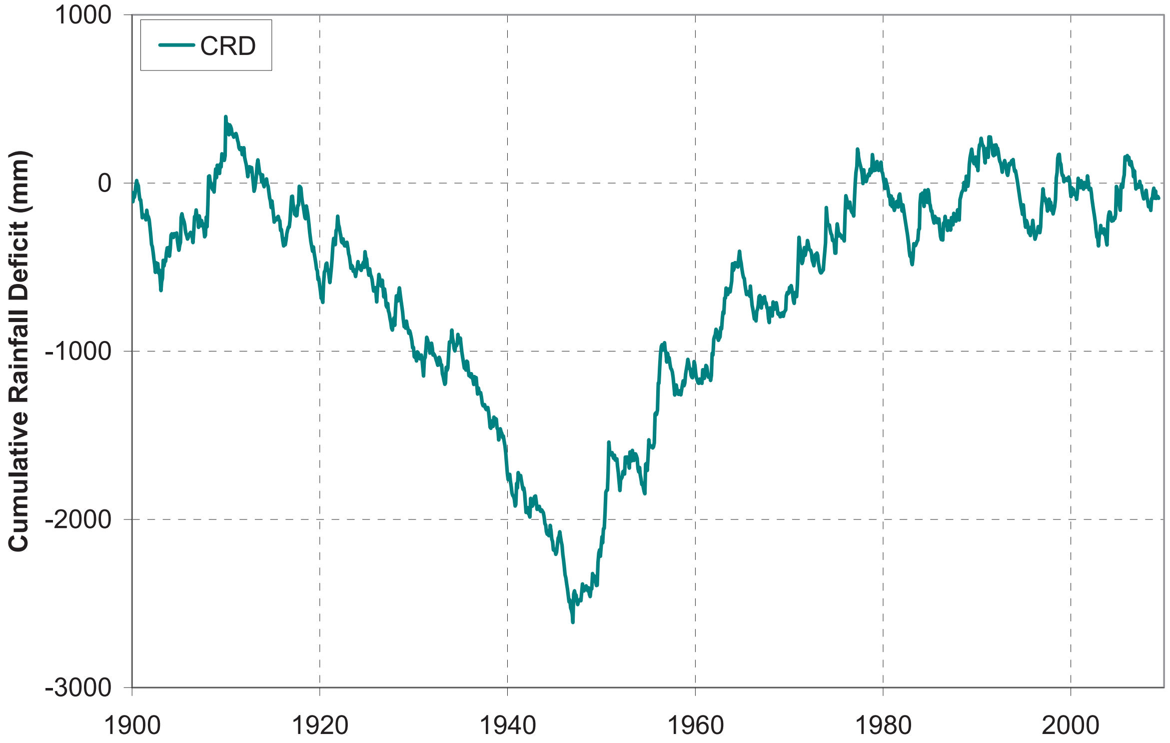


Figure 2: Cumulative Rainfall Deficit - Boggabri Post Office (mm)

5.6 Geology

The Boggabri coal deposit which is early Permian in age and part of the Bellata Group is located in the Maules Creek sub-basin. The Maules Creek sub-basin is underlain by the Boggabri Volcanics, and is physically separated from the western Mullaly sub-basin by a basement ridge formed by the Boggabri Volcanics (refer Figure 3).

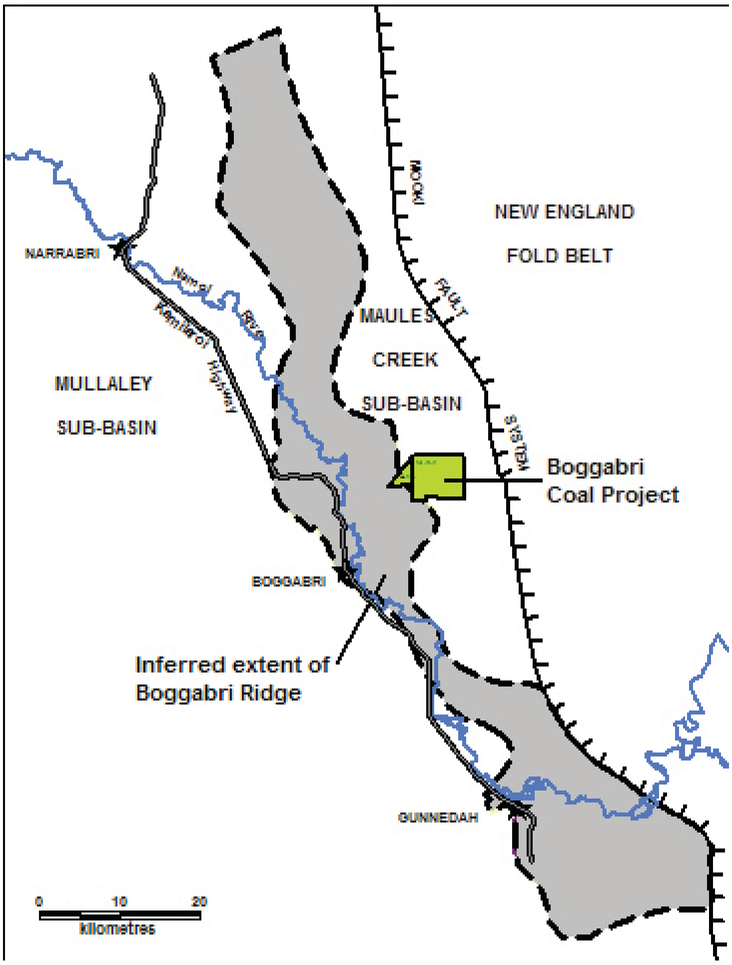


Figure 3: Maules Creek Sub-Basin

The Boggabri volcanics were subject to extensive erosion and weathering during the very early Permian resulting in the formation of an irregular palaeo-topography onto which the Belatta Group coal deposits were laid. A large area of the Permian bedrock is covered with an extensive blanket of unconsolidated Cainozoic sediments as shown in the regional geology map published by the then Department of Mineral Resources (now Department of Infrastructure and Investment [DII]) (1993)[2] which is reproduced in Drawing No. 3. The Cainozoic sediments can be subdivided into two distinct aquifers being the basal Gunnedah Formation and the overlying surficial Narrabri Formation.

The surface geology and a cross-section through the mining lease are shown in Figure 4.

[2] Department of Mineral Resources (1993). *"Gunnedah Coalfield (North) Regional Geology",* Geological Series Sheet including parts of 8836, 8837, 8936, 8937 first edition 1998.

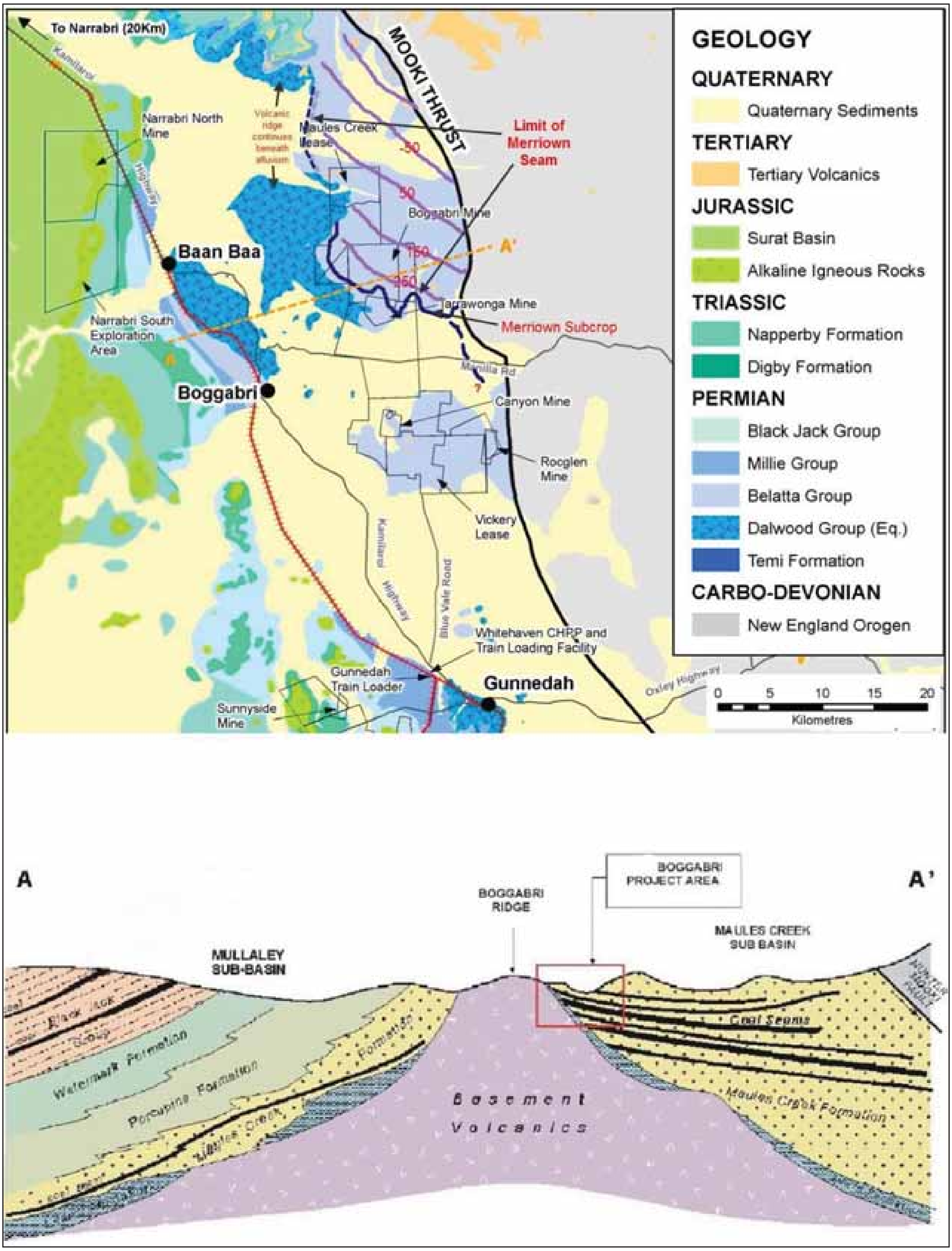


Figure 4: Geology and Cross Section

The Maules Creek Formation forms a regular layered easterly dipping sedimentary sequence that gradually thickens to the east to over 800m at the Mooki thrust fault. The Maules Creek Formation consists predominantly of conglomerate and sandstone, with minor siltstone, claystones and intercalated coal seams.

A total of 16 coal seams have been formally identified in the area of lease CL368. Boggabri Coal Mine currently recovers coal from the upper Braymont, Bollol Creek, Jeralong and Merriown Seams. Average thickness of coal seams in the above sequence is between 0.5m up to 5.0m. The generalised stratigraphy of the site is shown graphically in Figure 5.

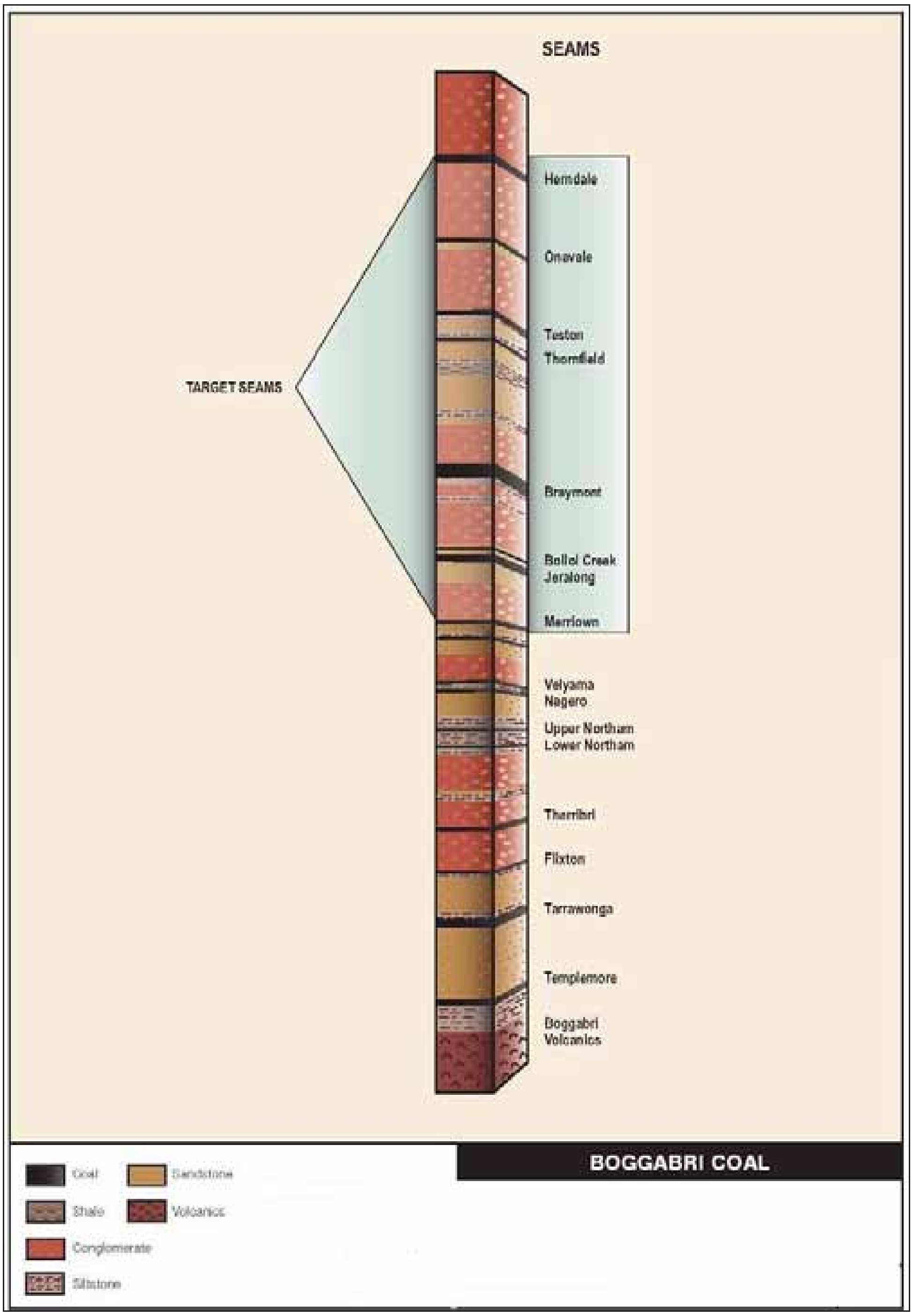


Figure 5: Generalised Stratigraphy

6.0 HYDROGEOLOGICAL REGIME

6.1 Previous Groundwater Investigations

A number of hydrogeological investigations have been undertaken at the Project site dating back to the late 1970s. The first investigation was undertaken by AMAX Coal Company in 1978 and included the installation and short term test pumping of five bores. The work is documented in a brief internal memo by Herring (1979)[3]. This was followed up with a more detailed investigation undertaken by Australian Groundwater Consultants [AGC] (1984)[4] that formed the basis of the original project Environmental Impact Statement. Short term airlift testing was undertaken to estimate coal seam permeability and the data used to estimate groundwater seepage rates to the proposed open cut pit. Australian Groundwater Consultants (1981)[5] also investigated the potential to develop a borefield in the alluvial aquifer about 12km to the west of the lease to supply process water to the mine. This investigation included a four day pumping test and recommendations for borefield design. The borefield was not developed.

Prior to the commencement of the Boggabri Coal Mine, Parsons Brinkerhoff [PB] (2005)[6] undertook a baseline groundwater assessment that included installation of monitoring bores, permeability testing and groundwater modelling of the first 6 years of the mine life. The groundwater model was subsequently recalibrated and detailed in Parsons Brinkerhoff (2008)[9]. The assessment found that mining activities would not impact on the alluvial aquifers and predicated a groundwater inflow rate in 2011 of up to 0.94ML/day.

Outside the mining lease the Namoi valley alluvial aquifer has been much more heavily investigated by government water departments and research institutions. The most recent report on the alluvial aquifer relevant to the current study is the groundwater model prepared for groundwater management zones 2, 3, 4, 5, 11 and 12 by New South Wales Office of Water [NOW] (2006)[7], formerly New South Wales Department of Natural Resources (2006). Also of relevance is groundwater modelling undertaken by CSIRO (2007)[8] that used previously developed models to investigate sustainable yields of surface water and groundwater in the Namoi Valley.

Relevant information from the above reports is provided in the following discussion of the hydrogeological regime of the alluvial and bedrock aquifers.

[3] Herring (1979), Memo *"Boggabri Groundwater Study",* AMAX Coal Company, August 1978.

[4] Australian Groundwater Consultants (1982). *"Boggabri Mine Site Hydrogeological Review and Pit Inflow Estimates",* Report 694/1, October 1982.

[5] Australian Groundwater Consultants (1981), *"Boggabri Coal Project, Water Resource Evaluation".*

[6] Parsons Brinkerhoff (2005), *"Boggabri Coal Project – Groundwater Assessment, December 2005",* for Idemistu Boggabri Coal Pty Ltd.

[7] New South Wales Department of Natural Resources (2006). *"Upper Namoi groundwater flow model, Groundwater Management Area 004; Zones 2,3,4,5,11 and 12, model development and calibration"*, prepared by Craig McNeilage.

[8] CSIRO, (2007), "*Water Availability in the Namoi – A Report to the Australian Government from the CSIRO Murray Darling Commission Sustainable Yields Project".*

6.2 Alluvial Aquifers

6.2.1 Distribution

The alluvial plain to the south of the Boggabri Coal Mine covers some 240km^2 and is drained by two separate creek systems, Bollol Creek in the northern area, and Driggle Draggle Creek and Barneys Spring Creek to the south. The alluvial plains constricts around Gins Leap where the outcropping Boggabri volcanics act as a natural barrier, similar to a dam wall in the aquifer. Further to the north, beyond Gins Leap, the floodplain again widens and merges with the Maules Creek alluvial plain. The extent of the alluvial aquifer is shown in Drawing No. 3, where it is symbolised with “Qx”.

The thickness of the alluvial aquifer was determined from a review of lithologic logs from registered monitoring bores constructed in the floodplain. Stock, domestic and irrigation bores were generally not useful for this task as they rarely penetrated the full thickness of the alluvial aquifer. The locations of the monitoring bores used in this assessment are shown in Drawing No. 4.

Logs for thirty bores were examined to determine the thickness of the alluvial aquifer in the study area. A summary of the aquifer thickness is presented as a histogram in Figure 6. The data indicates a maximum thickness of about 125m, with the majority of the bores intersecting between 25m and 75m of alluvium.

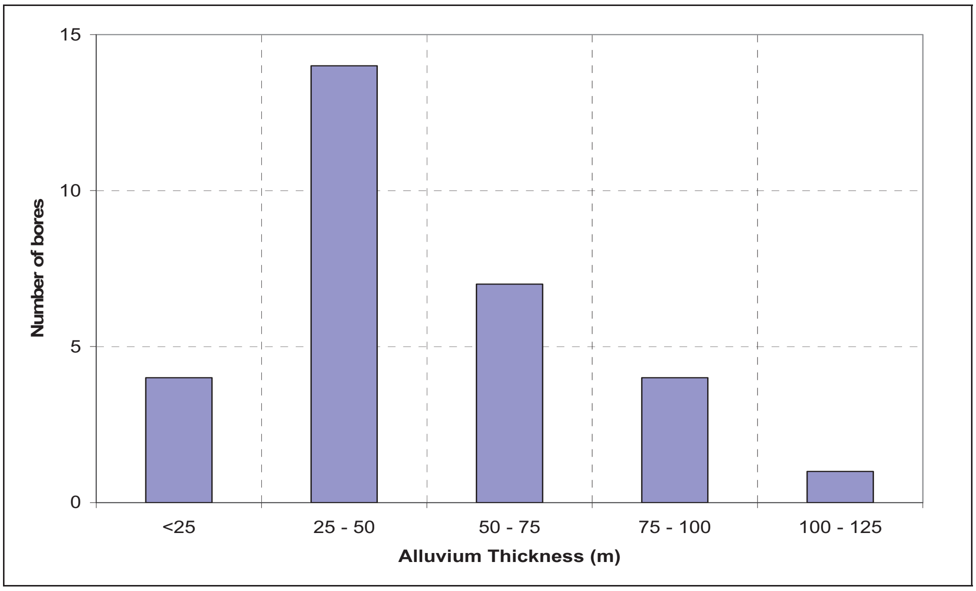


Figure 6: Alluvial Aquifer Thickness Histogram

Modelling undertaken by CSIRO (2007)[8] for the alluvial aquifer *“incorporated two aquifer layers of the basal Gunnedah Formation and the surficial Narrabri Formation. The Gunnedah Formation reaches a maximum thickness of 115 m and consists of sands and gravels with interbedded clays. It is conceptualised as a high-yielding aquifer with good quality, low salinity water. The overlying Narrabri Formation reaches a maximum thickness of 70 m and is conceptualised as a lower-yielding aquifer composed generally of clays with some sand and gravel.*

6.2.2 Yields

Bore yields in the alluvial aquifers are highly variable and dependent on the nature and thickness of the sediment intersected when drilling. Approximately 1,800 registered bores are present within the study area (refer Drawing No. 4), however information on yields was only available for about 28 of these bores. The bores show a very wide range in yields, from to less than 1L/s up to a maximum of 175L/s.

The locations of registered bores with information on yields are shown on Drawing No. 5 which indicates that all of the bores with very high yields are located along the Namoi River. This has been noted by CSIRO (2007)[8] indicating that *"a palaeochannel in the central valley area represents the deepest parts of the aquifer. Good quality groundwater is found in high-yielding aquifers across wide areas of the alluvial plain. The most productive aquifer is the main palaeochannel. The coarseness of the palaeochannel sediments supports high groundwater extraction rates."*

6.2.3 Water Quality

CSIRO (2007)[8] summaries the groundwater quality of the alluvial deposits and indicated that "*salt storage in the finer-grained units of these systems is high and groundwater salinity is variable from fresh to saline. Lower salinity levels characterise the coarser sediments. These systems respond rapidly to a change in the water balance."*

6.2.4 Groundwater Levels and Hydraulic Gradients

A network of groundwater bores monitored by the NSW government has been installed in the alluvial aquifer. The locations of the monitoring bores are shown in Drawing No. 4. Many of the bores have been monitored routinely since the mid 1970s providing a long record of groundwater fluctuations.

The closest site to the Boggabri Coal Mine with a long term record is GW030472, which has three separate piezometers constructed at different depths within the aquifer and is located about 7.8km south of the Project Boundary. The water level records for this bore are presented in Figure 7. The deeper zones show a slightly higher pressure and good correlation with rainfall (CRD in graph below), with a declining trend in water levels of about 2.5m over the 35-year monitoring period, potentially in response to abstraction. In contrast the piezometer constructed in the shallow aquifer recorded a very slight rising trend in water levels.

Hydrographs for monitoring bore GW030471, which is located about 9.4km to the south-west of the Project area, shows a similar declining trend as presented in Figure 8.

In contrast the hydrograph for monitoring bore GW0300052 presented as Figure 9 shows an increasing trend, potentially related to irrigation in the local area of the bores.

The hydrograph for monitoring bore GW967138 presented in Figure 10, which has two bores constructed in the Maules Creek alluvial aquifer, has a shorter monitoring record but indicates a more significant fluctuation in groundwater levels. A hydraulic gradient is also evident from the shallow zone in the alluvium in which pipe 1 is constructed to the deeper basal section in which pipe 2 is installed.

The hydrographs indicate that the water levels in the alluvial aquifer show responses to pumping abstraction and irrigation which on a local scale can result in either falling or rising water level trends.

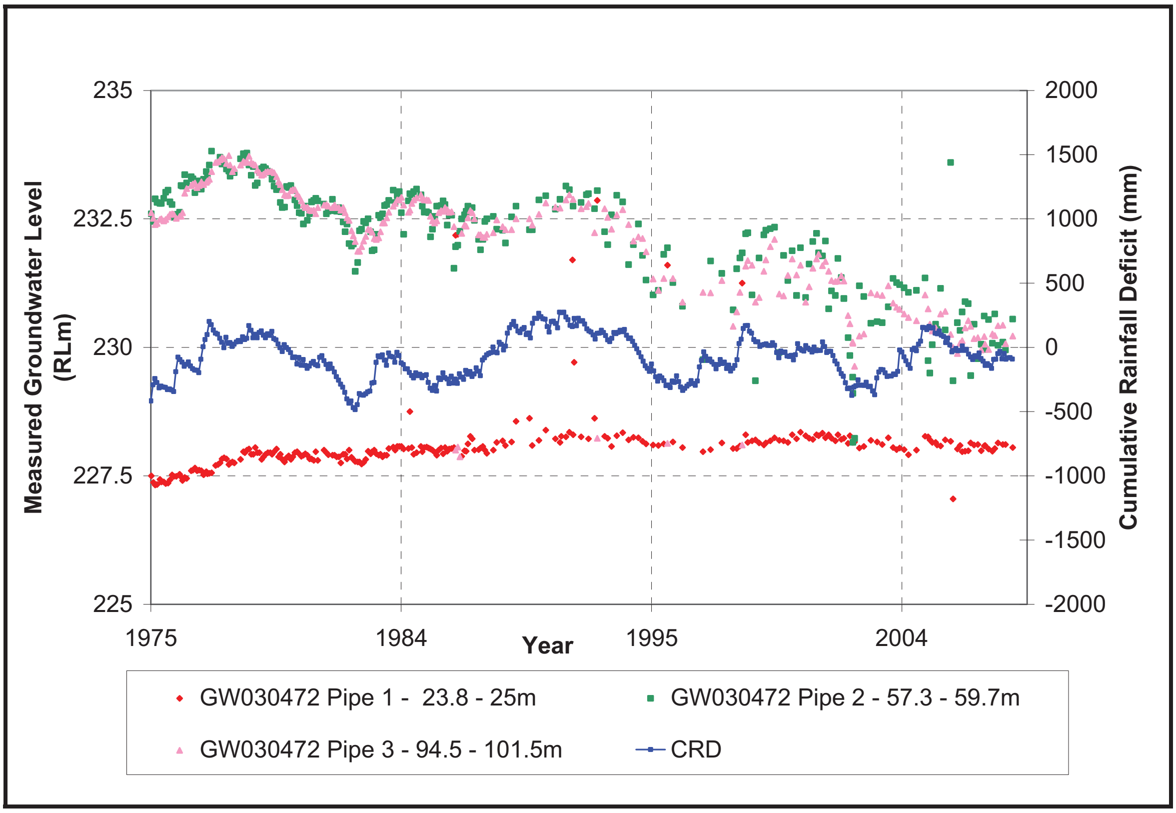


Figure 7: Hydrographs – Monitoring Bore GW030472

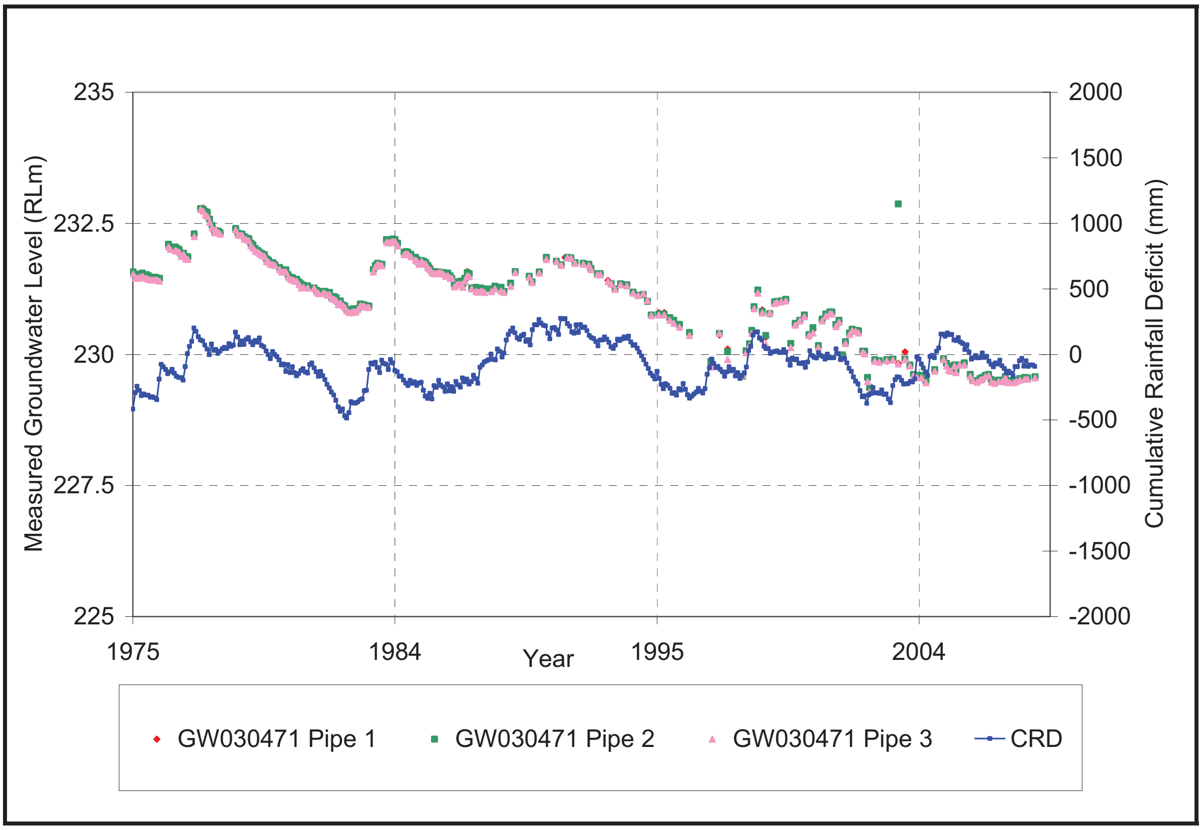


Figure 8: Hydrographs – Monitoring Bore GW030471

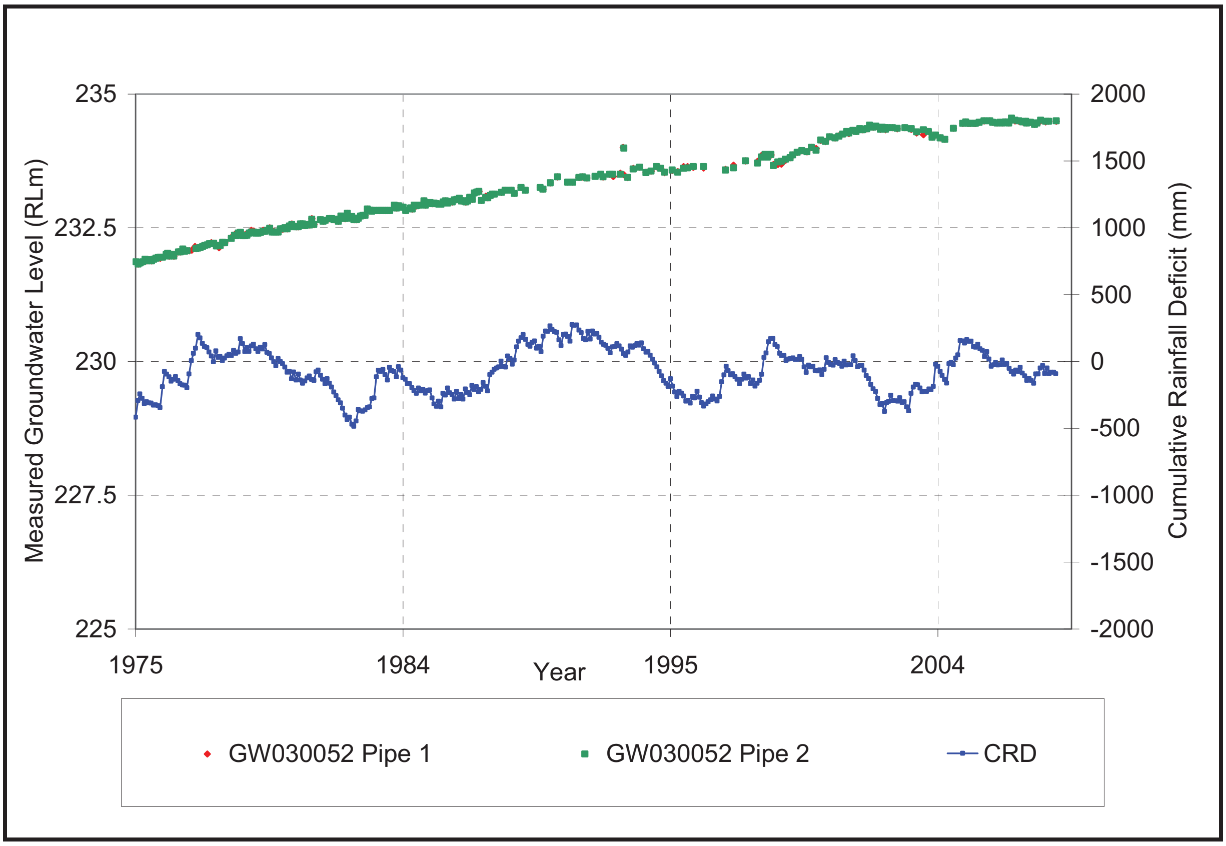


Figure 9: Hydrographs – Monitoring Bore GW030052

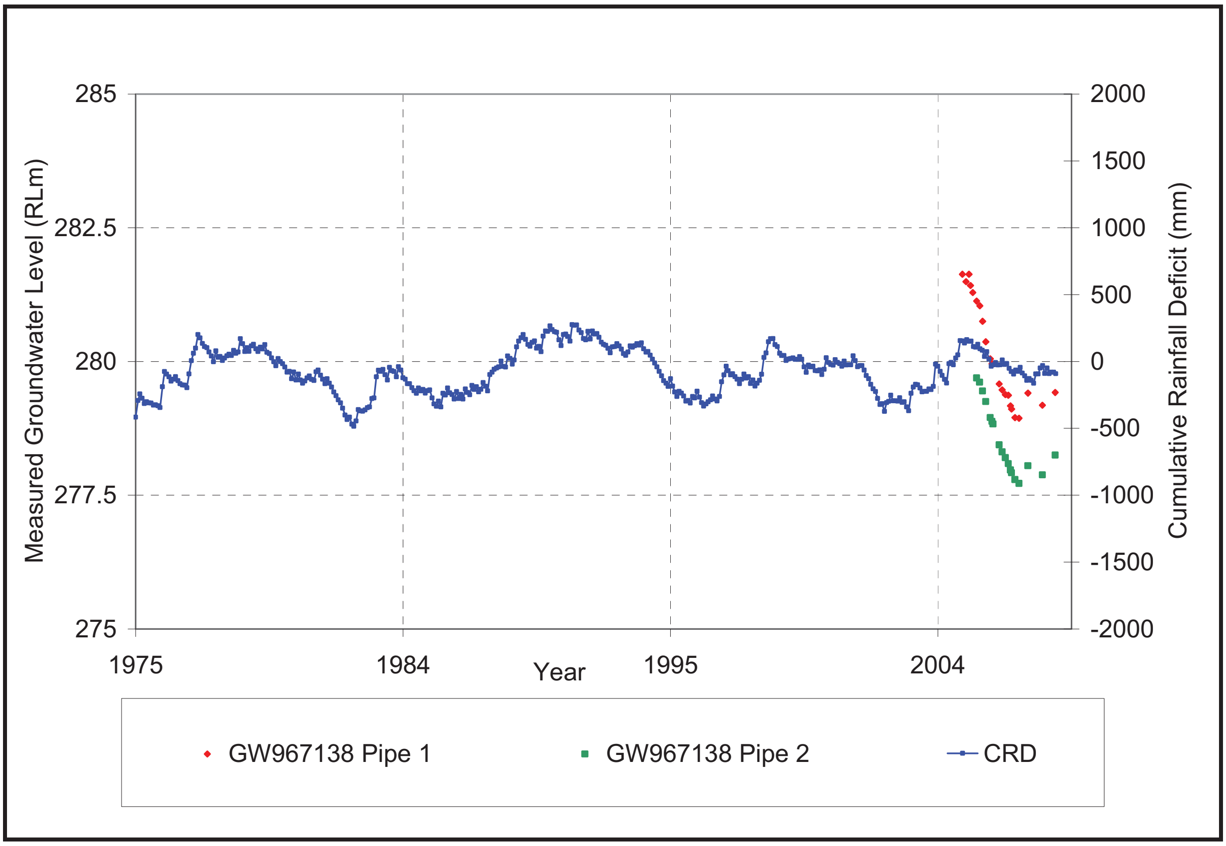


Figure 10: Hydrographs – Monitoring Bore GW967138

6.2.5 Recharge, Discharge and Groundwater Flow

Recharge and discharge from the alluvial aquifer is most recently summarised by CSIRO (2007)[8] as follows:

"Recharge to the aquifers occurs via six mechanisms: direct rainfall recharge, irrigation, river leakage, flood inundation, inflow from surrounding aquifers, and hillslope 'run-on' from outcropping bedrock at the aquifer margins. Direct rainfall recharge is modelled at 3 percent of rainfall with an adjustment for evapotranspiration. The Upper Namoi valley experienced average annual rainfall of 660 mm/year over the period 1985 to 2001; higher than the long-term average. Pan evaporation over the same period was approximately 1700 mm/year. Stream–aquifer interaction is an important part of the hydrological cycle in the Upper Namoi valley and the Namoi River has good hydraulic connection to the shallow aquifer. Traditionally the Namoi River was a losing stream upstream and a gaining stream downstream of Boggabri. Lower groundwater levels in recent times (post-2000) have produced increasing losses to groundwater. Groundwater discharges are largely restricted to pumping, river interaction and lateral groundwater flow to the Lower Namoi. Groundwater pumping has increased significantly since the 1980s and now approximately 70 GL/year is extracted. Watertables in the Namoi Valley are typically deeper than 2 m and consequently direct groundwater evapotranspiration is not a significant part of the water balance."

The groundwater flow model developed by NOW (2006)[7] included areal recharge via rainfall, side-slope runoff and floods, point source recharge from ephemeral streams and irrigation leakage.

6.2.6 Groundwater Dependent Ecosystems

The Water Sharing Plan notes that *"there are no high priority groundwater dependent ecosystems identified and scheduled at the commencement of this Plan."* Significant stands of groundwater dependent vegetation in the area is unlikely given that CSIRO (2007)[8] noted that *"watertables in the Namoi Valley are typically deeper than 2 m and consequently direct groundwater evapotranspiration is not a significant part of the water balance."* The creeks in the vicinity of the Boggabri Mine are also ephemeral and therefore are not expected to support groundwater dependent ecosystems (GDEs).

6.3 Shallow Bedrock (Regolith) Aquifer

The regolith or shallow bedrock aquifer comprises surficial soils and weathered bedrock. The depth of the aquifer is variable and depends on factors such as the depth of weathering and extent and frequency of fracturing. Deep weathering profiles averaging about 25m, and in some cases down to 60m are present throughout the Project mining area. Sandstones and conglomerates are most affected by the weathering process. Finer grained sediments where present form an effective barrier to the weathering process and can locally reduce the weathering depth. Deeper weathering profiles are found along fracture and potential fault zones. The regolith acts as a temporary water store during sustained wet periods and provides a source for recharge to the underlying fresh rock.

6.4 Permian Aquifers

The Permian strata may be categorised into the following hydrogeological units:

- hydrogeologically "tight" and hence very low yielding to essentially dry sandstone, and conglomerate that comprise the majority of the Maules Creek Formation strata;
- low to moderately permeable coal seams which are the prime water bearing strata within the Maules Creek Formation;
- the underlying Boggabri volcanics that act as a low permeability basement to the sedimentary units.

6.4.1 Distribution

The Permian sediments deposits occur as a regular layered easterly to north-easterly dipping sedimentary sequence. The basal Boggabri volcanics outcrop in the western area of the Leard State Forest and form the basement to the alluvial aquifer. In the eastern zone of the study area the Maules Creek Formation forms the alluvial basement.

6.4.2 Hydraulic Parameters

Hydraulic testing of the Permian coal measures strata was first undertaken by Herring (1979)[3] and Australian Groundwater Consultants (1982)[4] and most recently by Parsons Brinkerhoff (2005)[6]. AGC (1982)[4] undertook airlift testing on six test holes which indicated a transmissivity range of 0.12m^2/day to 0.68m^2/day, which it was noted is higher than is typical for Hunter Valley coal seams. PB (2005)[6] used packer tests to assess hydraulic conductivity. The results of the permeability testing undertaken by PB (2005)[6] are reproduced in Table 3.

Table 3: SUMMARY OF HYDRAULIC TESTING VALUES

Hole	Coal Seam	Hydraulic Conductivity (m/day)
AB1060	BR,BC,JE, MN	0.48
AB040	BC, JE, MN	0.68
AB030	JE	0.5
AB043	BR,BC,JE, MN	0.12
IBC2102	JE	0.01 - 0.03
IBC2102	MN	0.01 - 0.1
IBC2104	BR	0.01
IBC2105	JE	0.01
IBC2115	MN	0.005
Average	-	0.21

BR – Braymont Seam, BC – Bollol Creek Seam, JE – Jeralong Seam, MN – Merriown Seam.

NA – not available

The testing which included interburden and coal seam zones indicated a significant range in permeability, from low to moderate values, which is typical for fractured rock aquifers. The average value estimated from the testing was 0.21m/day, which is expected to be predominately associated with the coal seams, with limited influence from inter-burden units. Based on the permeability measured by PB (2005)[6] and assuming a 16m thickness of coal seams at the Boggabri Coal Mine, the transmissivity would be expected to vary from 0.1m^2/day and 10m^2/day, with an average of 2.8m^2/day.

Coal seam permeability is well known to reduce with depth and pressure, and therefore some reduction in hydraulic conductivity is likely in northern and eastern areas of the lease where the coal seams dip to the east and the overburden ratio increases.

No permeability testing is known to have been undertaken in the Boggabri volcanics, but they are generally known to be a poor producing aquifer and are therefore likely to be of very low permeability.

6.4.3 Yield and Usage

Usage of groundwater from the Permian strata via bores is limited, likely due to poor yields and quality and the better prospects obtainable in the alluvial aquifer.

A total of thirteen registered water bores were identified within the outcrop of the Maules Creek Formation. A summary of the available information for these bores is provided in Table 4 below. The locations of the bores are shown in Drawing No. 4.

Information on yields is limited with only two bores reporting relatively low yields, of 0.42L/s and 0.76L/s. The bores in the Maules Creek Formation were drilled between the 1920s and 1980s and given the age of the bores, it is unlikely all remain in use. Water quality is variable from fresh to brackish.

Table 4: SUMMARY OF REGISTERED BORES IN MAULES CREEK FORMATION

Work No.	Date	Work Status	Drilling Method	Completed Depth	Standing Water Level	Salinity	Yield
GW000583	1920	Reconditioned	Unknown	98.7	31.1	Fresh	0.76
GW001799	1926	Unknown	Cable Tool	78.3		Fresh	
GW001852	1926	Unknown	Cable Tool	88.7		3001-7000 ppm	
GW002506	1928	Unknown	Cable Tool	33.5		Fresh	
GW002523	1928	Unknown	Cable Tool	38.4		Good	
GW002748	1929	Unknown	Cable Tool	72.2		Good Stock	
GW003466	1937	Unknown	Cable Tool	50		Fresh	
GW003496	1937	Supply Obtained	Cable Tool	172.8	61.6	Salty	0.42
GW008255	1951	Abandoned Bore	Cable Tool	91.4			
GW001869	1962	Unknown	Cable Tool	63.1		Good	
GW029832	1968	Unknown	Cable Tool	66.8			
GW048934	1976	Reconditioned Bore	Rotary Air	49.4		1001-3000 ppm	
GW053825	1981	Unknown	Rotary	257		1001-3000 ppm	

Fourteen registered water bores were identified within the outcrop zone of the Boggabri volcanics. A summary of the available information for these bores is provided in Table 5 below. The locations of the bores are shown in Drawing No. 4.

Yields are not available for bores in the Boggabri volcanics, probably because the majority of the bores are relatively old, being drilled prior to 1965 using the cable tool method and given the age of the bores, it is unlikely all remain in use. Water quality is variable from fresh to brackish.

Table 5: SUMMARY OF REGISTERED BORES IN BOGGABRI VOLCANICS FORMATION

Work No	Date	Work Status	Drilling Method	Completed Depth	Standing Water Level	Salinity Description	Yield
GW020434	1927	unknown	Cable Tool	85.3	-	Salty	-
GW002799	1929	unknown	Cable Tool	21	-	Good Stock	-
GW002831	1930	unknown	Cable Tool	33.2	-	Unknown	-
GW003115	1932	unknown	Cable Tool	82.9	-	Good	-
GW003478	1937	unknown	Cable Tool	33.8	-	Fresh	-
GW003483	1937	unknown	Cable Tool	32.9	-	Fresh	-
GW003489	1937	unknown	Cable Tool	45.4	-	Fresh	-
GW006529	1939	unknown	Cable Tool	34.7	-	Good	-
GW006567	1940	unknown	Cable Tool	59.1	-	Fresh	-
GW008221	1951	unknown	Cable Tool	108.2	-	Unknown	-
GW019267	1962	unknown	Cable Tool	20.7	-	1001-3000 ppm	-
GW020607	1963	unknown	(Unknown)	29.9	-	Brackish	-
GW025637	1965	unknown	Cable Tool	36.6	-	Unknown	-
GW900043	1995	unknown	Cable Tool	32.9	-		-

The prime users of groundwater from the Permian Maules Creek Formation are the Boggabri Coal Mine and Tarrawonga Mine that use in-pit seepage from the coal seams for dust suppression purposes.

The rate of groundwater seepage into the open cut pits is difficult to monitor due to mixing with rainfall runoff. At Boggabri Mine volumes of pit seepage into the Jeralong Pit have been estimated by PB (2008)[9] at 0.5ML/day.

6.4.4 Water Quality

Routine monitoring of groundwater quality in a network of monitoring bores completed in various coal seams has been undertaken at the Boggabri Coal Mine since 2005. PB (2009)[10] undertook a review of recent water quality data collected between January 2008 and January 2009 and concluded:

- The highest conductivity value (3115μS/cm) was measured in GW3115 located approximately 2.5km west of the mine workings while the lowest values (530μS/cm) were recorded in monitoring wells to the north of the existing pits, which are at higher elevations (IBC2102, IBC2103, IBC2104). The water quality in these monitoring wells has an EC between 530 to 660μS/cm, while EC in the remaining monitoring wells varies from 1770 to 2720μS/cm).
- The dominant water types are sodium and bicarbonate based, however, water type is variable between monitoring wells and also with sample date. There does not appear to be any trends associated with geology.
- Over the period metal concentrations in all monitoring wells were below the guidelines, with the exception of iron where the concentrations were slightly above the guidelines in all

[9] Parsons Brinkerhoff Australia Pty Ltd (2008), *"Updated Groundwater Model for Boggabri Mine Extension, Boggabri".*

[10] Parsons Brinkerhoff Australia Pty Ltd (2009), *"Boggabri Coal Project – Annual Groundwater Levels and Quality Monitoring Review",* January 2009.

monitoring events. The iron values were elevated in monitoring well GW3115, which is equipped with rusted steel casing that explains the iron concentrations.

- Over the year nitrite and nitrate were detected on occasion but below guideline values in all of the monitoring wells. Ammonia and nitrogen were detected above the detection limit in IBC2113, IBC2114, IBC2115, and IBC2139 in January 2008. Since then the nitrogen concentrations have declined, while the ammonia concentrations have increased to January 2009.

6.4.5 Groundwater Levels

Groundwater levels have been measured in a network of monitoring bores at Boggabri Coal Mine on a quarterly basis since commencement of mining. The locations of the monitoring bores are shown in Drawing No. 6. Measured groundwater levels in the key monitoring bores since mid 2006 are presented in Figure 11.

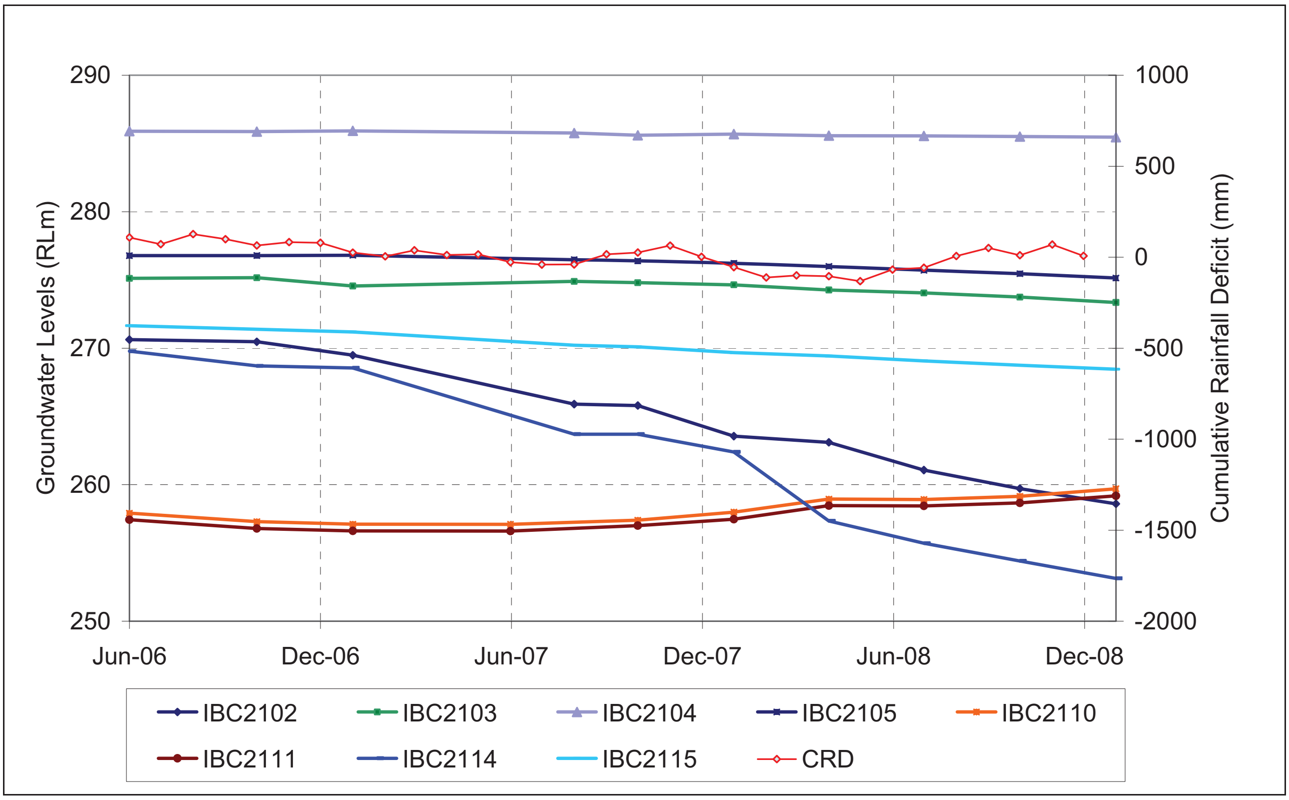


Figure 11: Hydrographs – Boggabri Mine Monitoring Bores

The hydrographs show decreasing groundwater levels in most of the monitoring bores, a decrease which is not correlated with rainfall as indicated by the CRD, and therefore is attributed to mine dewatering. The bores in closest proximity to the open cut pit show the largest decline in groundwater levels, with the magnitude of the decline decreasing with distance from the pit. This is typical of the effects of open cut mining on coal seam aquifers. The exception is monitoring bores IBC2010/IBC2011 down-gradient of the mine, constructed in the Boggabri volcanics that show a clearer association with rainfall and do not appear to have been impacted by mining activities.

6.4.6 Recharge, Discharge and Groundwater Flow

Groundwater recharge to the Permian formations is expected to be relatively low due to the steep slopes in the outcrop areas that shed runoff, in addition to the tree cover that intercepts rainfall. Groundwater modelling undertaken by PB (2008)[11] adopted a groundwater recharge of 3mm/year (0.5% of average annual rainfall) for the Maules Creek Formation and up to 20mm/year in the ranges of the Leard State Forest. The creeks in the outcrop area do not have any permanent baseflow and therefore discharge from the Permian aquifer is expected to occur via direct discharge to the alluvial aquifer.

It is also understood that some NOW monitoring bores to the north of the Project in the Maules Creek area have groundwater levels in the alluvium higher than the groundwater level in the deeper underlying Permian, suggesting groundwater recharge from the alluvium into the underlying bedrock occurs in some areas.

6.4.7 Faulting

The Mooki thrust fault is the major structural fault in the area which marks the boundary of the Gunnedah Basin and the New England Fold Belt. Within the area Project Boundary, Whitehouse (1993)[12] found that *"two major faults have been identified. One group with a north-south orientation and displacements ranging from 25m to 40m occur in the central southern part of the area. A second group of faults with displacements up to 30m and a dominantly northerly orientation occurs to the north-west."*

Whitehouse (1993)[12] also identified a number of faults in the northern extent of the Project Boundary and noted that *"faulting, both sub-parallel and perpendicular to the Hunter-Mooki Fault system, has displaced a block in the south-east, with respect to the remainder of the area. Several of the other blocks have been displaced some 40m to 50m, by prominent faults."*

The current active pit area is characterized by extensional faulting overprinted by compressional faulting. Extensional faulting is typically high angle planar. Trace clays can be found on fault faces and also on associated joints which are mostly open. They are oriented in an east-west direction with the maximum recorded throw on a normal fault of about 10m. Compressional faulting is low angle undulating again with trace clays found on fault faces and also on associated joints which are mostly open. Reverse faults are orientated in a north-west – south-east direction and are typically low angle. The maximum throw recorded on an in seam on a reverse fault is horizontally 30m in the Merriown Seam. The compressional phase has also resulted in 5-10m crush zones particularly adjacent or below conglomerate channels. There is also evidence of bedding plane shear both within each coal seam and at the coal floor interface (personal communication John Rogis)[13].

A number of north-south trending faults have also been identified in the Permian sequence at the adjacent Tarrawonga Mine with displacements in the order of 30m. Several north-south trending faults have also been mapped in the area of the Vickery Mine to the south of the Project Boundary (refer Drawing No. 3).

---

[11] Parsons Brinkerhoff Australia Pty Ltd, (2008), *"Updated Boggabri Model for Boggabri Mine Extension, Boggabri"*, August 2008.

[12] Whitehouse (1993) *"Coal Resources of the Maules Creek Sub-Basin*, in *The Gunnedah Basin, New South Wales"*, Department of Mineral Resources, Geological Survey of New South Wales, Memoir Geology 12, 1993 ed Tadros, Z.

[13] John Rogis – Exploration Geologist – Boggabri Coal.

7.0 MINE PLAN

The Project will continue mining operations from the existing mining area, with the Merriown Seam being the basal seam mined. When mining approaches the eastern limit of the Project Boundary, operations will commence uncovering coal in strips (approximately 75m wide) in an east-west direction while progressing to the north-west towards Leard Forest Road. The depth of the void will reach a maximum of about 200m at the eastern and northern highwall limits.

An out-of-pit overburden emplacement area will be established in the south-east and north-east sections of the Project Boundary. The overburden emplacement area will be constructed up to maximum RL 395m.

At the end of mining in Year 21, a void will remain at the northern extent of the mine footprint with an area of approximately 413ha. The lowest point in the final void will be RL 176m, a depth of about 156m below the spill level of approximately RL 332m.

The Project will remain at least 1km from the Namoi River alluvial aquifer as shown in Figure 12 below.

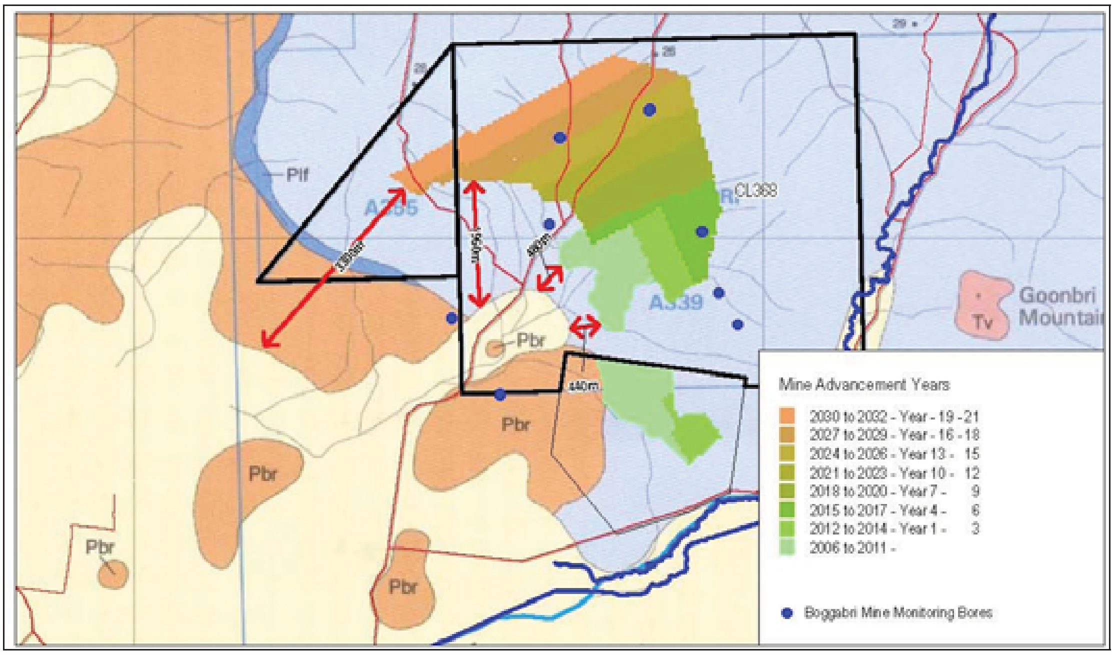


Figure 12: Distance from Proposed Mine Extension to Alluvial Aquifer

8.0 NUMERICAL GROUNDWATER MODEL

8.1 Modelling Objectives

Predictive numerical modelling was undertaken to assess the impact of the Project on the groundwater regime. The objectives of the predictive modelling were to:

- estimate groundwater inflow to the open cut void over the 21-year mine life,
- predict the zone of influence of dewatering and the level and rate of drawdown at specific locations,

- predict the magnitude of any drainage from the alluvial aquifer into the underlying Permian strata,
- predict the impact of mine dewatering on groundwater discharges to surface flows and other groundwater users, and
- identify areas of potential risk where groundwater impact mitigation/control measures may be necessary.

8.2 Conceptual Model

Every numerical groundwater model has as its foundation a conceptual model. The conceptual model is an understanding of how the groundwater system operates and is an idealised and simplified representation of the natural system.

Extensive information on the natural system is typically required to develop an equivalent and simplified conceptual groundwater model representative of the system. Development of the conceptual groundwater model is a crucial step in groundwater modelling. Care has to be taken during development of such models since errors in the conceptual model cannot be corrected during the model calibration, or at any later stage of the modelling study, without major revisions. Formulation of the conceptual model often highlights gaps in data or deficiencies in understanding of the groundwater system.

Zheng and Bennett (1995)[14] note that '*a conceptual model contains numerous qualitative and subjective interpretations. The appropriateness of the conceptual model can not be tested until a numerical model is built and comparisons between field observations and model simulation results are made'.*

The following sections present the available information that has been used to develop a model of the hydrogeological regime. This task includes an initial conceptual model and a more detailed numerical model. This conceptual model forms the basis of the assumptions used when developing the more detailed numerical model. MDBC (2000)[15] define a conceptual model as an "*idealised summary of the current understanding of catchment conditions, and the key aspects of how the flow system works…subject to some simplifying assumptions.*

The data indicate the area supports three separate groundwater systems:

- alluvium associated with the Namoi River and its tributaries;
- weathered bedrock (regolith) near ground surface; and
- low permeability Permian aquifers associated with the Maules Creek Formation and the Boggabri volcanics.

Recharge to the groundwater system is from rainfall, lateral groundwater flow at the boundaries of the Project Boundary study area, and leakage from the major rivers and tributaries. The water balance is dominated by recharge to the alluvial aquifer that is significantly higher than recharge to the bedrock basement that forms elevated "island" outcrops though-out the study area. Groundwater inflow to the alluvial aquifers from the surrounding bedrock is considered to be low as evident in previous government studies that have excluded bedrock from groundwater models.

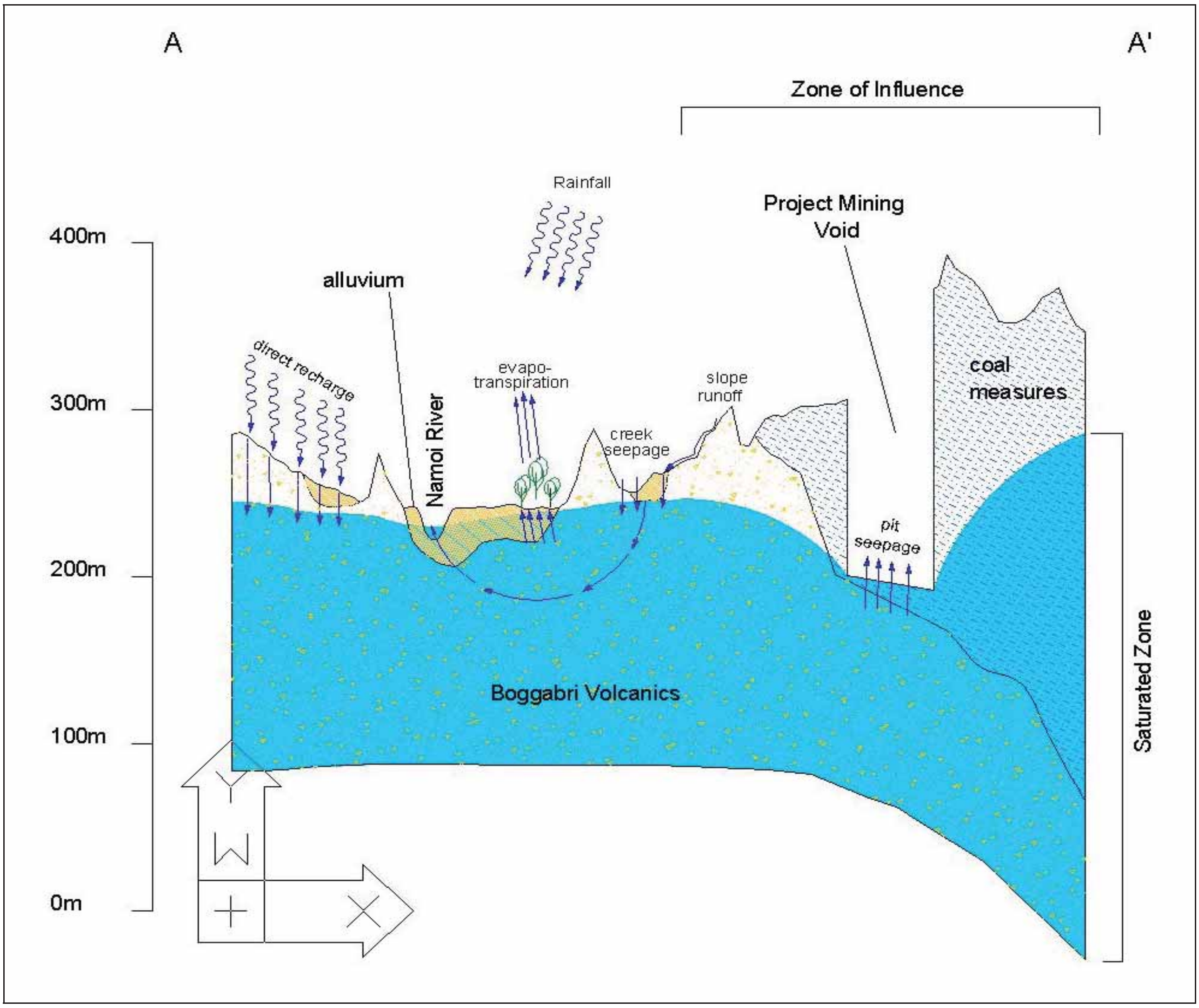
[14] Zheng C. and Bennett G., (1995), *"Applied Contaminant Transport Modelling"*. Wiley, New York.

[15] Murray Darling Basin Commission (2000). *"Groundwater Flow Modelling Guideline",* November 2000, Project No. 125, Final guideline issue January 2001.

Although groundwater levels are sustained by recharge, they are controlled by surface topography, surface water levels and aquifer permeability. Groundwater mounds are present beneath the hill areas, with a hydraulic gradient towards the lower lying alluvial lands. Groundwater flow is from these elevated areas with discharge to the Namoi River, in areas where the potentiometric surface is above the bed of the river and removal by evaporation and/or evapotranspiration through vegetation where the water table is within a few metres of ground surface. Irrigation, stock and domestic bores also remove a significant amount of water from the alluvial aquifer.

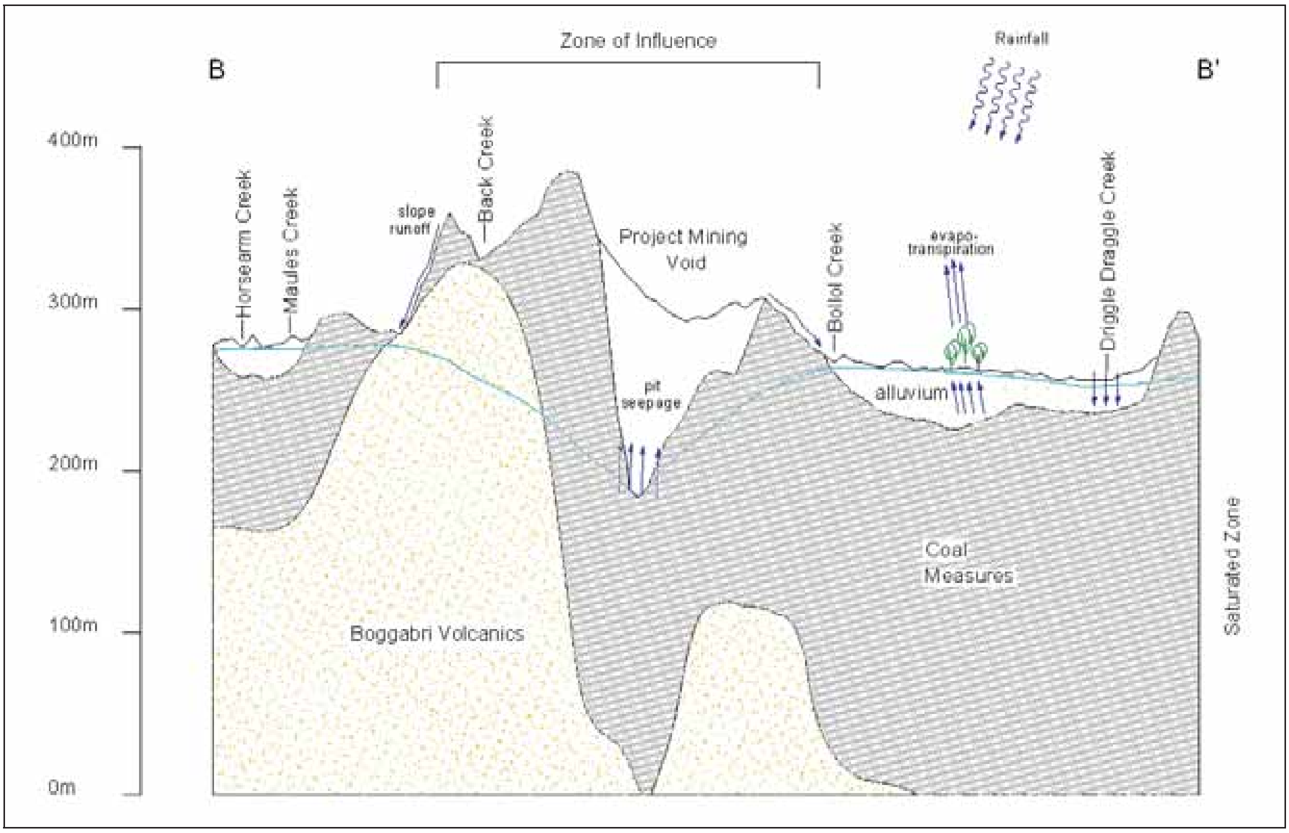
During events of high water flows in the ephemeral creeks, water can discharge or leak into the alluvial aquifers. In places where mining has occurred, groundwater discharge is expected to be via the mined seam and to a lesser extent from the strata above and below at a rate related to the permeability and the hydraulic gradient.

The conceptual model is illustrated in a cross section in Figure 13 and Figure 14. The location of the cross sections is shown on Drawing No. 3. It should be noted this figure displays the key concepts in the hydrogeological regime but does not represent localised detail in the geological surfaces.



Note – this figure is conceptual only - 5 x vertical exaggeration

Figure 13: Conceptual Cross Section – Section A – A'



Note – this figure is conceptual only - 5 x vertical exaggeration

Figure 14: Conceptual Cross Section – Section B – B'

8.3 Model Development

8.3.1 Model Code

Numerical simulation of groundwater flow in the aquifers was undertaken using the MODFLOW SURFACT code (referred to as SURFACT for the remainder of the report). A commercial derivative of the standard MODFLOW code, SURFACT is distributed by Hydrogeologic Inc[16] and has some distinct advantages over the standard MODFLOW, that are critical for the simulation of groundwater flow in the vicinity of the Project Boundary.

The MODFLOW code (on which SURFACT is based) is the most widely used code for groundwater modelling and is presently considered an industry standard. Use of the SURFACT modelling package is becoming increasingly widespread, particularly in mining applications where mine dewatering and recovery are simulated.

SURFACT is capable of simulating variably saturated conditions. This is critical for the requirements of the Project where coal seams will be progressively dewatered with time until the end of mining when overlying strata will be essentially desaturated. Then active dewatering will cease, and groundwater recovery will rewet the seams. SURFACT is also supplied with more robust numerical solution schemes to handle the more complex numerical problem resulting from the unsaturated flow formulation. Added to the more robust numerical solution schemes is an

[16] Hydrogeologic Inc., MODFLOW SURFACT Software (Version 3.0), Herdon, VA, USA.

adaptive time-stepping function that aides the progression of the solution past difficult and complex numerical situations such as oscillations.

The MODFLOW pre- and post processor PMWIN (Chaing and Kinzelbach, 1996)[17] was used to generate some of the input files for the SURFACT model, such is the similarity between it and the standard MODFLOW. Where files differ to allow for the additional capabilities of SURFACT, these changes were undertaken through manual editing of the model files.

8.3.2 Model Geometry and Boundary Conditions

Consideration was given to representing each of the main coal seams as individual layers in the numerical model. The coal seam structure is well defined within the Project Boundary, but there is very limited data on the structure of the individual coal seams under the alluvial cover to the south. A review by Whitehouse (1993)[12] indicated *"a substantial amount of drilling is needed to resolve complex stratigraphic problems now apparent. In this area, the Maules Creek Formation thickens and dips to the east at 2 to 5 degrees. Localised dips of up to 20 degrees occur near the inferred position of the Hunter-Mooki Fault system in the north-east. A number of coal seams are affected by igneous intrusions."*

To the north of the Boggabri Coal Mine, on the adjacent Maules Creek lease significant coal exploration has been undertaken, but this data is not in the public domain.

Given the lack of data on the regional structure of the Maules Creek Formation, it was decided to represent both the overburden and coal seams in combined layers in the model, similar to the approach adopted by PB (2008)[9]. The numerical model consists of five model layers as shown in Figure 15 below.

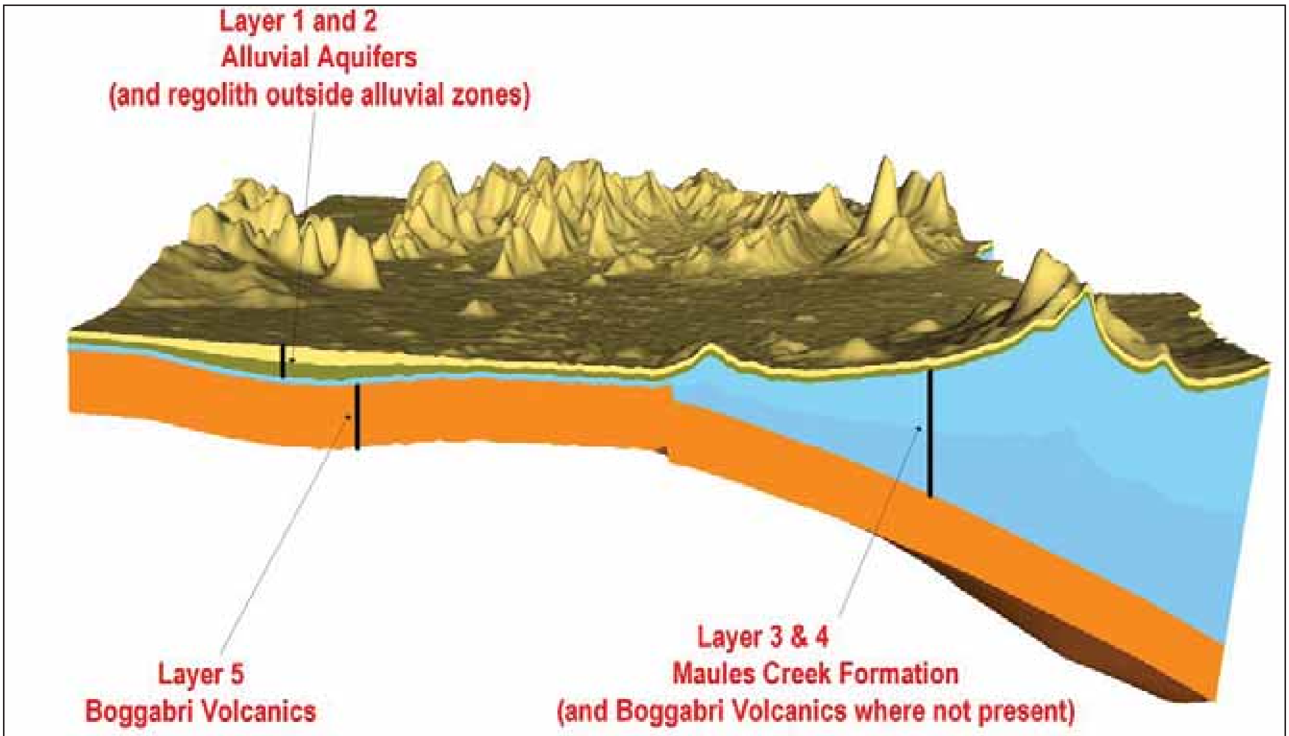


Figure 15: 3D Representation of Model Domain - Southern Model Boundary looking North

[17] Chaing W.H. and Kinzelbach W., (1996), *"Processing MODFLOW for Windows"*

The boundary of the model which covered the study area is shown in Drawing No. 7.

Each layer represented the following stratigraphic units:

- Layer 1 represented:
    - the shallow alluvial Narrabri Formation associated with the Namoi River and tributaries which was set with a maximum thickness of 30m.
    - in the hills outside the alluvial plain where the basement units outcrop, the thickness of Layer 1 was set to a nominal 10m to represent the zone of weathering.
- Layer 2 represented:
    - the alluvial Gunnedah Formation that underlies the Narrabri Formation with variable thickness based on information in drillers logs where available and with assumed thickness where no information was present.
    - outside the alluvial plain where the basement units outcrop, the thickness of Layer 2 was set at 10m to represent a second zone of weathering.
- Layer 3 and 4 represented the Maules Creek Formation in the eastern area of the model and the Boggabri volcanics directly underlying the alluvial sediments in the western area.
- Layer 5 represented the Boggabri volcanics with a constant thickness of 100m.

The model grid is overlain on the regional geology in Drawing No. 7. The model domain was discretized into 137,497 rectangular cells comprising 383 rows and 359 columns. The dimensions of the model cell size vary from 50m by 50m within the mining area and up to 100m by 100m outside the Project Boundary as shown on Drawing No. 7.

The north-west corner of the grid is located at 212,100mE and 6,623,800mN (MGA94, Z56), with the grid rotated at 1.5 degrees to align with major geological and hydrological features. The model extent is about 29km x 30.75km covering an area of approximately 891.75km^2. The cells located to the east of the Mooki Fault, where the coal seams are not present were excluded from the simulation.

Publicly available digital elevation data[18] with a 250m x 250m grid spacing was used to represent the ground surface in the model. This data was chosen as the open cut pits were not evident and therefore the dataset was suitable for the pre-mining calibration.

The model domain extent has the following boundary conditions applied:

- a "no flow" boundary along the Mooki Fault zone marks the eastern boundary of the model;
- a constant head boundary set at RL 234m was used to represent upstream flow into the model from the Gunnedah Formation alluvial aquifer, with a second constant head boundary set on the downstream side at RL 224m to represent outflow from the model;
- "no flow" boundaries were set along the northern and southern boundaries at an arbitrary distance considered beyond the influence of the mining operations.

[18] Geoscience Australia – Geodata 9 Second Digital Elevation Model Version 3, Gridded Elevation and Drainage Data, 1:250,000.

8.3.3 Hydraulic Parameters

The hydraulic parameters adopted for the model are as shown in Table 6.

Table 6: HYDRAULIC PARAMETERS

Layer	Parameter	Value
Layer 1 (alluvium & regolith in hill areas)	Horizontal Hydraulic Conductivity kh	regolith zone 0.1m/day alluvial aquifer 5 m/day
	Vertical Hydraulic Conductivity kv	10% of kh (above)
	Specific Yield S_y	regolith zone 0.001 alluvial aquifer 0.05
	Specific Storage S_s	regolith zone 1×10^{-5} alluvial aquifer 5×10^{-4}
Layer 2 (alluvium and regolith in hill areas)	Horizontal Hydraulic Conductivity kh	regolith zone 0.01m/day alluvial aquifer 10m/day
	Vertical Hydraulic Conductivity kv	10% of kh (above)
	Specific Yield Sy	Permian/regolith zone 1×10^{-4} alluvial aquifer 0.05
	Specific Storage Ss	regolith zone 1×10^{-5} alluvial aquifer 5×10^{-4}
Layer 3 and 4 (Boggabri volcanics and Maules Creek Formation)	Horizontal Hydraulic Conductivity kh	Boggabri volcanics 0.0001m/day Permian $T = 2.5m^2/day$
	Vertical Hydraulic Conductivity kv	10% of kh (above)
	Specific Yield Sy	1×10^{-4}
	Specific Storage Ss	1×10^{-5}
Layer 5 (Boggabri volcanics)	Horizontal Hydraulic Conductivity kh	0.0001m/day
	Vertical Hydraulic Conductivity kv	10% of kh (above)
	Specific Yield Sy	1×10^{-5}
	Specific Storage Ss	1×10^{-5}

8.3.4 Recharge and Discharge

Recharge zones and rates were based on previous modelling studies by NOW (2006)[7] and CSIRO (2007)[8]. The recharge zones and rates are shown in Drawing No. 8 and were as follows:

- Alluvial aquifer 18mm/yr - 3% of annual rainfall
- Slope wash zone 90mm/yr - 15% of annual rainfall
- Ephemeral creeks 90mm/yr - 15% of annual rainfall
- Bollol Creek headwaters 150mm/yr - 25% of annual rainfall
- Outcrop hill zones 1mm/yr - 0.2% of annual rainfall

The recharge was applied to the uppermost layer in the model that represented the topographic surface.

Discharge from the model was via river cells assigned along Namoi River and drain cells set along the ephemeral creeks. The bed of Namoi River was set at a depth of 10m below ground level. The water level in the river was set at 2m above the bed level. The base level for the drain cells were set at 2m below ground surface.

Evaporation was applied to the entire model domain at a rate of 0.1mm/day with an extinction depth of 2m below ground surface using the SURFACT evapotranspiration package.

Extraction of water from irrigation bores in the alluvial aquifer was not included in the model as this data was not available in the public domain. However the extraction from bores is accounted for in the balance of inputs and outputs adopted in the steady state model calibration. Groundwater discharging from the model via drains, river flow, evapotranspiration and constant head cells accounts for water that would be removed by irrigation from the aquifer.

Discharge and recharge also occur through the fixed head representing the down gradient flow in the alluvial aquifer.

8.4 Model Calibration

Anderson and Woessner (1992)[19] note that *'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'.*

8.4.1 Calibration Targets

Groundwater levels were collated for monitoring bores at Boggabri Coal Mine and Tarrawonga Mine and from publicly available levels measured in registered monitoring bores.

A long record of water level measurements was available for the government monitoring bores. The median water level was calculated and adopted as the steady state calibration target. Calibration targets adopted for the monitoring bores at the mining operations were selected from pre-mining measurements, or from sites that were relatively distant from the mining operations and hence unaffected by any existing mine dewatering.

The objective of the steady state modelling was to simulate pre-mining conditions and therefore bores which had been potentially affected by mining activities were removed from the calibration process. A total of 63 bores were used to calibrate the model.

During the simulations the recharge rate to the alluvial aquifer was fixed and the hydraulic conductivity and recharge rate to the coal seam aquifers altered to obtain model calibration. The main objective of model calibration was to reproduce groundwater levels at the individual monitoring bores and hence the general pattern of the groundwater contours and the direction of the groundwater flow.

---

[19] Anderson, M. P. and Woessner, W. W., (1992), *"Applied Groundwater Modelling, Simulation of Flow and Advective Transport"*, Academic Press.

A transient calibration was not attempted because information on abstraction rates from individual bores was not available in the public domain which would have been necessary to match the water levels measured in the government monitoring bores with the model predictions. In addition no accurate measurements of groundwater seepage rates to the Boggabri Coal Mine and Tarrawonga Mine were available for a transient calibration. The hydraulic properties adopted in the model for the alluvial aquifers were within the range NOW (2006)[7] had previously estimated using a transient modelling simulation.

8.4.2 Calibration Results

Comparison of observed and simulated groundwater levels in the model area are given in Table 7 and as scattergram in Figure 16. The simulated steady state water levels in Layer 2 are presented in Drawing No. 9.

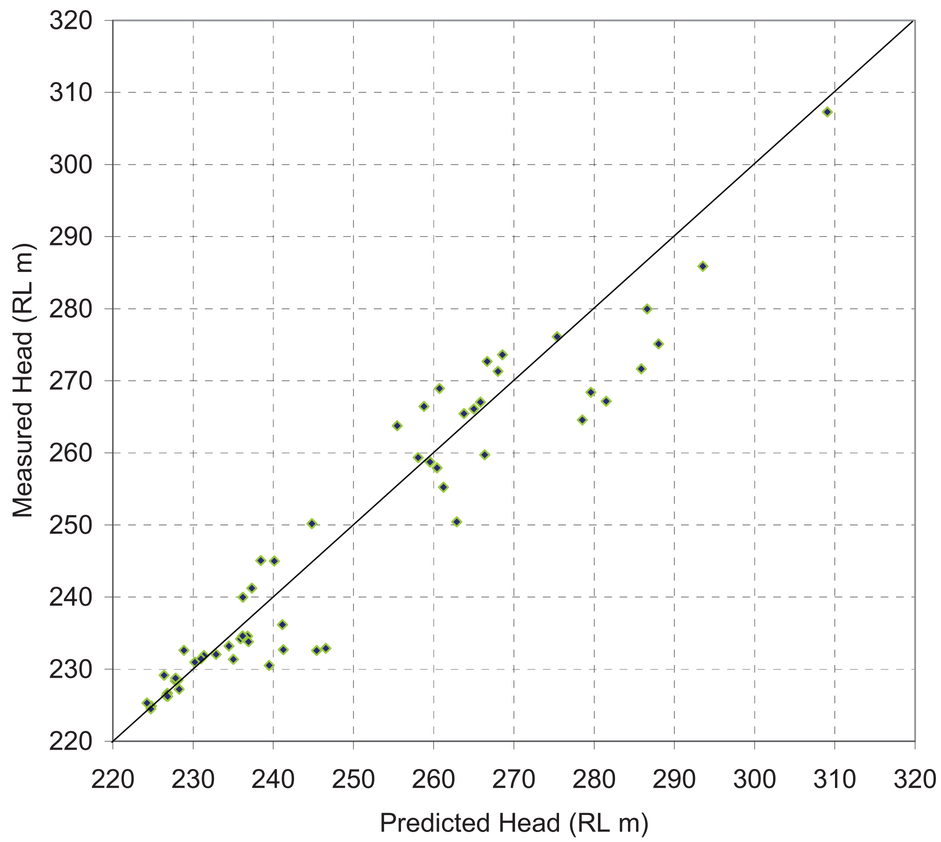


Figure 16: Observed vs Simulated Groundwater Levels – Steady State Model

Table 7: CALIBRATION TARGETS AND SIMULATED WATER LEVELS – STEADY STATE MODEL

BORE_ID	Easting	Northing	Measured Water Level (RL m)	Modelled Water Level (RL m)	Residual (m)	Location
IBC2103	226898	6611773	275.1	288.0	-12.9	Boggabri Coal Mine
IBC2104	228336	6612215	285.9	293.6	-7.7	Boggabri Coal Mine
IBC2110	225939	6607684	257.9	260.4	-2.5	Boggabri Coal Mine
IBC2113	229720	6608797	268.4	279.6	-11.2	Boggabri Coal Mine
IBC2115	229155	6610279	271.7	285.9	-14.2	Boggabri Coal Mine
IBC2138	226725	6610387	264.6	278.5	-14.0	Boggabri Coal Mine
IBC2139	229421	6609296	267.2	281.5	-14.3	Boggabri Coal Mine
GW3115	225174	6608903	250.4	262.9	-12.5	Boggabri Coal Mine
MW1	228743	6605702	265.4	263.8	1.6	Tarrawonga Mine
MW3	226041	6607875	255.3	261.2	-6.0	Tarrawonga Mine
MW5	229488	6605985	272.7	266.7	6.0	Tarrawonga Mine
MW6	225385	6607871	258.7	259.6	-0.8	Tarrawonga Mine
MW7	229823	6607932	276.1	275.4	0.8	Tarrawonga Mine
MW8	226795	6606958	268.9	260.7	8.2	Tarrawonga Mine
GW002129	228724	6606271	259.7	266.4	-6.6	Tarrawonga Mine
GW002501	228013	6606613	267.1	265.8	1.2	Tarrawonga Mine
GW044997	230870	6605895	273.6	268.6	5.0	Tarrawonga Mine
GW031856	229157	6603179	266.5	258.8	7.7	Tarrawonga Mine
GW020432	224451	6607991	263.8	255.4	8.3	Tarrawonga Mine
GW052266	227848	6604674	259.4	258.1	1.3	Tarrawonga Mine
Templemore A	230997	6605537	271.3	268.0	3.3	Tarrawonga Mine
Templemore B	230544	6604345	266.1	265.0	1.1	Tarrawonga Mine
GW030051	224986	6599590	232.7	241.3	-8.6	Govt monitoring bore
GW030052	226616	6599386	232.9	246.6	-13.7	Govt monitoring bore
GW030129	217136	6619638	240.0	236.2	3.8	Govt monitoring bore
GW030130	217406	6620539	241.2	237.3	3.9	Govt monitoring bore
GW030131	217455	6621711	245.1	238.5	6.6	Govt monitoring bore
GW030132	217321	6623773	245.0	240.1	4.8	Govt monitoring bore
GW030468	217748	6603410	231.0	230.2	0.7	Govt monitoring bore
GW030469	218614	6603895	231.9	231.3	0.5	Govt monitoring bore
GW030470	218997	6604552	232.1	232.9	-0.8	Govt monitoring bore
GW030471	219450	6605581	231.4	235.0	-3.7	Govt monitoring bore
GW030472	225148	6602615	232.6	245.4	-12.8	Govt monitoring bore
GW030535	222609	6599838	230.5	239.5	-9.0	Govt monitoring bore
GW036003	212979	6618419	224.9	224.8	0.1	Govt monitoring bore
GW036007	216174	6607530	228.5	228.1	0.3	Govt monitoring bore
GW036008	216601	6607510	228.4	227.8	0.6	Govt monitoring bore
GW036014	213903	6611723	226.3	226.7	-0.4	Govt monitoring bore
GW036015	215136	6611509	226.6	226.8	-0.2	Govt monitoring bore
GW036016	216205	6611383	226.7	226.8	-0.2	Govt monitoring bore
GW036056	215028	6609534	227.2	228.3	-1.1	Govt monitoring bore
GW036057	216488	6607723	228.7	227.8	0.9	Govt monitoring bore

Table 7: CALIBRATION TARGETS AND SIMULATED WATER LEVELS – STEADY STATE MODEL						
BORE_ID	**Easting**	**Northing**	**Measured Water Level (RL m)**	**Modelled Water Level (RL m)**	**Residual (m)**	**Location**
GW036092	218434	6603674	231.4	231.0	0.4	Govt monitoring bore
GW036093	212642	6617022	225.3	224.3	1.0	Govt monitoring bore
GW036164	213083	6617497	224.5	224.7	-0.2	Govt monitoring bore
GW036185	215750	6611464	226.2	226.8	-0.6	Govt monitoring bore
GW036186	214347	6618116	229.1	226.4	2.7	Govt monitoring bore
GW036187	215355	6618358	232.6	228.9	3.8	Govt monitoring bore
GW036548	222929	6594698	236.2	241.1	-5.0	Govt monitoring bore
GW036565	217594	6598104	234.2	235.9	-1.7	Govt monitoring bore
GW036567	217798	6596445	234.6	236.8	-2.2	Govt monitoring bore
GW036568	217621	6595084	234.6	236.2	-1.6	Govt monitoring bore
GW036598	217315	6593569	233.2	234.5	-1.3	Govt monitoring bore
GW041027	232730	6620523	307.3	309.1	-1.8	Govt monitoring bore
GW967137	219846	6622452	250.2	244.8	5.4	Govt monitoring bore
GW967138	227001	6622422	280.0	286.6	-6.6	Govt monitoring bore
GW030048	220712	6600066	233.8	236.9	-3.1	Govt monitoring bore

The calibrated model provides a good match between the observed and simulated heads within the alluvial aquifer zone. The exception was the head waters of Bollol Creek where a number of observation bores have been installed by the Tarrawonga Mine. The measured water levels in this area were 30m to 40m above model predicted levels, suggesting the alluvium is a perched system in this area, although this has not been confirmed with deeper test holes. Due to this uncertainty these calibration points were excluded from the calibration, but are shown in Drawing No. 9 for reference.

In the Permian outcrop the model predicted groundwater levels were higher than observed. Hydraulic conductivity and recharge rates were adjusted within plausible ranges to obtain an improved match, but the final calibration still had an over prediction of up to 14m in the area of the Boggabri Coal Mine. The final adopted recharge rate for the Permian was relatively low at 1mm/year and considered a lower bound of potential recharge rates. Conversely the adopted transmissivity of 2.5m^2/day was relatively high and considered an upper bound, based on previous testing (AGC 1982)[4], (PB 2005)[6]. It was decided not to vary these parameters any further to obtain an improved calibration as they would be outside the considered representative range.

The affect of the adopted parameters, particularly the low recharge rate in the outcrop areas, on the model predictions would be to allow the zone of influence to expand to a greater extent, and therefore these adopted parameters are considered conservative.

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. The root mean square (RMS) error is expressed as follows:

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

where: n = number of measurements
h_o = observed water level
h_m = simulated water level

The RMS error calculated for the calibrated model was 6.3m. 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 change is small, known as the Scaled RMS (SRMS), the errors are only a small part of the overall model response (Anderson and Woessner, 1992)[19]. The ratio of RMS (6.3m) to the total head change across the calibration points (82.8m) indicated a SRMS of 7.6%. The acceptable target for SRMS varies between models but is typically below 5% (MDBC 2000)[15]. However when the following points are taken into account, the calibration is considered to be the best achievable:

- the steady state model used a simplified uniform representation of permeability based on limited data to represent complex heterogeneous fractured rock systems,
- the model did not represent faults that can act as barriers to groundwater flow and result in variability in water levels that are not reproducible when a homogenous system is assumed, and
- the water levels recorded at the calibration points are assumed to have been representative of pre-mining conditions, however no long term groundwater level records were available prior to the commencement of mining to confirm this assumption.

The mass balance error, that is, the difference between calculated model inflows and outflows, at the completion of the calibration run expressed as a percentage of discrepancy, was 0%, indicating good accuracy of the numerical solution and overall stability of the model. The model water budget is summarised in Table 8 below.

Table 8: WATER BUDGET – STEADY STATE MODEL (ML/DAY)

Parameter	Input	Output
Rainfall recharge	41.8	0.0
River leakage	18.7	28.8
Drains	0.0	20.5
Evapotranspiration	0.0	0.5
Fixed head	0.8	11.3
TOTALS	**61.2**	**61.2**

The water budget indicates a net discharge of 10.1ML/day to the Namoi River and 21ML/day via ephemeral creeks and evapotranspiration.

9.0 PREDICTIVE SIMULATIONS

After the steady state model was calibrated to the available data, the model was then converted to transient flow conditions to undertake the predictive scenarios. The steady state heads were used as the starting heads in the transient model. To achieve the transient simulation of mine progression, a number of assumptions were made as discussed below.

9.1 Set-up and Assumptions

The transient model was set up with 107 quarterly (91.3125 day) stress periods, representing the period from the second quarter of 2006 to last quarter of 2032. This period covers the historical mining that commenced at both Boggabri Coal Mine and Tarrawonga Mine in 2006 and the 21-year period of the Project (2012 to 2032).

Specific yield and specific storage values for the alluvial aquifer were set at values similar to those used by NOW (2006)[7].

Dewatering of the open cut mines was represented by the introduction of drain cells to the floor of the seam being mined (Merriown Seam). The simulation of the mining operations required a number of simplifying assumptions as follows:

- Boggabri Coal Mine – the proposed extension to the mine was based on annual mining strips provided by Boggabri Coal with the floor of the pits set at the base of Layer 3 which represented the floor of the Merriown Seam. Drain cells were also active in the overlying Layer 1 and Layer 2 to simulate open cut mining.
- Tarrawonga Mine – a similar approach was used to represent Tarrawonga Mine, with the floor of the open cut pit set at the base of the Nagero Seam, which was represented using publicly available data. Mining was simulated until 2014, the currently approved period of mining, at which time the drain cells were removed from the model to simulate closure of the mine.

The locations of the mines and the rate of advancement used in the transient simulations are shown in Drawing No. 10.

Vickery Mine is an open cut operation located about 12km to the south of the Boggabri Coal Mine, at the southern limit of the model boundary domain and was not expected to interact with the Boggabri Coal Mine or Tarrawonga Mine and was therefore not included in the predictive modelling.

As two different mining operations were active in the model with potentially interactive cumulative affects on groundwater levels, the model was run twice, firstly with both Boggabri Coal Mine and Tarrawonga Mine operating and, secondly excluding the Boggabri Coal Mine. The results of the two models were then compared to separate the cumulative impact of the mining operations from those attributable to the Boggabri Coal Mine only.

The water balance error for the transient model is shown in Figure 17 and was below the MDBC (2000)[15] recommendation of less than 1% for each stress period and cumulatively for the entire simulation. The cumulative water balance is shown in Figure 18.

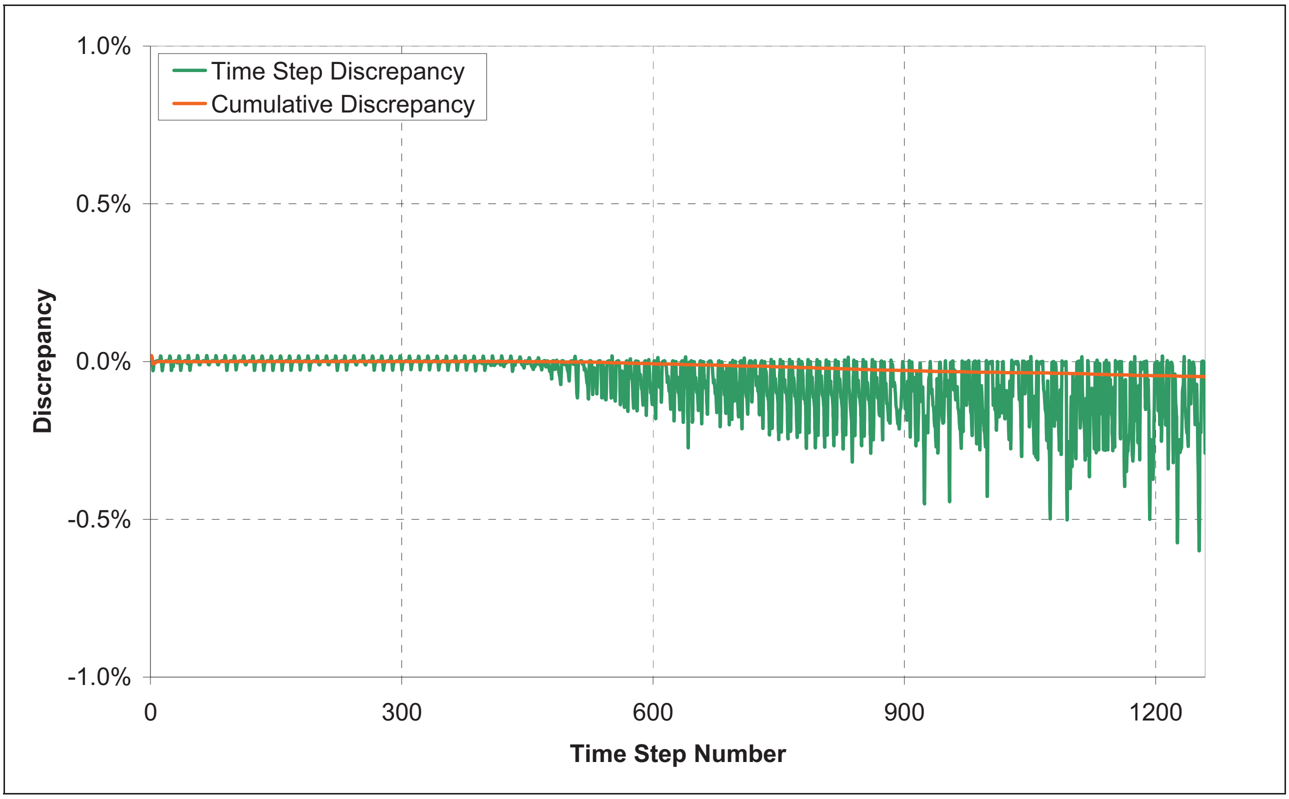


Figure 17: Active Mining Phase Model Budget Error

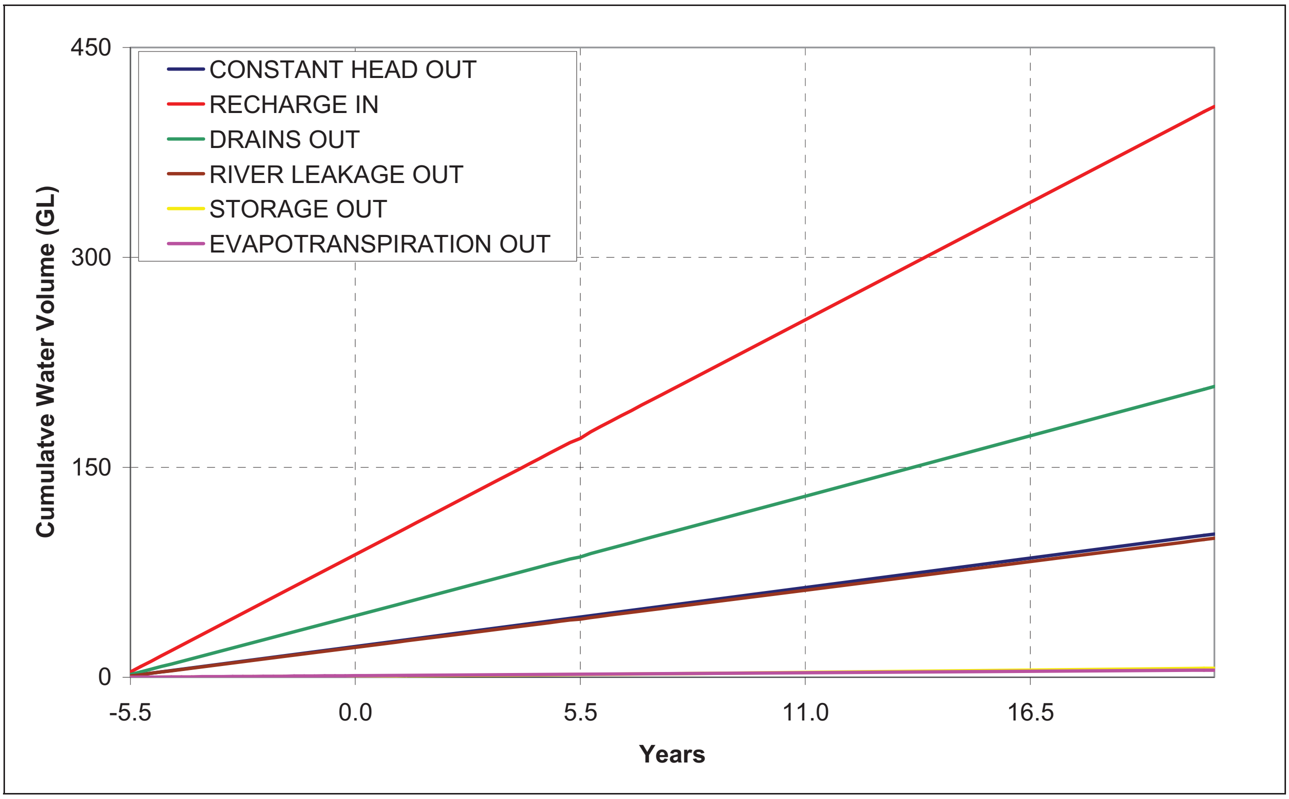


Figure 18: Cumulative Model Water Budget – Mining Phase

9.2 Piezometric Surface/Water Table Levels

Model simulated water levels at the end of mining in Year 21 in Layer 2, which represents the Maules Creek Formation regolith and the Gunnedah Formation aquifer in the alluvial lands, are presented in Drawing No. 11. The zone of depressurisation around the Project is clearly evident. Simulated drawdown in Layer 2, which is the difference between the pre-mining water levels and the levels at the end of the 21-year mining period are presented in Drawing No. 12.

The software used has the capability to calculate hydraulic heads below the base of each layer, and in some areas this occurs where the water level or drawdown extends below the base of Layer 2 indicating water levels have fallen below the base of the layer, mainly in the outcrop area. The growth of the zone of influence overtime defined by the 1m drawdown contour is shown in Drawing No. 13.

The modelling indicates the depressurised zone extends between about 3km and 3.5km from the edge of the open cut pit at the end of mining in Year 21. The zone of influence largely remains within the Permian outcrop zone, but does extend slightly into the alluvial aquifer, in the south-west where a thin zone of alluvium is present in a small valley extending into the outcropping hill. As the alluvium thickens to the south-west the transmissivity and ability to transmit water increases and the zone of influence does not extend further into the alluvium for this reason.

9.3 Impact on Groundwater Users

The modelling indicates a zone of influence extending between about 3km and 3.5km beyond the open cut pit at the end of mining in Year 21. A total of 28 registered bores are encompassed within this zone. The locations of the registered bores within the zone of depressurisation are shown in Drawing No. 13. Details on the registered bores from the NOW groundwater database are summarised in Table 9.

Table 9: REGISTERED BORES WITHIN ZONE OF INFLUENCE

Work No	Date	Land Ownership	Usage	Depth (m)	Aquifer [1]
GW000507	1920	NSW State Forest on Boggabri Mine Lease		60.7	Maules Creek Formation
GW000526	1920	Boggabri Coal		105.2	Boggabri Volcanics
GW002129	1928	Whitehaven Coal	Tarrawonga Monitoring Bore	297.1	Maules Creek Formation
GW002501	1928	Whitehaven	Tarrawonga Monitoring Bore	77.1	Maules Creek Formation
GW002748	1929	Namoi Valley Coal		72.2	Maules Creek Formation
GW003115	1932	Boggabri Coal	Boggabri Mine Monitoring Bore	82.9	Boggabri Volcanics
GW020432	1963	Boggabri Coal	Tarrawonga Monitoring Bore	48.8	Alluvial
GW020434	1927	Boggabri Coal		85.3	Boggabri Volcanics
GW020437	1963	Boggabri Coal		36.6	Boggabri Volcanics
GW026419	1966	Boggabri Coal		60	Alluvial
GW053825	1981	NSW State Forest		257	Maules Creek Formation
GW967855	2006	NSW State Forest	Boggabri Mine Monitoring Bore	92.79	Maules Creek Formation
GW967856	2006	NSW State Forest	Boggabri Mine Monitoring Bore	66.5	Maules Creek Formation
GW967857	2006	NSW State Forest	Boggabri Mine Monitoring Bore	111.5	Maules Creek Formation
GW967858	2006	NSW State Forest	Boggabri Mine Monitoring Bore	86	Maules Creek Formation
GW967859	2006	NSW State Forest	Boggabri Mine Monitoring Bore	96.8	Maules Creek Formation
GW967860	2006	Boggabri Coal	Tarrawonga Monitoring Bore	100	Boggabri Volcanics

Table 9: REGISTERED BORES WITHIN ZONE OF INFLUENCE

Work No	Date	Land Ownership	Usage	Depth (m)	Aquifer [1]
GW967861	2006	NSW State Forest	Boggabri Mine Monitoring Bore	59	Maules Creek Formation
GW967862	2006	NSW State Forest	Boggabri Mine Monitoring Bore	85	Maules Creek Formation
GW967863	2006	NSW State Forest	Boggabri Mine Monitoring Bore	160	Maules Creek Formation
GW967864	2006	NSW State Forest	Boggabri Mine Monitoring Bore	91	Maules Creek Formation
GW967881	2006	Boggabri Coal		32	Alluvial
GW967882	2006	Whitehaven Coal	Tarrawonga Monitoring Bore	26	Boggabri Volcanics
GW968046	2006	Boggabri Coal		65.5	Maules Creek Formation
GW968046	2006	Boggabri Coal		65.5	Boggabri Volcanics
GW968397	2006	Whitehaven Coal		144	Maules Creek Formation
GW968397	2006	Whitehaven Coal		144	Maules Creek Formation
GW968515	2008	Whitehaven Coal		179.1	Maules Creek Formation

1 – based on Gunnedah North Geology Map

The majority of the bores within the zone of influence are located on land owned by Boggabri Coal or other neighbouring mining companies. Fifteen bores are for groundwater monitoring at either the Boggabri Coal Mine or Tarrawonga Mine. As the remaining bores are located on land owned by mining companies, it is unlikely they remain in use. No registered irrigation bores constructed in the alluvial sediments are present within the zone of influence.

It is also important to note that a conservative approach has been adopted in the modelling, and the zone of influence is not expected to develop to the extent predicted by the numerical modelling for the following reasons:

- the model does not include the faults and igneous intrusions in the area and simulates a continuous hydraulically connected aquifer system. Faults offset the coal seams and intrusions can act as barriers to groundwater flow, which both limit the expansion of the zone of depressurisation;
- the model assumes the entire mine footprint remains dewatered over the Project life. In reality spoil will be progressively placed in the void which will saturate and limit the extent of drawdown.

9.4 Inflow to Mined Void

Flows into drain cells representing dewatering were extracted for each stress period to assess the rate of groundwater inflow to the mine pits. The model simulated inflow rates to the Project are shown in Figure 19 below. Inflows to the Project void are predicted to rise gradually as the length of the advancing face increases and the mine progresses down-dip. Predicted pit seepage rates peak at about 1.25ML/day (457ML/yr) in the final six years of mining.

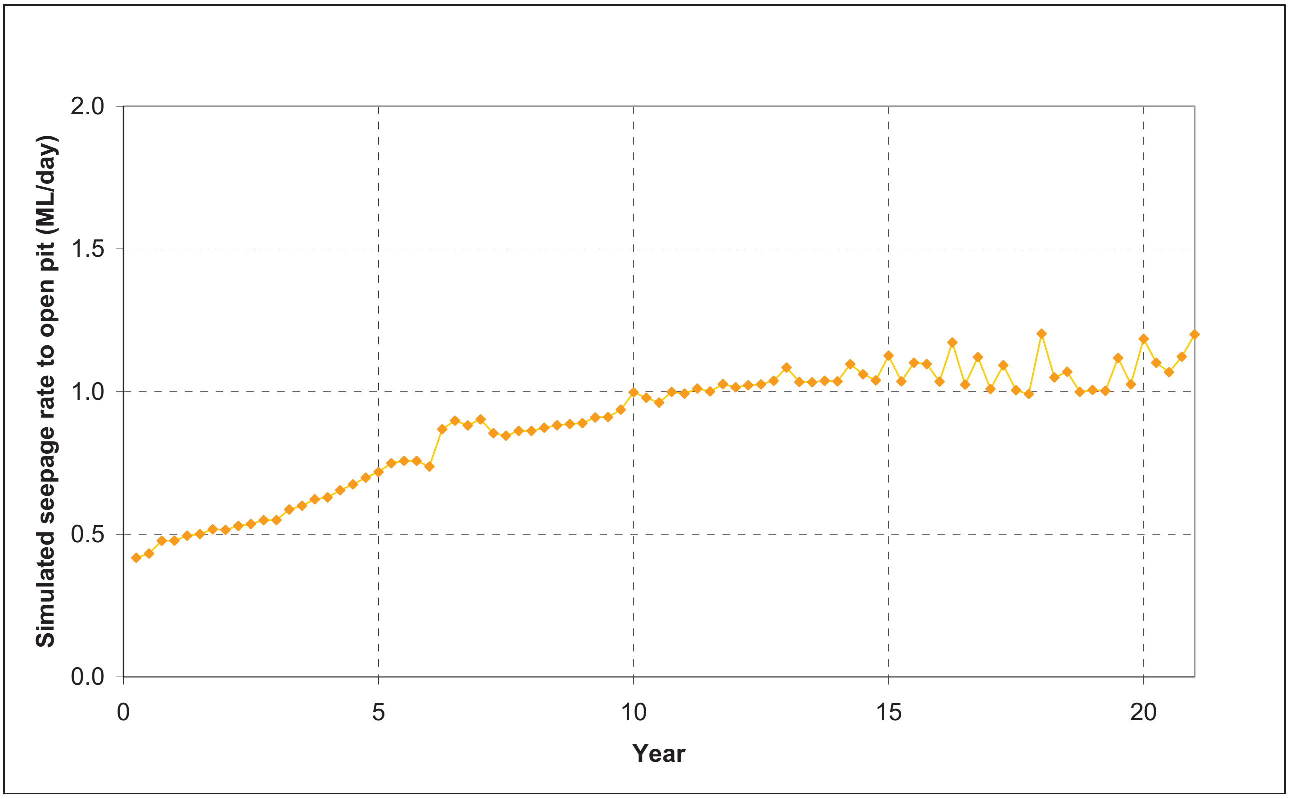


Figure 19: Simulated Seepage into the Boggabri Coal Mine

The inflow rates presented in Figure 19 have not been corrected for groundwater that is lost as moisture in coal and evaporation from the pit face. The above rates therefore do not represent water that will report to in-pit sumps for pumping, which is likely to be less. It is difficult to quantify the total volume of water lost though direct evaporation from the coal seam face, however 0.5L/s (~0.06ML/day) is considered feasible. This is based on 16m of exposed coal seam thickness in a 1000m advancing face, and an evaporation rate of 4mm per day. The volume of water lost through evaporation may also be slightly higher if water loss through the pit floor and inter-burden zones is considered.

Water removed in coal as moisture may also account for significant volumes of water. Assuming 7Mt/year and 5% moisture content approximately 11L/s (0.95ML/day) may be removed with the coal. It should also be noted that for the reasons mentioned previously, the simulated inflows are considered to be a conservative overestimate for the following reasons:

- the model simulates a continuous aquifer system and does not include the minor faults and igneous intrusions in the area – assuming these faults act as barriers to groundwater flow, inflows to the model will be lower than predicted by the laterally continuous aquifers in the model,
- the model assumes the entire mine footprint remains dewatered over the Project life, which increases inflow rates, and
- the starting heads used in the model were higher than the observed head and this has the effect of increasing the hydraulic gradients between the aquifer and the pit, increasing inflow rates to the pit.

9.5 Leakage from Alluvial Aquifers

The Project and the Tarrawonga Mine are in relatively close proximity to each other which results in interaction between the zones of depressurisation created by each mine. In order to determine the leakage from the alluvial aquifer into the mine pit that was attributable to the Project only, two model scenarios were compared, firstly with both mines operating, and secondly with the Project removed. Leakage from the alluvial aquifer was then estimated by extracting the cell by cell flow data for each stress period from the model and subtraction of the two scenarios. The predicted impact on the alluvial aquifer is shown in Figure 20 below.

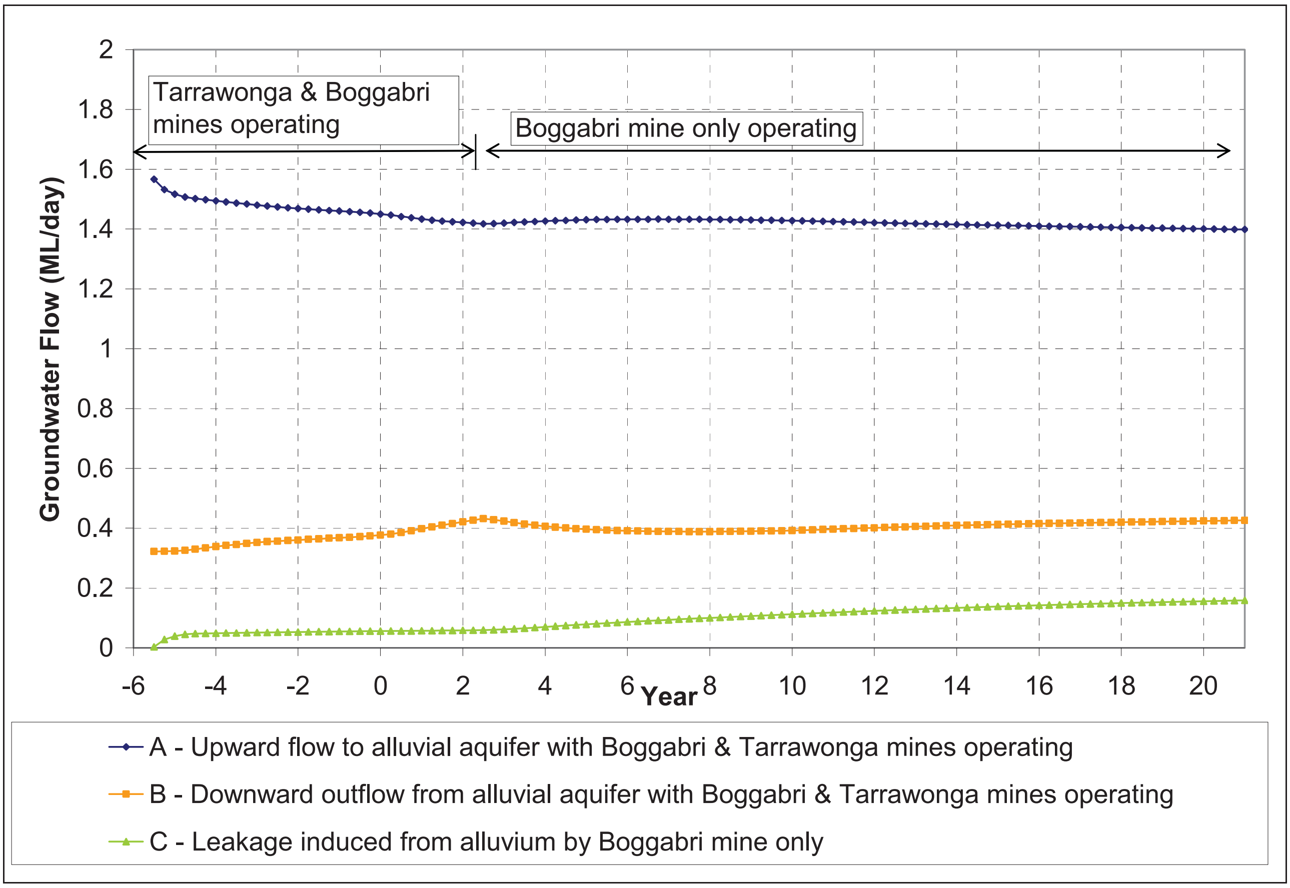


Figure 20: Simulated leakage from Namoi River alluvial aquifer (Narrabri and Gunnedah Formations – Layer 1 and Layer 2)

Figure 20 shows:

- A - the cumulative upward inflow of groundwater into the Namoi Valley alluvial aquifer from the underlying bedrock for the entire model domain,
- B - the cumulative downward leakage from the Namoi Valley alluvial aquifer due to depressurisation of the underlying bedrock associated with mining, and
- C - the leakage from the alluvial aquifer due to the Boggabri Coal Mine only. This is the difference between the simulated downward flow predicted by one model with Boggabri Coal Mine and second model excluding Boggabri Coal Mine.

The modelling indicates that the loss of water from the alluvial aquifer due to the Project reaches a maximum at almost 0.2ML/day (73ML/yr) at the end of mining when the zone of influence and depressurisation of the bedrock has expanded to the maximum extent.

9.6 Groundwater Recovery

Once mining operations cease, dewatering of the open void will not be required and a slow recovery in groundwater levels in the area will occur. The current mine plan is based on the assumption that approval for 21 years additional mining will be granted, after which there is the possibility of a further seven years of mining, which will need another further approval in the future. If this approval for a further seven years in granted the mine will advance in a north-westerly direction into a relatively elevated area and effectively no final void will remain after this additional eight year period of mining.

After the 21 year mining approval a void will remain at the northern extent of the mine footprint with an area of approximately 413ha. The lowest point in the final void will be RL 176m, a depth of about 156m below the spill level of the void (approximately RL 332m). Assuming that mining ceases by year 21 the final void will be backfilled with spoil to a point where the ground surface will be at or above the pre-mining groundwater level of about RL 285m. This backfilling will prevent the pooling of water in the final void as the reshaped ground surface will be above the groundwater level. A long dish shaped depression will remain in the area of final void after backfilling which may accumulate some runoff; however this will not be a window to the underlying aquifer, as the ground surface will be above the regional groundwater level.

Direct rainfall on the spoil will recharge the dewatered coal seam/overburden units and the dry spoil, with groundwater levels eventually reaching an average stable water level which will be influenced by the recharge rate and the hydraulic conductivity/storage properties of the spoil material.

Recovery of groundwater levels in the spoil was estimated by running the groundwater model with the following modifications:

- the spoil areas were represented with a hydraulic conductivity of 1m/day and specific yield of 0.1,
- the evapotranspiration extinction depth was set to RL 285m across the area of the final void to simulate backfilling and evaporation on the re-profiled land surface,
- the recharge rate to the spoil was varied from 1mm per year to 500mm per year

The water balance error for the recovery modelling was below the MDBC (2000)[15] recommendation of less than 1% for both the individual time steps and on a cumulative basis for the complete model run.

The simulated recovery in water levels in the spoil zone of the backfilled void are shown in Figure 21 below.

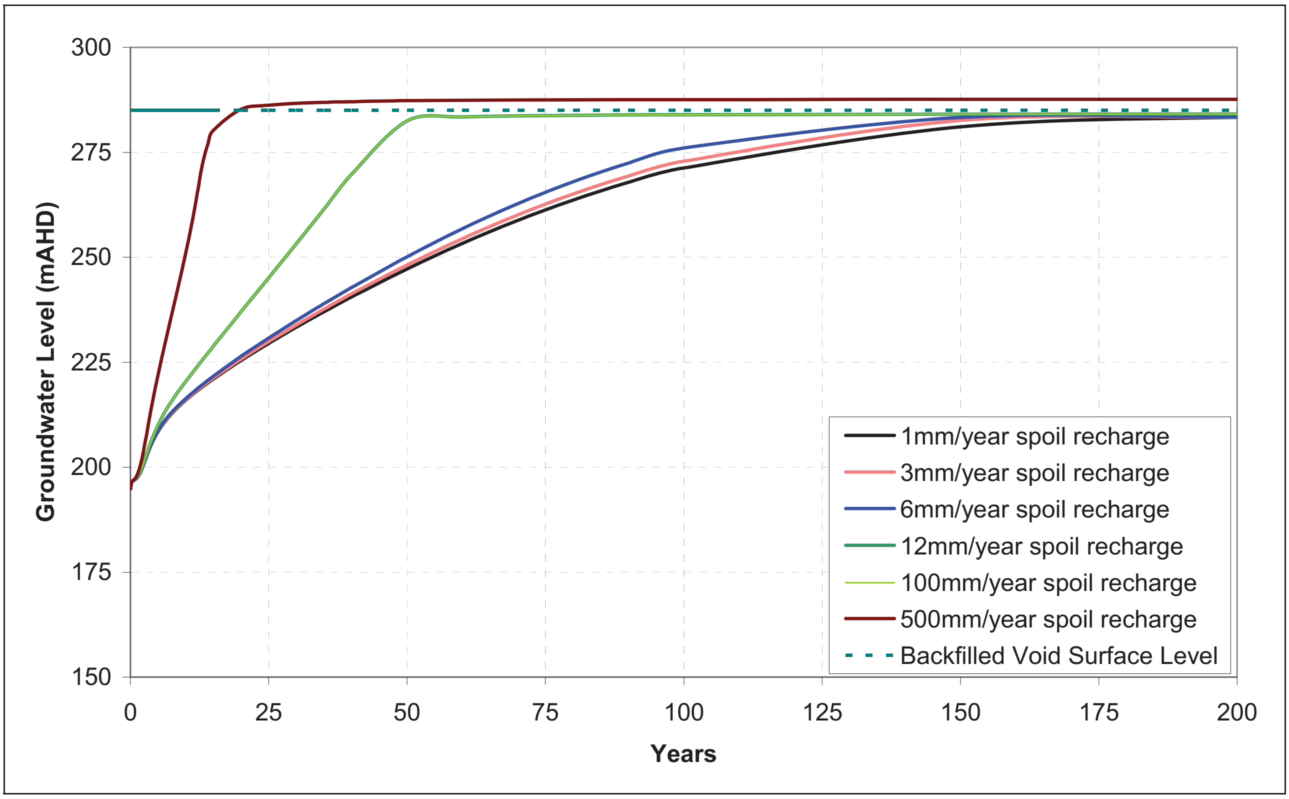


Figure 21: Simulated Water Level in Final Void

The simulation results indicate the groundwater level in the backfilled void will not exceed the reprofiled surface level for recharge rates of less than 100mm per year, which is about 16% of rainfall. The recovery rate is dependent on the recharge rate and will likely vary between 50 and 150 years. Should recharge rates exceed 100mm/year, the modelling suggests groundwater levels could rise above the ground surface level, in which case it will be necessary to backfill the void above RL 285m, or cut a drain to remove excess rainfall recharge.

The groundwater levels induced by the changed aquifer parameters at 100 years are shown for Layer 2 in Drawing No. 14.

The modelling indicates that a limited zone of depressurisation will remain at 100 years but it does not extend into the alluvial aquifer and the magnitude of the drawdown is relatively limited.

9.7 Sensitivity Analysis

A sensitivity analysis was undertaken to assess the model responses to variations in uncertain input parameters. The sensitivity analysis was one sided and therefore adopted changes to parameters that would increase the zone of influence and therefore the impact of the proposed mine. The following scenarios were examined:

- a reduction of 10% in the rainfall recharge rate to the alluvial aquifer; and
- a 2 times increase in the transmissivitiy of the Permian Maules Creek coal measures aquifer represented in Layer 3 and Layer 4 from 2.5m^2/day to 5m^2/day.

The predicted zone of influence in Layer 2 for each of the above scenarios is presented in Drawing No. 15 and Drawing No. 16 respectively.

The zone of influence for both scenarios is slightly more extensive than predicted in the base model, primarily in the 1m to 2m drawdown zone which extends slightly further into in a northerly direction. The natural fluctuation in the alluvial aquifer is in the order of 3m and as such this impact is not likely to be detectable.

A further sensitivity analysis on the Worst case cumulative impact scenario was undertaken and is outlined included in Appendix A.

9.8 Model Uncertainty and Limitations

This model has been constructed based on limited available data and the use of the model predictions should be treated as such. The uncertainty in the model results can be reduced through the collection of mine pit seepage records, which were not available for this study. If significant divergence is observed between the measured and model predicted inflows, revisiting the model and specifically re-calibration of the model parameters against the measured inflow data will reduce the model uncertainty and gain better predictions for the future.

Development, calibration and the results of predictive simulations from any groundwater model is based on available 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. These assumptions and the impact of the on the simulation results are discussed in this report. Where an assumption was necessary, a conservative approach was taken (such as adopting model parameters from plausible ranges) so that the model would likely over predict impacts or be representative of the worst case scenario.

The model assumed that the hydraulic properties of the aquifers were uniform across the entire model domain. In reality the permeability of the aquifers is variable and this variability can result in a less uniform zone of depressurisation than that predicted by the numerical model.

The conceptual model assumes that the hydraulic properties of the Permian coal seams present and the interburden/overburden can be represented by two major layers. The hydraulic properties of a number of coal seams present within these layers were merged with the properties of the interburden/overburden. This simplification may lead to underestimation of the extent depressurisation in the coal seams. This is because the cone of depression in coal seams that have relatively higher hydraulic conductivity is likely to develop somewhat quicker than in the less permeable interburden.

However, the chosen approach is considered to be reasonable since the extent of the zone of depressurisation is limited and the period of the simulated mine development is sufficiently long to compensate for any major difference between the development of the zone of depressurisation in the coal seams and in the interburden/overburden.

10.0 WATER QUALITY

To assess the potential for the overburden and reject material from the coal washery to contaminate groundwater reference was made to the geochemical assessment report prepared by RGS (2009)[20]. The assessment geochemically characterised overburden, interburden and potential coal reject material and concluded that:

Overburden

- *Most overburden materials will generate slightly alkaline and relatively low-salinity run-off and seepage following surface exposure. The major ion chemistry of initial surface run-off and seepage from overburden materials is likely to be dominated by sodium, bicarbonate, chloride and sulphate.*
- *The concentration of dissolved metals in initial run-off and seepage from overburden materials is unlikely to present any significant environmental issues associated with surface and ground water quality as a result of the Project.*

Coal rejects

- *Most potential coal reject materials will generate slightly alkaline and relatively low-salinity runoff and seepage following surface exposure. The exception is potential coal reject material from the Braymont seam (and potentially the Jeralong seam) where PAF materials may generate acidic and more saline run-off and seepage.*
- *The major ion chemistry of initial surface run-off and seepage from potential coal reject materials is likely to be dominated by sodium, bicarbonate, chloride and sulphate, although for PAF materials, calcium and sulphate may become more dominant. For PAF materials, the initial concentration of soluble sulphate in run-off and seepage is expected to remain within the applied water quality guideline criterion, although further exposure to oxidising conditions could lead to increased soluble sulphate concentrations.*
- *The concentration of dissolved metals in initial run-off and seepage from potential coal reject materials is unlikely to present any significant environmental issues associated with surface and ground water quality as a result of the Project.*

Considering the conclusion reached by RGS (2009)[20] following geochemical assessment of the overburden and potential reject materials, it is considered unlikely that leachate generated from these materials will adversely impact groundwater quality.

The quality of the water in the final void will be determined by the quality of the rainfall which falls directly in the void, groundwater seepage quality, leaching of salts from the spoil piles and coal washery waste disposed of within these and evaporative concentration of these inputs. As the rainfall inputs dominate the water balance, the salinity of the water would be expected to be initially fresh becoming brackish to saline over time. The final void will act as a sink and draw in groundwater from surrounding aquifers, which will prevent the release of potentially brackish to saline water being released back into the aquifers.

There is potential for spills and contamination by metals and hydrocarbons from mine workshop, waste disposal and fuel storage areas, however adequate bunding and immediate clean-up of spills which is standard practice or a legislated requirement at mine sites, should prevent contamination of shallow groundwater system. Any spills from these areas are typically very localised and not regionally significant.

[20] RGS (2009). *"The Boggabri Continuation of Mining Project Geochemical Assessment of Overburden and Potential Reject Materials",* 3 November 2009.

The construction of the rail spur and loop does not intersect the alluvial aquifers and will therefore not have any impact on the groundwater in this system.

11.0 WATER LICENCING

Boggabri Coal Mine currently holds water licence 90BL255090 under the *Water Act 1912,* which allows the use of up to 142ML/year of groundwater seepage from the open cut pits. The numerical modelling predicts a maximum groundwater seepage rate associated with the Project of 1.25ML/day which is equivalent to about 457ML/year. It is understood an application has been made to expand this license to reflect the groundwater seepage rates predicted by the numerical modelling.

The model predicts a loss of water from the alluvial aquifer starting at 0.05ML/day, gradually rising to 0.2ML/day during the 21 year mining period, which is equivalent to a maximum of 73ML/year. Boggabri Mine currently holds 52 unit shares under licence 90BL252849 for a bore on the Daisymede property that is not in use. Assuming 0.6ML per unit share this licence will offset 31.2ML of alluvial groundwater. A licenced allocation under the current Water Sharing Plan will be required to account for the remaining water loss to the Project from the alluvium. Boggabri is in the process of acquiring additional adjacent property with any attached water licences. It is envisaged that these licences will more than compensate for any alluvial losses.

Additional groundwater monitoring bores, outlined in Section 12.1 below will also require borehole licences before installation.

12.0 GROUNDWATER MONITORING SYSTEM

This section of the report provides a recommended groundwater monitoring program that will provide both an on-going assessment of the impact of the Project and a proactive indicator of any adverse impacts on the groundwater regime.

12.1 Installation of Additional Monitoring Bores

Existing monitoring bores IBC2102, IBC2103, IBC2104, IBC2105, IBC2114 and IBC2115 are within the footprint of the proposed mining area and will therefore be removed by mining. It is recommended that the remaining sites be augmented with additional monitoring bores that will not be disturbed during the life of the mine. The sites of the existing and proposed additional monitoring bores are shown in Drawing No. 17. The purpose of the additional bores is to monitor for depressurisation of the coal measures strata and drawdown in the alluvial aquifer on an on-going basis.

A bore licence must be obtained from NOW before installation of any new monitoring bores. All monitoring bores should be constructed according to the Australian guidelines[21] by an appropriately qualified water bore driller. The recommended sites for additional monitoring bores are summarised in Table 10 below. All coal seam monitoring bores should be of a nested construction with separate bores in the Merriown Seam and overlying saturated coal seams above the Merriown Seam.

[21] Land and Water Biodiversity Committee (Sept. 2003) *"Minimum Construction Requirements for Water Bores in Australia"* Ed. 2

Table 10: SUMMARY OF RECOMMENDED ADDITIONAL MONITORING BORES			
Monitoring Site ID	**Easting (m)[1]**	**Northing (m)**	**Target Zone for Monitoring Bore**
MB1	222941	6609729	Boggabri Volcanics
MB2	224918	6612464	Merriown seam
MB3	225155	6610686	Merriown seam
MB4	226848	6612477	Merriown seam
MB5	230994	6612988	Merriown seam
MB6	229699	6610899	Merriown seam
MB7	229684	6610269	Merriown seam
MB8	229714	6609787	Merriown seam
MB9	231468	6608167	Merriown seam
MB10	222998	6604841	Alluvium
MB11	220355	6608607	Alluvium

1. Notes: Projection MGA94 Zone 56

Monitoring bores MB4 and MB6 were installed in January/February 2010 as part of the ongoing exploration program at the site. Borehole logs are included in Appendix B. It is understood installation of the remaining bores will be worked in with further proposed exploration drilling.

12.2 Water Level Monitoring Plan

Groundwater levels are currently measured in the existing monitoring network on a quarterly to six monthly basis. Manual monitoring is suitable for identification of long term trends in groundwater levels but does not provide data on short term events such rainfall recharge that can occur within a three monthly monitoring cycle.

It is therefore recommended that electronic water level loggers are installed in the key monitoring bore sites to the south of the Project Boundary and set to monitor water level fluctuations at six-hour intervals. This will enable water level fluctuations due to rainfall recharge and pumping to be distinguished from potential water level declines due to depressurisation as a result of open cut mining.

Registered bores identified as being within the simulated zone of depressurisation should also be inspected to determine if the bores are still operational and in-use. Monitoring should be undertaken in a subset of key bores within the simulated zone of influence.

12.3 Water Quality Monitoring Plan

The current water quality monitoring program consists of quarterly field measurements of water level, pH, temperature and electrical conductivity in all monitoring bores. On an annual basis water samples are also collected from the monitoring bores and analysed in the laboratory for:

- major cations and anions,
- nutrients - ammonia, nitrate, nitrite,
- metals - iron, lead, chromium, cadmium, zinc, arsenic, copper and nickel.

It is recommended the current water quality monitoring regime continue for the life of the mining operation.

12.4 Mine Water Seepage Monitoring

It is recommended that monitoring of mine water seepage should be undertaken, particularly to identify seepage rates and quality. Samples should be collected of any pumped seepage with the objective of providing an early indication of any mixing of shallow alluvial groundwaters with the deeper and poorer quality groundwaters of the Permian strata. Analysis should be the same as for the groundwater monitoring bores. The seepage monitoring program should include:

- recording of the time, location and volume of any unexpected increased groundwater outflow from the highwall and endwall;
- measurement of all water pumped from the pits particularly using flow meters or other suitable gauging apparatus;
- monitoring of water pumped from the pits for the same analytical suite outlined in Section 12.3;
- correlation of rainfall records with pit seepage records so groundwater and surface water can be separated; and
- monitoring of coal moisture content.

12.5 Data Management and Reporting

It is recommended data management and reporting include:

- Annual assessment of departures from identified monitoring data trends. If consecutive monitoring data over a period of 6 months exhibit an increasing divergence in an adverse impact sense from the previous data or from the established or predicted trend, then such departures should initiate further actions. These may include a need to conduct more intensive monitoring or to invoke impact re-assessment and/or mitigative measures.

- Formal review of depressurisation of coal measures and alluvial aquifers should be undertaken annually by a suitably qualified hydrogeologist. Every five years the validity of the model predictions should be assessed and if the data indicates significant divergence from the model predictions an updated or new groundwater model should be constructed for simulation of mining.
- Annual reporting (including all water level and water quality data).

AUSTRALASIAN GROUNDWATER AND ENVIRONMENTAL CONSULTANTS PTY LTD

Reviewed by:

JAMES S. TOMLIN
Principal Hydrogeologist

ANDREW M. DURICK
Principal Hydrologist

GLOSSARY

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

LIMITATIONS OF REPORT

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) has prepared this report for the use of Boggabri Coal Pty Limited in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal of 25 March 2009.

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

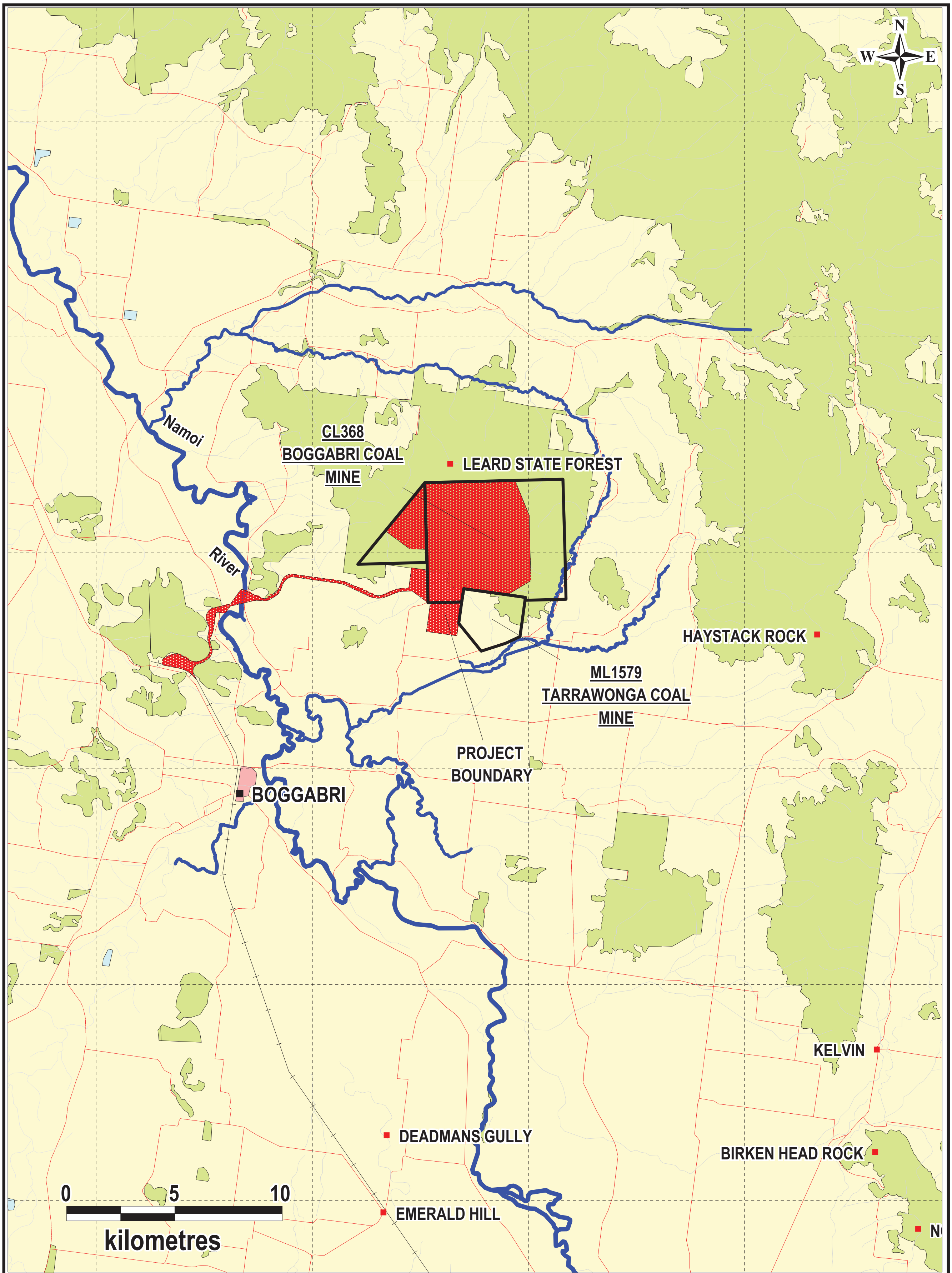
This study was undertaken between 21 April 2009 and 21 October 2010 and is based on the conditions encountered and the information available at the time of preparation of the report. AGE disclaims responsibility for any changes that may occurred after this time.

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

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

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

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



- LEGEND -

Boggabri Coal Mines

Native Vegetation

Rivers and Creeks

Roads

Railway

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD

36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: CONTINUATION OF BOGGABRI COAL MINE GROUNDWATER ASSESSMENT SITE LOCATION

CLIENT: Boggabri Coal

OFFICE: Brisbane

DRAWN BY: JST

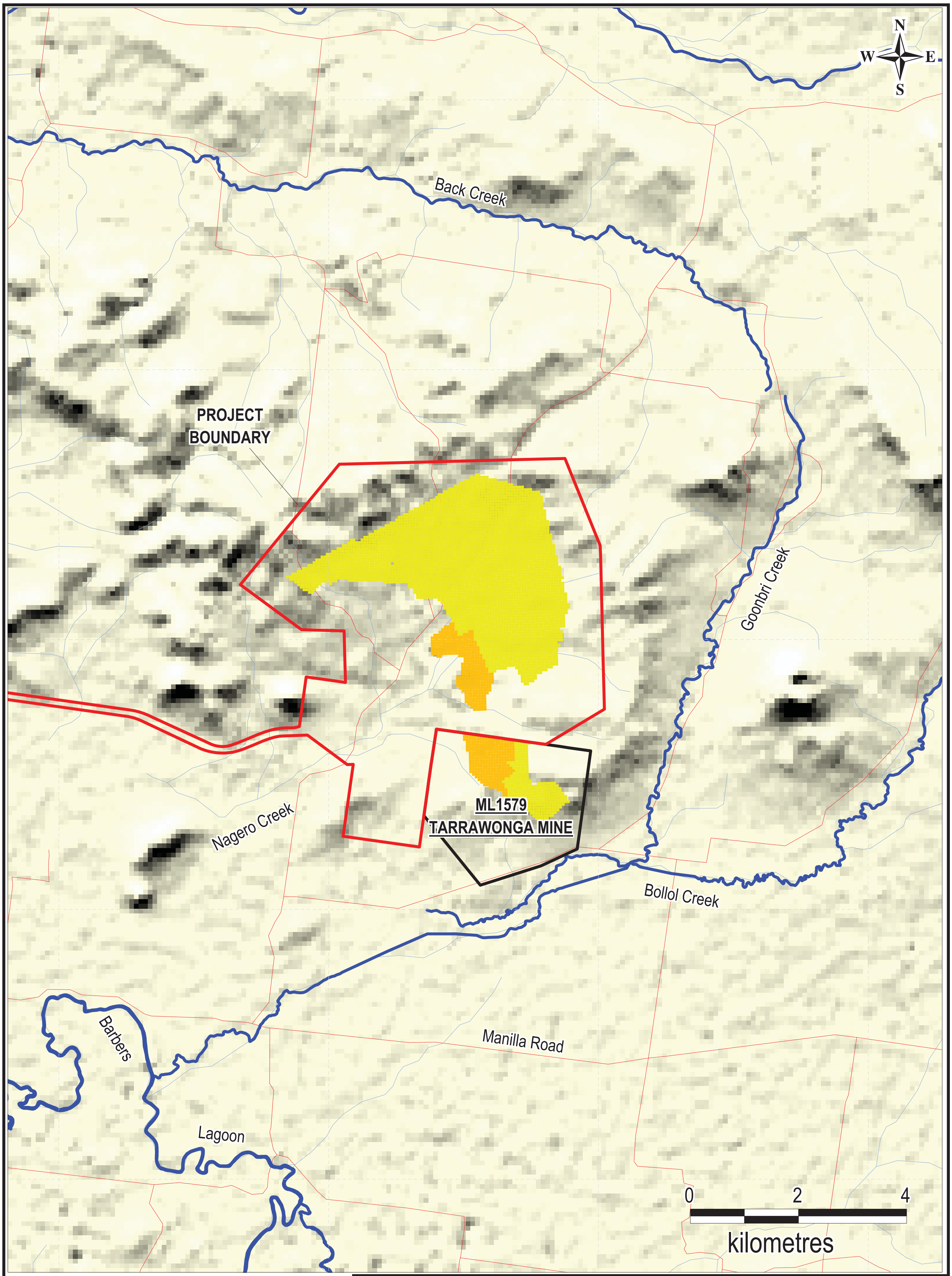
SCALE: 1 : 250,000 (A4)

PROJECT No: G1465

DRAWING No: 1

APPROVED BY:

DATE: October 2010

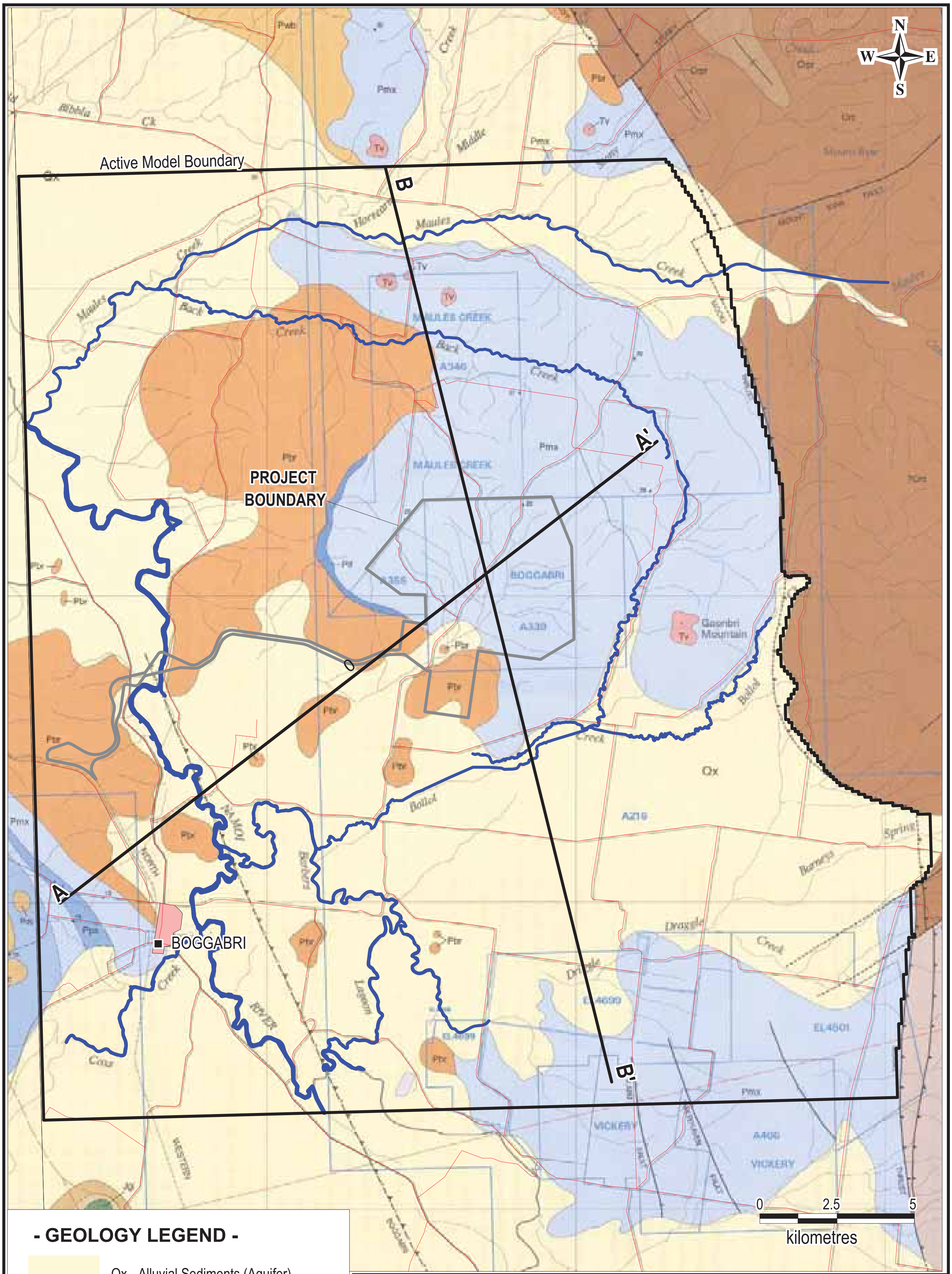


- LEGEND -

- Future Mining
- Existing Mined Areas

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: CONTINUATION OF BOGGABRI COAL MINE GROUNDWATER ASSESSMENT SITE LAYOUT			
CLIENT: Boggabri Coal			OFFICE: Brisbane
DRAWN BY: JST	SCALE: 1 : 100,000 (A4)	PROJECT No: G1465	DRAWING No: 2
APPROVED BY:		DATE: October 2010	



- GEOLOGY LEGEND -

Qx - Alluvial Sediments (Aquifer)

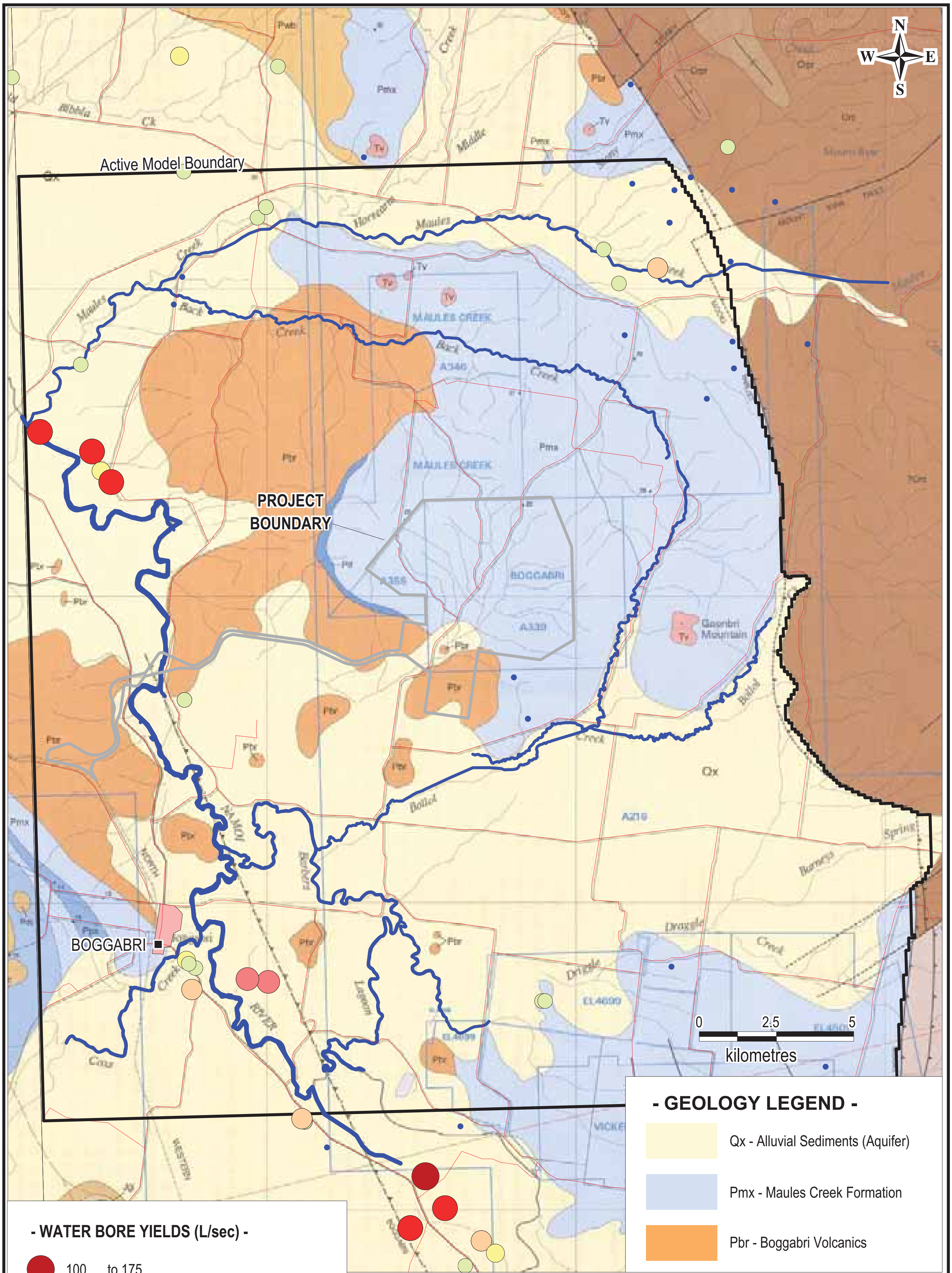
Pmx - Maules Creek Formation

Pbr - Boggabri Volcanics

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD 36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA			
TITLE: CONTINUATION OF BOGGABRI COAL MINE GROUNDWATER ASSESSMENT REGIONAL GEOLOGY			
CLIENT: Boggabri Coal			OFFICE: Brisbane
DRAWN BY: JST	SCALE: 1 : 175,000 (A4)	PROJECT No: G1465	DRAWING No: 3
APPROVED BY:		DATE: October 2010	

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

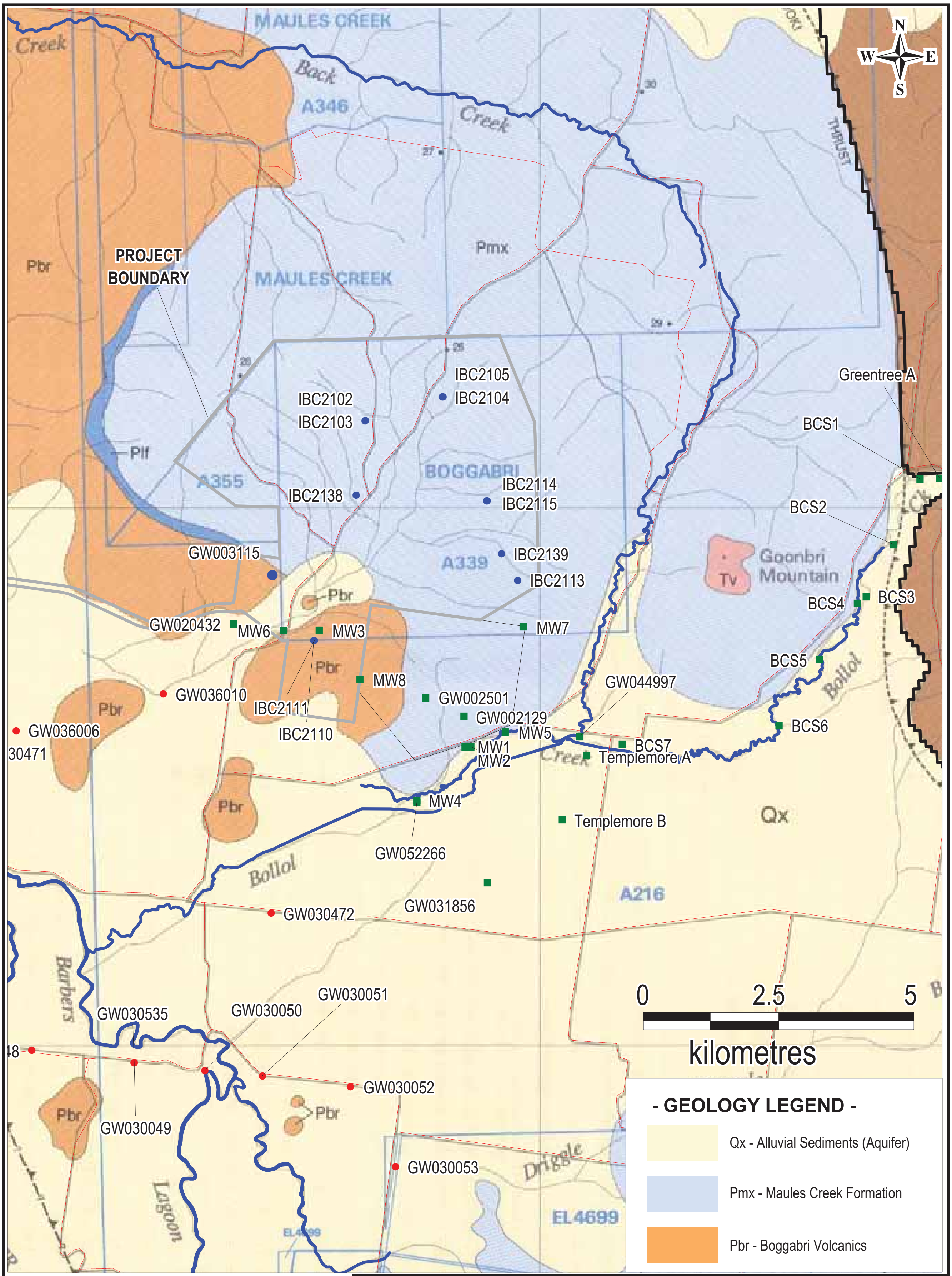
TITLE: CONTINUATION OF BOGGABRI COAL MINE GROUNDWATER ASSESSMENT REGISTERED WATER BORES AND MONITORING BORES			
CLIENT: Boggabri Coal			OFFICE: Brisbane
DRAWN BY: JST	SCALE: 1 : 175,000 (A4)	PROJECT No: G1465	DRAWING No: 4
APPROVED BY:		DATE: October 2010	



AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: CONTINUATION OF BOGGABRI COAL MINE GROUNDWATER ASSESSMENT REGISTERED WATER BORE YIELDS

CLIENT: Boggabri Coal			OFFICE: Brisbane
DRAWN BY: JST	SCALE: 1 : 175,000 (A4)	PROJECT No: G1465	DRAWING No: 5
APPROVED BY:		DATE: October 2010	

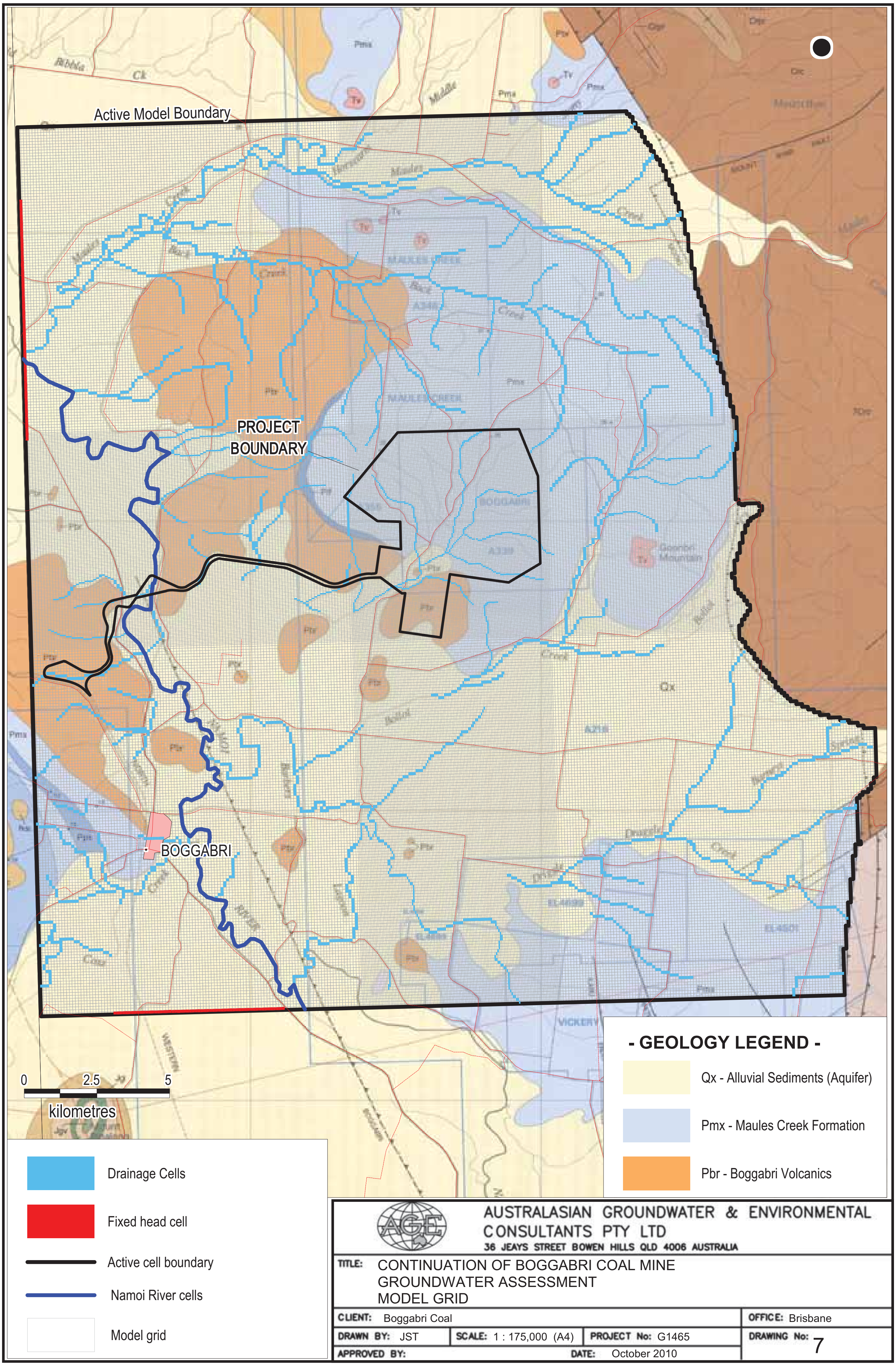


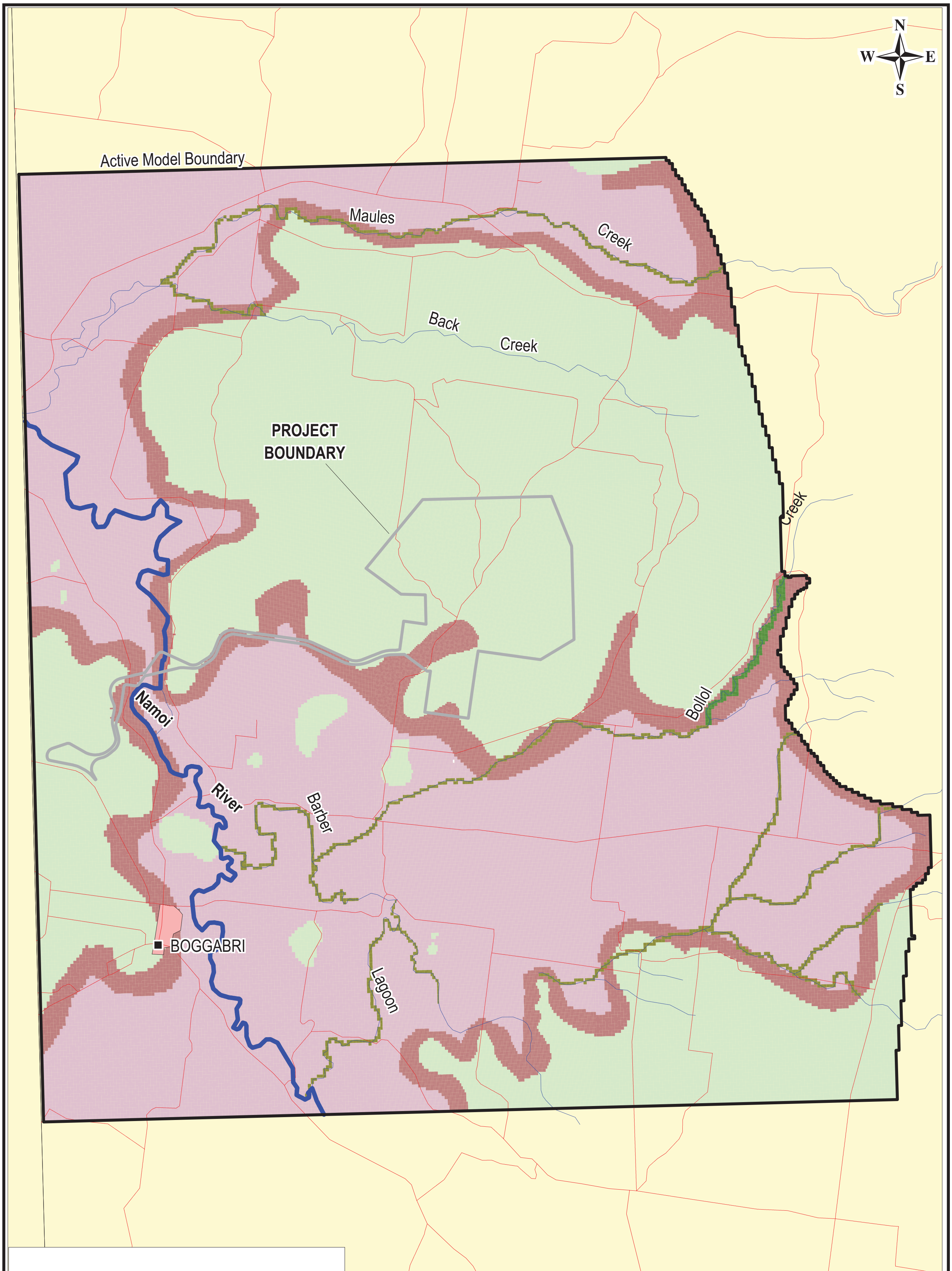
- LEGEND -

- NOW Monitoring Bores
- Tarrawonga Mine Monitoring Bores

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: CONTINUATION OF BOGGABRI COAL MINE GROUNDWATER ASSESSMENT MONITORING BORES			
CLIENT: Boggabri Coal			OFFICE: Brisbane
DRAWN BY: JST	SCALE: 1 : 100,000 (A4)	PROJECT No: G1465	DRAWING No: 6
APPROVED BY:	DATE: October 2010		


Active Model Boundary
PROJECT
BOUNDARY
BOGGABRI
0
2.5
5
kilometres
Qx
- GEOLOGY LEGEND -
Qx - Alluvial Sediments (Aquifer)
Pmx - Maules Creek Formation
Pbr - Boggabri Volcanics
Drainage Cells
Fixed head cell
Active cell boundary
Namoi River cells
Model grid
AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL
CONSULTANTS PTY LTD
36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA
TITLE: CONTINUATION OF BOGGABRI COAL MINE
GROUNDWATER ASSESSMENT
MODEL GRID
CLIENT: Boggabri Coal
OFFICE: Brisbane
DRAWN BY: JST
SCALE: 1 : 175,000 (A4)
PROJECT No: G1465
DRAWING No: 7
APPROVED BY:
DATE: October 2010

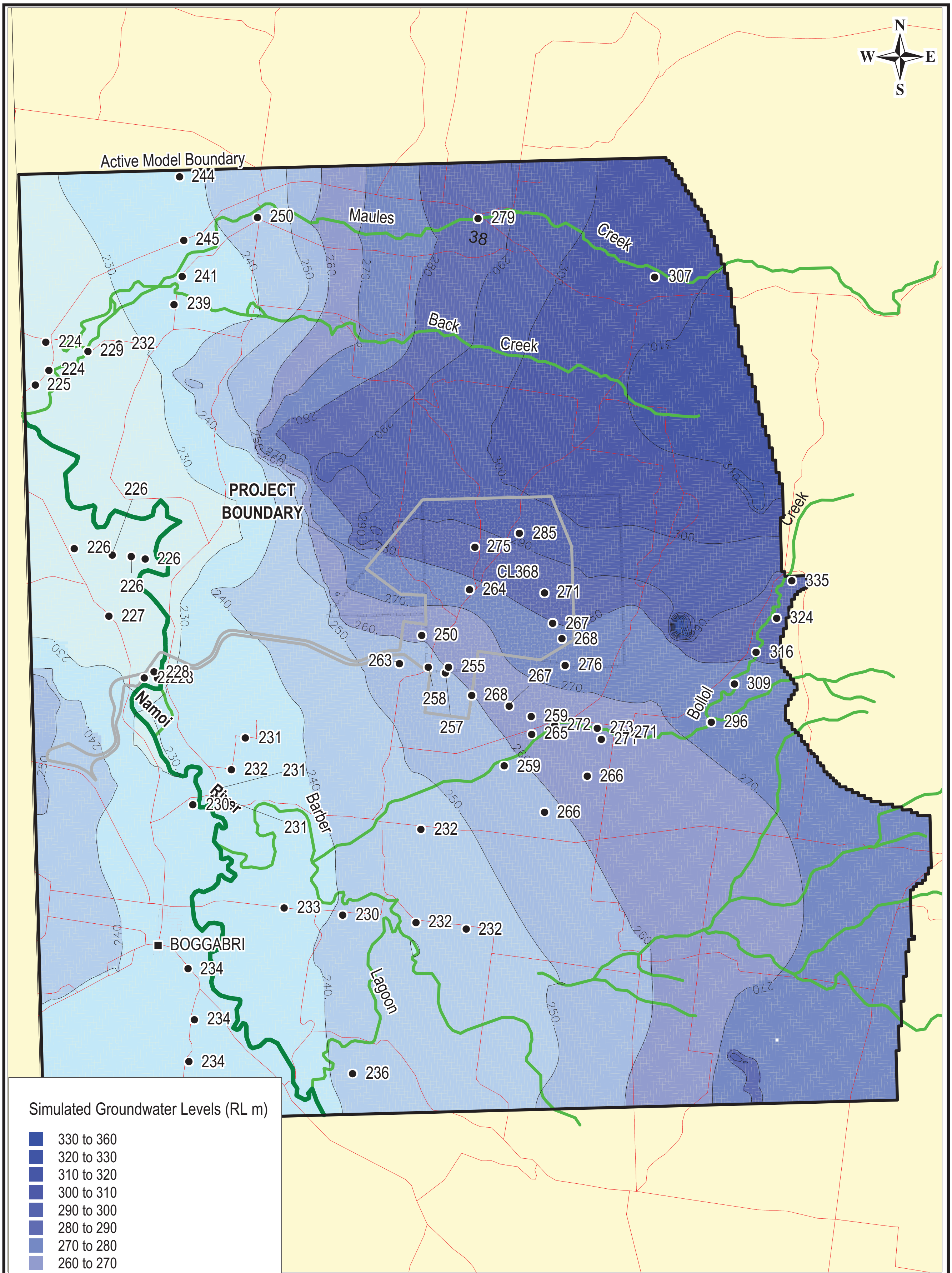


Recharge Zones

- Bollol Creek Headwaters - 150 mm/yr (25%)
- Ephemeral Drainage Lines - 90 mm/yr (15%)
- Slope Wash Zone - 90 mm/yr (15%)
- Alluvial aquifer - 18 mm/yr (3%)
- Outcrop zones - 1mm/yr (0.2%)

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: CONTINUATION OF BOGGABRI COAL MINE GROUNDWATER ASSESSMENT MODEL RECHARGE ZONES			
CLIENT: Boggabri Coal			OFFICE: Brisbane
DRAWN BY: JST	SCALE: 1 : 175,000 (A4)	PROJECT No: G1465	DRAWING No: 8
APPROVED BY:		DATE: October 2010	



Simulated Groundwater Levels (RL m)

- 330 to 360
- 320 to 330
- 310 to 320
- 300 to 310
- 290 to 300
- 280 to 290
- 270 to 280
- 260 to 270
- 250 to 260
- 240 to 250
- 230 to 240
- 220 to 230

● Observed Groundwater Level (RL m)

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: CONTINUATION OF BOGGABRI COAL MINE GROUNDWATER ASSESSMENT PRE-MINING SIMULATED AND OBSERVED HEADS - LAYER 2			
CLIENT: Boggabri Coal			OFFICE: Brisbane
DRAWN BY: JST	SCALE: 1 : 175,000 (A4)	PROJECT No: G1465	DRAWING No: 9
APPROVED BY:		DATE: October 2010	