Idemitsu Australia

Boggabri Coal Mine - Drawdown Impact Assessment of Proposed Borefield Operations

28 August 2015

PARSONS BRINCKERHOFF

Document information
Client: Idemitsu Australia Title: Boggabri Coal Mine - Drawdown Impact Assessment of Proposed Borefield Operations Document No: 2200555A_WAT_REP_Borefield assessment_RevC Date: 28 August 2015

Rev	Date	Details
A	30/06/2015	Draft
B	12/08/2015	
C	28/08/2015	Updates done by David Whiting

Author, Reviewer and Approver details			
Prepared by:	Sebastian Focke	Date: 07/08/2015	Signature: S. Focke
Prepared by:	David Whiting	Date: 28/08/2015	Signature:
Reviewed by:	Stuart Brown	Date: 12/08/2015	Signature:
Approved by:	Rob Leslie	Date: 12/08/2015	Signature: Rob Leslie

Distribution
Idemitsu Australia, Parsons Brinckerhoff file, Parsons Brinckerhoff Library

©Parsons Brinckerhoff Australia Pty Limited 2015
Copyright in the drawings, information and data recorded in this document (the information) is the property of Parsons Brinckerhoff. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that for which it was supplied by Parsons Brinckerhoff. Parsons Brinckerhoff makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information.

Document owner
Parsons Brinckerhoff Australia Pty Limited *ABN 80 078 004 798* Level 3 Northbank Plaza 69 Ann Street Brisbane QLD 4000 GPO Box 2907 Brisbane QLD 4001 Australia Tel: +61 7 3854 6200 Fax: +61 7 3854 6500 www.pbworld.com *Certified to ISO 9001, ISO 14001, OHSAS 18001*

Contents

Page number

List of tables

Page number

List of figures

Page number

List of appendices

Executive summary

Boggabri Coal Operations Pty Ltd (BCOPL) is a subsidiary of Idemitsu Australia Resources Pty Limited (Idemitsu) and operates the Boggabri Coal Mine. BCOPL received government approval in July 2012 for an increase in production from five to seven million tonnes per annum of product coal and the construction of Coal Handling and Preparation Plant and associated infrastructure. Additional water supply is required to meet the project water demand. BCOPL is seeking to source additional water supply from a borefield located west of the Boggabri Mine, within alluvium on the floodplain of the Namoi River.

An environmental assessment of drawdown impacts for operation of a proposed alluvial borefield up to the year 2033 has been prepared to support an application to modify PA 09_0182 under Section 75W of the *Environmental Planning and Assessment Act 1979.* Parsons Brinckerhoff was engaged by Idemitsu to carry out a groundwater impact assessment using a numerical model. This report summarises the results of the numerical modelling, and provides an estimate of the extent of drawdown from bore field operations and potential impact to environmental and water supply assets.

There are seven bores within the borefield of which three bores (Cooboobindi, Victoria Park and Daisymede) are intended to be used for production with the remaining four bores (Roma, Heathcliffe, Belleview 1 and Belleview 2) for contingency. A numerical model was developed using MODFLOW to simulate operation of the borefield under two rainfall scenarios: Scenario A relates to operation of the borefield under average rainfall conditions (5.7 ML/day total abstraction), while Scenario B simulated an extended dry period during which additional groundwater may be required (up to 9.4 ML/day in total). Additional scenarios considered the use of contingency bores in the event of failure of one or more production bores.

Pumping rates of the proposed borefield production bores were optimised to meet required water supply demand with consideration of limiting environmental impacts and drawdown to landholder groundwater works. Interference drawdown effects between pumping bores were assessed for longterm sustainability.

Results from this modelling assessment

- Groundwater drawdown related to bore field extraction will extend across the floodplain to the west of the borefield. A small number of neighbouring landholder bores will be impacted by borefield operations; for a take of 5.7 ML/day two active bores within 1km of the bores will experience over 2m drawdown; for a take of 9.4 ML/day (extended dry conditions) a predicted six bores (2 active and 4 inactive) will receive over 2 m of drawdown within 2km of the borefield. In addition, five shallow active bores or wells are predicted to receive less than 2m drawdown and will be adversely affected due to the limited depth of the water column; in some instances these groundwater supplies are predicted to dry up. Appropriate arrangements will need to be made to mitigate these impacts.
- Drawdown due to pumping is likely to lead to a reduction in net groundwater discharge to the Namoi River (baseflow) under both normal and extended dry conditions simulations, assuming the river is hydraulically well-connected to the aquifer. According to the NSW Aquifer Interference Policy, any induced net loss from a surface water source is considered to be an indirect take from that surface water source and needs to be accounted for by relevant water access licences. The calculated loss of baseflow is between 769 ML/year and 1,133 ML/year for average and dry condition scenarios respectively. These losses represent less than 0.2% and 0.9% respectively of the average and 10th percentile Namoi River flows at Boggabri.
- The watertable of the alluvial plain is typically greater than 2m depth and therefore unlikely to support stands of groundwater dependant vegetation along ephemeral streams. The Water Sharing Plan for the Upper and Lower Namoi Groundwater Sources identified there are no high priority groundwater dependent ecosystems. A BOM desktop assessment shows some areas on the alluvium plain and

along the Namoi River, which have low to moderate potential for vegetation reliant on subsurface groundwater. These areas comprise River Red Gum open forest, Pilliga Box – Poplar Box – White Cypress Pine grassy open woodland and Plains Grassland communities. Grassland communities have been identified as obtaining water from perched systems and the River Red Gum communities obtain water source from their deep extensive taproot system from both groundwater and Namoi River associated source. Abstraction from the borefield is unlikely to affect the perched systems due to disconnect with underlying alluvial aquifer and the River Red Gum communities due to their deep extensive taproots and associated reliance on the Namoi River.

- The Victoria Park, Belleview and Daisymede bores may experience minor drawdown (<1m) from mine dewatering over the longterm (as predicted from cumulative mine impacts modelling), which, when compounded with borefield pumping interference, is unlikely to affect the sustainability of pumping rates in these bores, with the possible exception of Daisymede bore.
- The alluvial aquifer comprises gravel-sand channel deposits with variability in thickness across the region, and overlies the Boggabri Volcanics, which is of low permeability and considered an aquitard. There is minimal risk of deterioration in alluvial aquifer water chemistry from basement leakage due to the low permeability of the rock.
- No high priority culturally significant sites in the region will be impacted by drawdown from borefield operations.
- Baseline water level and water quality information has been collected in the borefield region, and included hydrocensus data of landholder bores and wells, longterm monitoring records from NOW bores and water level and quality data from BCOPL production and monitoring bores. With exception of NOW bore monitoring records there is limited temporal information.

Recommendations

- Conduct a revision of the groundwater management plan for the Boggabri Coal Operations in consultation with NSW Office of Water to incorporate the alluvial borefield region. This includes the development of a groundwater monitoring program for on-going assessment of the impact from the borefield operations on the alluvial aquifer resource, surface water bodies and regional users.

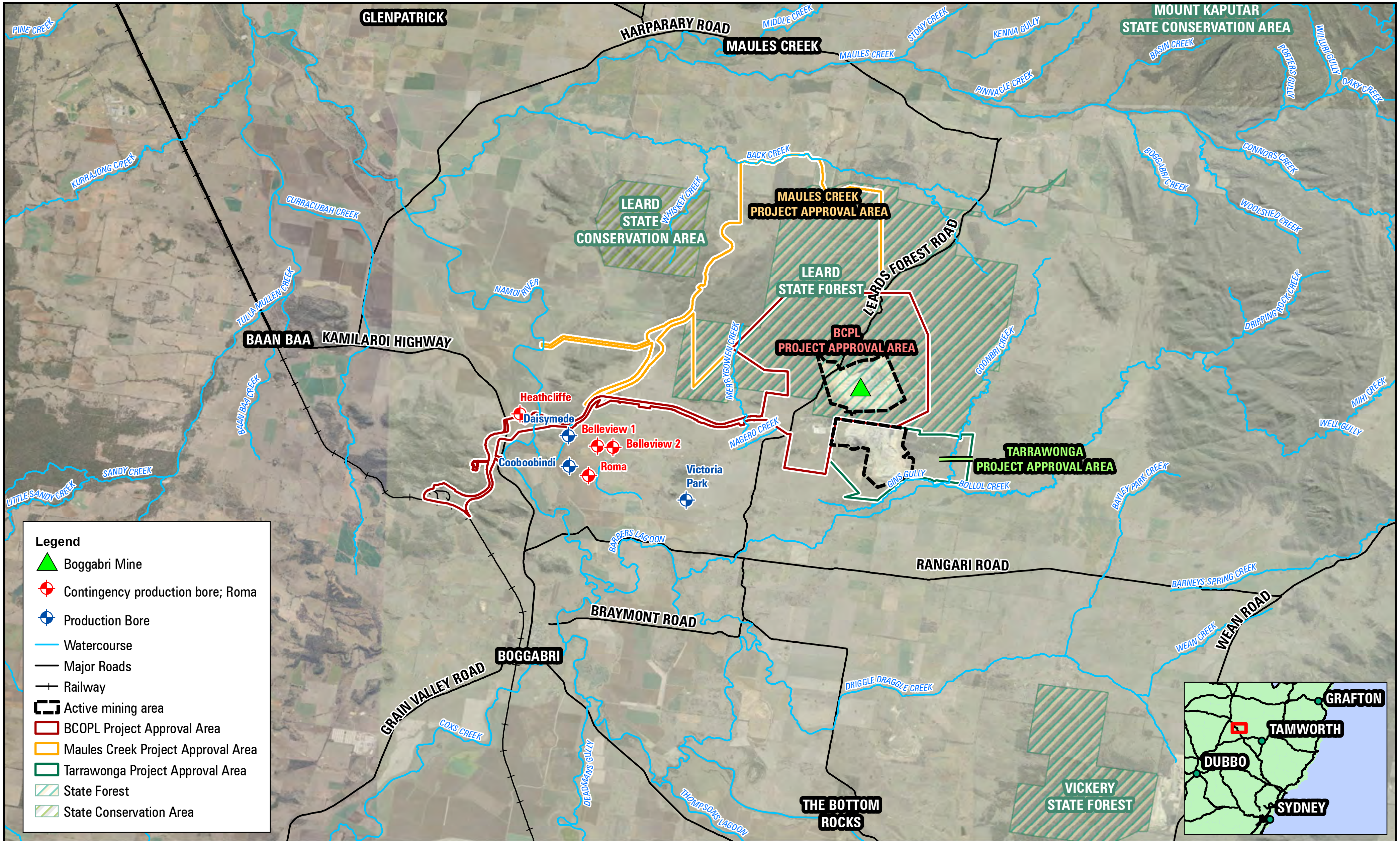
1. Introduction

Boggabri Coal Operations Pty Ltd (BCOPL) is a subsidiary of Idemitsu Australia Resources Pty Limited (Idemitsu) and operates the Boggabri Coal Mine. The Boggabri Coal Mine is located 15 kilometres north-east of the township of Boggabri in the north-west region of NSW (refer to Figure 1.1). Full scale mining commenced at Boggabri Coal Mine in 2006. BCOPL lodged an application for continuation of the mine that included an increase of production from five to seven million tonnes of product coal per annum. This was approved on 18 July 2012 (project approval 09_0182) and included the construction of a new Coal Handling and Preparation Plant (CHPP).

A BCOPL internal review supported by site water balance study (Parsons Brinckerhoff, 2015a) for the mine's anticipated water demand associated with the increased production and the new CHPP identified potential water supply deficits during extended dry periods and during times of peak demand from existing surface water and groundwater supplies. To meet the water demand for project upgrade, a secure water supply could be achieved through the operation of a borefield within the alluvium aquifer source located on the floodplain of the Namoi River to the west of the mine. During average weather conditions where water inputs to the project are sourced from surface water (direct rainfall and runoff storage) and groundwater, the demand from the borefield is anticipated to be 5.7 ML/day (50% median rainfall percentile). However, in the event of extended dry conditions, where there is no surface water input and no assumed pit inflow contributions then the demand from the borefield may possibly be up to 9.4 ML/day. BCOPL has an existing licence to take water from the Namoi River.

BCOPL is preparing an environmental assessment to support an application under Section 75W of the *Environmental Planning and Assessment Act 1979* (EP&A Act) to modify PA 09_0182 to include additional activities of borefield and ancillary infrastructure installation and operation. The application for modification of the existing project approval is referred to as Mod 5. Part of this modification requires, under the Water Management Act 2000, to conduct an environmental assessment of drawdown impacts from the operational borefield during life of mine with expected project life of up to the year 2033.

BCOPL commissioned Parsons Brinckerhoff to prepare this groundwater impact assessment for the operation of the borefield. The groundwater impact assessment includes the development of a numerical groundwater model to predict the extent of drawdown from borefield operations, with consideration of impacts to the aquifer resource and sensitive receptors, such as private landholder groundwater works (bores and wells) in the region.



Map: 2200555A_GIS_002_A1_Fig1-1	Author: K Saflian		0 1.5 3 Km 1:200,000 Coordinate system: GCS GDA 1994 Scale ratio correct when printed at A4
Date: 26/08/2015	Approved by: - D Whiting		
Data source: -			

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine

Figure 1.1

Location plan of BCOPL borefield

1.1 Background of alluvium aquifer borefield

The borefield extends over an area of about 7.5 km long by 2.5 km wide. Three production bores and four contingency bores are for backup in emergency when a primary production bore fails (refer to Figure 1.1 for their locations). The current status, operational use and proposed pumping rate of these bores are provided in Table 1-1. The Daisymede bore currently has water access license WAL's 15037, 12691 and 24103 attached to its groundwater works approval. Victoria Park, Daisymede, Heathcliffe and the Belleview bores are located on BCOPL owned land while the Cooboobindi and Roma bores are located on private landholder properties with access corridor approvals.

Table 1-1 Borefield details

Bore	Easting (MGA94)	Northing (MGA94)	Current status	Operation use
Cooboobindi	217917	6606240	TPB	Production
Victoria Park (VP02)	221961	6605011	TPB	Production
Daisymede (DM1)	217880	6607431	Operational	Production
Roma	218612	6605874	TPB	Contingency
Heathcliffe (HC01)	216209	6608260	TPB	Contingency
Belleview1 (BCBF8)	218884	6607055	TPB	Contingency
Belleview 2 (BCBF10)	219408	6607016	TPB	Contingency

TPB = test production bore

Distance between production bores:

- Cooboobindi and Victoria Park bores are 4.2km apart
- Cooboobindi and Daisymede bores are 1.2km apart
- Victoria Park and Daisymede bores are 4.7km apart.

The proposed long-term sustainable pumping rates, aquifer characteristics and construction details for the production and contingency bores are provided in Table 1-2. This information was extracted from pumping test investigation reports as follows:

- Cooboobindi and Roma (Parsons Brinckerhoff, 2015a)
- Victoria Park and Heathcliffe (Parsons Brinckerhoff, 2015b)
- Daisymede (Parsons Brinckerhoff, 2010)
- Belleview 1 and Belleview 2 (AFGES, 2013).

The aquifer thickness has been determined based on interpretation of borelogs and considers subtraction of aquitard (clay-silt) units within the sand-gravel sequence and the depth of standing water level.

The aquifer thickness of the production bores increases towards the centre of the Namoi Valley and this corresponds with higher sustainable yields. The Cooboobindi and Roma bores have the greatest aquifer thickness and sustainable pumping rates. The bores with lowest sustainable pumping rates are located closer to the margin of the alluvium aquifer and have the least available aquifer thickness and include Daisymede and Belleview 1 and 2 bores.

Table 1-2 Bore depth, aquifer and longterm sustainable pumping rates derived from pumping tests

Bore	Sustainable Rate (ML/day) [1]	Aquifer system [1]	Bore screened depth (m bgl)	Aquifer thickness to base of bore (m)	Top of aquifer below surface (m bgl)	Standing water level (m bgl)
Cooboobindi	7 - 7.5	confined	89	78	9.49	9.49 (May 2015)
Victoria Park[2] (VP02)	3.4	leaky confined	57	13	34	11.2 (Oct 2014)
Daisymede (DM1)	1	confined	22	8	10	7.7 (Oct 2014)
Roma[3]	7 - 7.5 (4.5)	confined	84	66	15 (8.5)	9.72 (May 2015)
Heathcliffe (HC01)	1.5	leaky - confined	26.5	13	9.45	9.45 (Oct 2014)
Belleview1 (BCBF8)	1	leaky confined - confined	34	12	19.5	9.82 (Dec 2012)
Belleview 2 (BCBF10)	0.5	leaky confined - confined	35	5	26	8.78 (Dec 2012)

(1) Projected long-term maximum sustainable pumping rate and aquifer system type determined from pumping test data assessment

(2) Victoria Park bore aquifer thickness is gravel and sand units below bore annular seal within clay zone

(3) Roma bore sustainable rate of 4.5 ML/day excludes screen dewatering; Roma bore between 8.5 to 15m is predominantly clay with some interpreted clayey gravel/sand layers.

(4) mbgl = metres below ground level

2. Scope of work

The tasks for this groundwater drawdown impact assessment were as follows:

- provide an outline of project water supply requirements from the borefield
- characterise the hydrogeological regime in the region of the borefield
- identify groundwater stakeholders in the region
- develop a numerical groundwater flow model and simulate borefield operations and associated groundwater drawdown impacts during the life of mine (2033). The modelling will include:
    - identifying upper and lower thresholds of impacts to groundwater levels for average weather conditions and for extended dry seasons where there is required peak demand for mine operations from the borefield
    - quantifying the potential drawdown impacts to regional stakeholders
    - optimising pumping rates from production bores to meet required water supply demand with consideration of limiting environmental impacts and drawdown to landholder groundwater works
    - conducting sensitivity analysis of aquifer parameters
    - the provision of contingency bore scenarios, where backup bores will be used in the circumstance the production bore fails
    - assessing recovery of groundwater levels and potential residual impacts at the cessation of borefield operations
    - assessing the influence of predicted cumulative drawdown impacts from the Boggabri – Tarrawonga and Maules Creek (BTM) mine complex and borefield drawdown assessment on the alluvial aquifer resources.
- assessment of interference effects between pumping bores
- identify groundwater management strategies and mitigation measures
- assessment of impacts against the aquifer interference policy

3. Water Management Act, Policies and Water Sharing Plans

The objective of the NSW Water Management Act (2000) is the sustainable and integrated management of the State's water for the benefit of both present and future generations. The Act provides arrangements for controlling land based activities that affect the quantity and quality of the State's water resources. Under the umbrella of the Act is the Aquifer Interference Policy (AIP) (NOW, 2012) which clarifies water license and impact assessment requirements for aquifer interference activities such as the abstraction of groundwater resources for mine operation activities. The AIP forms the basis of the assessment and subsequent advice provided by NSW Office of Water (NOW) at various stages of assessment under the *Environmental Planning and Assessment Act 1979*. The policy strikes a balance between the water needs of towns, farmers, industry and the environment, ensuring equitable water sharing among different types of users.

Three key components of the AIP are as follows:

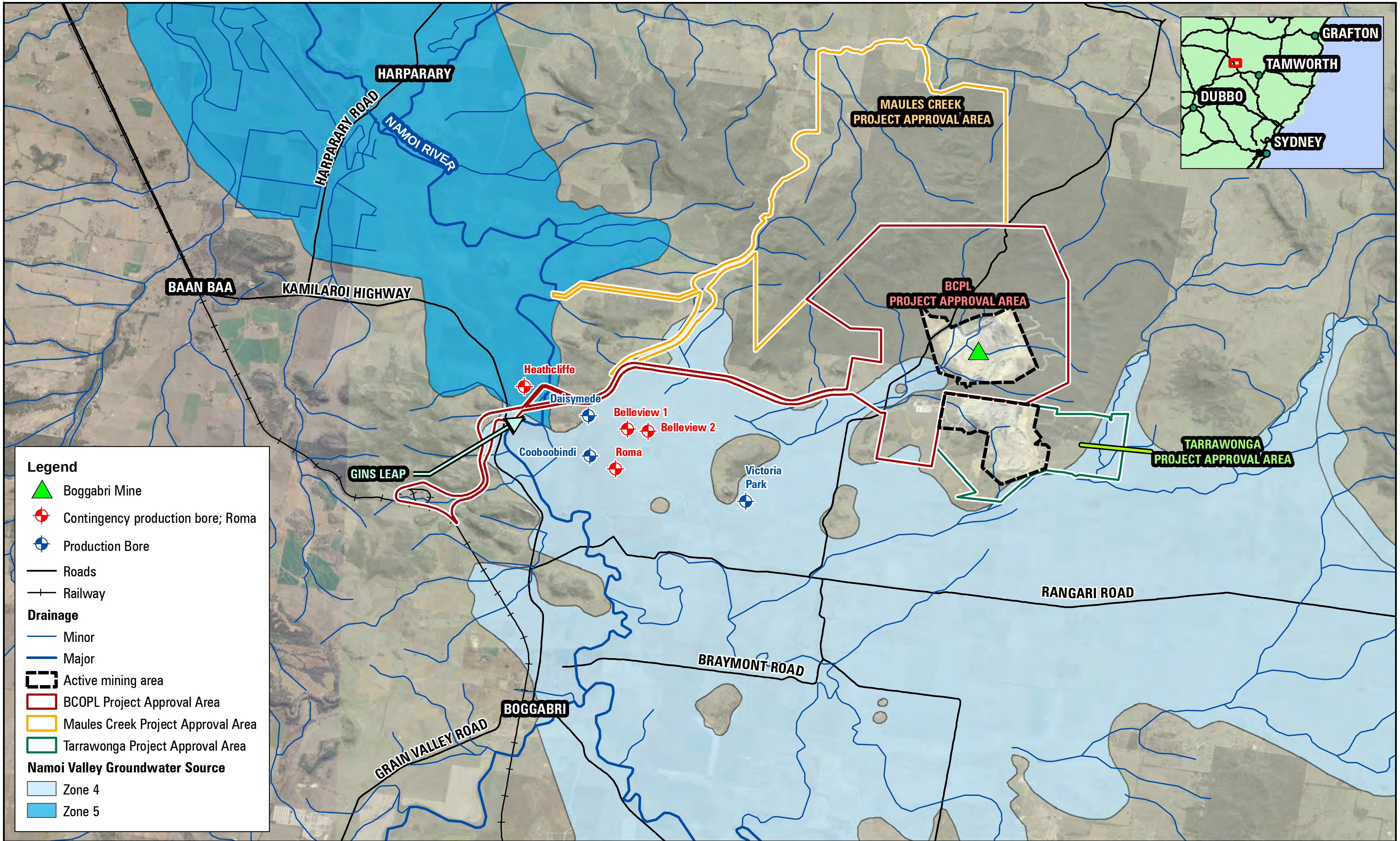
1. All groundwater taken must be properly accounted for.
2. The activity must address minimal impact considerations for impacts on water table, water pressure and water quality in different types of groundwater systems. Impacts on connected alluvial aquifers and surface water systems are also considered, as well as the impacts on other water-dependent assets. These include impacts on water supply bores, groundwater-dependent ecosystems and culturally significant sites that are groundwater-dependent.
3. Planning for (mitigation) measures in the event that the actual impacts are greater than predicted, including making sure that there is sufficient monitoring in place.

The classification according to the AIP for the alluvium aquifer in the vicinity of the borefield is considered to be a "Highly Productive Groundwater Source" based on the criteria:

- total dissolved solids of less than 1,500 mg/L
- contains water supply works that can yield water at a rate greater than 5 L/s.

Also under the Water Management Act is the partition of Water Sharing Plans for the State's regional water resources. Water sharing plans set extraction limits and rules for water access, available water determinations, accounts management and trading in order to protect water sources and their dependant ecosystems, while recognising the social and economic benefits of the sustainable and efficient use of water (NOW, 2012). The alluvium aquifer is located within the Water Sharing Plan of the Upper Namoi Groundwater Source which commenced in November 2006 and is in effect until 2017. The Upper Namoi Groundwater Source includes all water contained in unconsolidated alluvial sediments associated with the Namoi River and its tributaries and is divided up into 13 zones.

The borefield is located within Zone 4 (Keepit Dam to Gin's Leap) with the exception of a contingency bore (Heathcliffe) located in Zone 5 (Gin's Leap to Narrabri). The location of production and contingency bores relative to the zone boundaries is provided in Figure 3.1. The Upper Namoi groundwater management area has been identified as a high risk groundwater system for long term sustainability as part of a state wide program for Aquifer Risk Assessment by the NSW Department of Land and Water Conservation (1998). Aquifer Risk Assessment is a measure of the likelihood for contamination and/or over extraction of a groundwater resource (NSW DLWC, 1998). The implementation of the local water sharing plan has resulted in a reduction of water entitlements and overall volumes extracted from the resource with consequences of improvement to water level declines and seasonal drawdowns (Barrett, 2010).



Map: 2200555A_GIS_003_A1_Fig3-1	Author: M Goganovski	
Date: 26/08/2015	Approved by: - D Whiting	

Data source: - LPI, Murray Darling Basin Authority

1:150,000

Coordinate system: GCS GDA 1994

Scale ratio correct when printed at A4

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine

Figure 3.1

BCOPL borefield relative to Upper Namoi Groundwater Source Zone 4 and 5

4. Regional setting

4.1 Site location

The borefield is located approximately 15 km north east of the township of Boggabri on the Namoi Valley plain and approximately 9km west of the open cut Boggabri Mine (refer to Figure 1.1). The production bores are located in an agricultural region predominantly comprising cotton crop production and cattle usage. Water supply for agricultural land use is sourced from surface water (runoff and Namoi River) storage in dams and groundwater from bores accessing the alluvial aquifer. West of the borefield is the Namoi River which flows in a north-westerly direction.

4.2 Climate

The borefield area generally experiences a temperate climate of hot summers with regular thunderstorms and mild dry winters. Rainfall is seasonal, with the highest mean monthly rainfall occurring in the summer months between January and March. The long term average rainfall at Boggabri Post Office BOM station 055007 is 591.9 mm, obtained from records from 1885 to 2015.

The long-term, annual cumulative deviation from mean (CDFM) rainfall for Boggabri station 055007 is plotted in Figure 4.1. The long-term cumulative rainfall residual plots are formulated by subtracting the average monthly rainfall for the recorded period from the actual annual rainfall and then accumulating these residuals over the assessment period. Periods of below average rainfall are represented as downward trending slopes while periods of above average rainfall are represented as upward trending slopes. The CDFM graph indicates below average rainfall from 1910 to 1947. From 1947 to 1980 there has been above average rainfall indicated by a general rising trend of the CDFM. There have been several cycles of wetter and drier periods over the last 70 years with very dry conditions occurring generally over a two to three year period every 10 to 15 years. However there have been no long-term deviations from mean conditions, such as the prolonged drought periods that characterised the first half of last century.

Figure 4-1 Plot showing the cumulative departure from mean monthly rainfall

4.3 Geomorphology and drainage

The borefield is located on a relatively flat alluvial valley on the eastern side of the Namoi River. The alluvium comprises floodplain sediments from the Namoi River and tributaries. Outcropping volcanic rocks form hills and low slopes to the west and east and also rise as low isolated hills within the alluvium. The volcanics provides the basement geology underlying the alluvial sediments in the borefield region. The alluvial plain is open to the west and south with a narrow constriction, approximately 1.5 km wide, bordered by prominent volcanic hills at Gins Leap in the northern part of the borefield. Low angle colluvial slopes occur as a transition between the volcanic hills and the alluvial plains. The elevation drops from about 400 to 500 m RL in the volcanic hills to about 240 m RL at the Namoi River. With the exception of one test production bore the borefield is located south of Gins Leap.

The Namoi River is the most significant water body dissecting the alluvial plain and flows in a north-westerly direction passing through the township of Boggabri and then through Gin's Leap in the north. The eastern volcanic hills are drained by a series of ephemeral streams which meander westerly across the alluvial plain and eventually drain into the Namoi River and include Bollol Creek and 'Nagero' Creek. Maules Creek flows into the Namoi River north of Gins Leap and the borefield area. Also discontinuous drainage depressions provide wetlands during the wetter months.

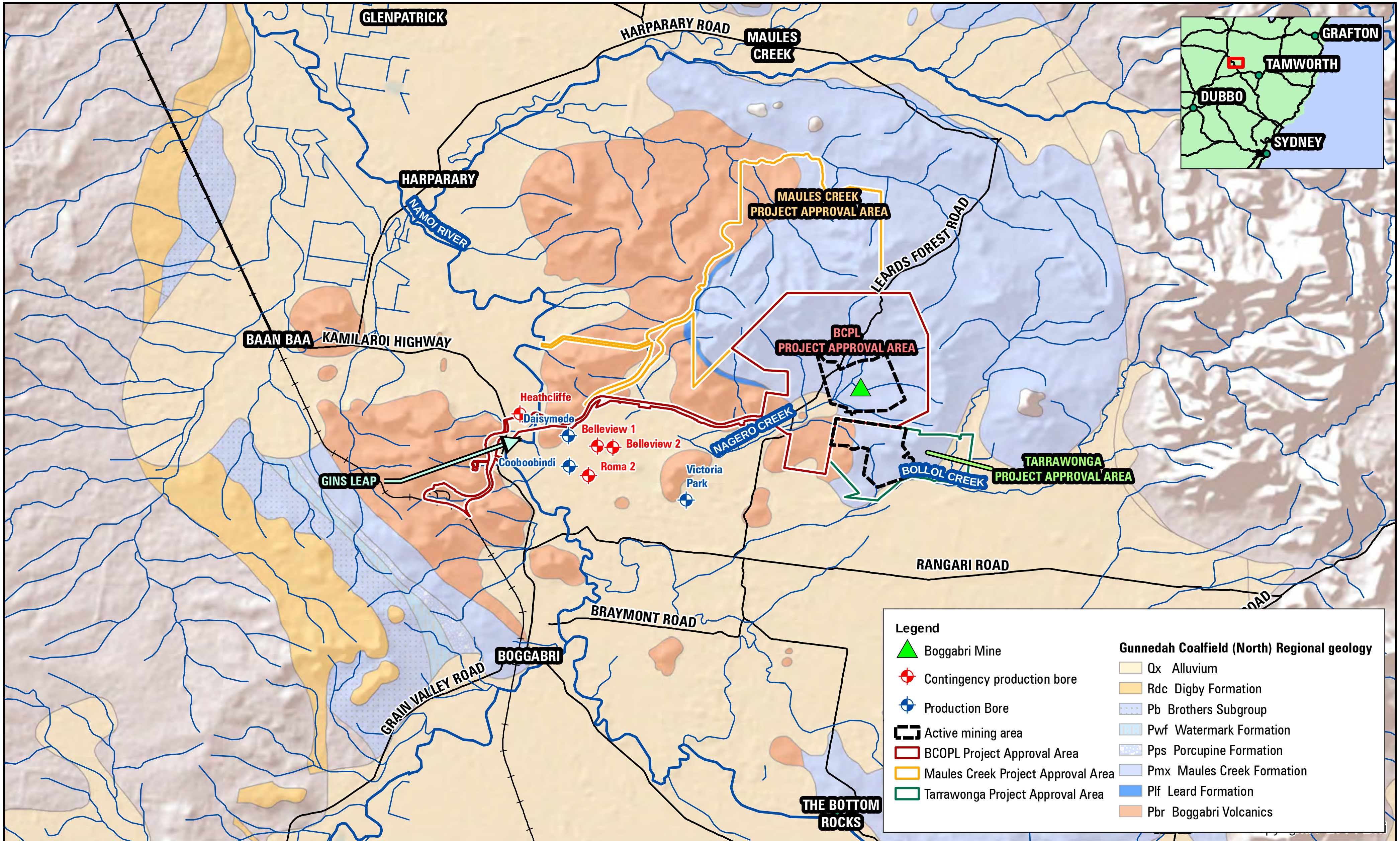
The nearest river flow gauging station (419012) on the Namoi River is located at the township of Boggabri. Records have been kept since November 1911. The largest recorded flood event with maximum flow occurred in February 1955 with a discharge of 264120 ML/day (Parsons Brinckerhoff, 2014). Other large flood events have occurred in January 1971, February 1956 and February 1984. Water levels for the Namoi River are heavily regulated by upstream dams and releases are made from Keepit Dam. Releases are lower during winter months, with less demand from irrigators. Examination of gauging station hydrographs for the Namoi River show peaky responses to rainfall with rapid rising and falling limbs and extended periods of no or very low flow (Parsons Brinckerhoff, 2014).

4.4 Geology

The borefield region is located within the Gunnedah Basin, which predominantly comprises Permian Age metasediments and volcanics and is overlain by Quaternary alluvial deposits within the valleys. The Permian metasediments in the region include the Maules Creek Formation which outcrop further to the east of the Boggabri Volcanics and are mined for coal at Boggabri, Tarrawonga and Maules Creek mines. The volcanic units belong to the Boggabri Volcanics and include basalt, trachyte and rhyolite flows and pyroclastics. In the borefield region the Boggabri Volcanics form the basement rock underlying the alluvium and bordering the alluvial plain. The surface geology of the borefield region is presented in Figure 4.2.

The alluvial deposits in the proposed borefield area are associated with the Namoi River and the lower reaches of 'Nagero' and Bollol Creeks. The thickness of alluvium has been recorded exceeding 125 m deep in places but may typically be between 25 to 75m thick. Within alluvial creek embayments bordered by the volcanics, such as along Bollol Creek and 'Nagero' Creek the alluvial pile may be up to 30m deep.

The alluvial sediments are recognised as belonging to two formations, although they are not always distinguishable. The uppermost Narrabri Formation predominantly consists of clay with minor sands and gravels. Underlying the Narrabri Formation is the Gunnadah Formation which typically comprises gravel and sand with minor clay beds. The geological logs from registered bores in the alluvium and from the Boggabri test production bores discriminate an upper 8 – 25 m largely consisting of clay which is floodplain sediments deposited in low energy environment, and possibly the Narrabri Formation. The sand and gravel layers are likely to be channel deposits along the meandering river systems and commonly are clayey and silty in composition and poorly sorted. Gravel clasts are typically sub-angular to subrounded and are probably derived from volcanics and metasediments in the local region. Interlayed clay – silt layers are low energy floodplain sediments.



Map: 2200555A_GIS_004_A1_Fig5-2	Author: M Goganovski
Date: 21/07/2015	Approved by: - D Whiting

Data source: -

0 1.5 3 Km
1:200,000
Coordinate system: GCS GDA 1994
Scale ratio correct when printed at A4

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine
Figure 4.2
Regional Geology

\\Apbnefil03\proj\I\Idemitsu_Aus_Resources\2200555A_DRWDN_IMPCT_BOREFIELD_BOGGABR\10_GIS\Projects\Maps\2200555A_GIS_004_A1_Fig5-2.mxd

Idemitsu Australia Resources

4.1 Land use

The borefield region is located within an agricultural region with the main use comprising crops of cotton and less commonly wheat and cattle fodder (sorghum) and livestock grazing. Cropping occurs in areas with access to productive reliable water supply, and this is generally within a few kilometres of the Namoi River, where the alluvial aquifer is thickest and high yielding and includes access to harvesting Namoi River water. Further from the Namoi River where water resources are less plentiful cattle grazing typically occurs. Surface runoff is also captured in dams or drainage depressions as an alternative or supplementary water supply for crop irrigation and cattle grazing.

Within the hill regions to the northeast to south east of the alluvial plains the landuse comprises coal mining (Boggabri, Tarrawonga and Maules Creek Coal Mines) within the Maules Creek Formation and forestry in the Leard State Forest.

5. Hydrogeological regime

5.1 Regional hydrogeology

The regional hydrogeology is divided into two main units comprising:

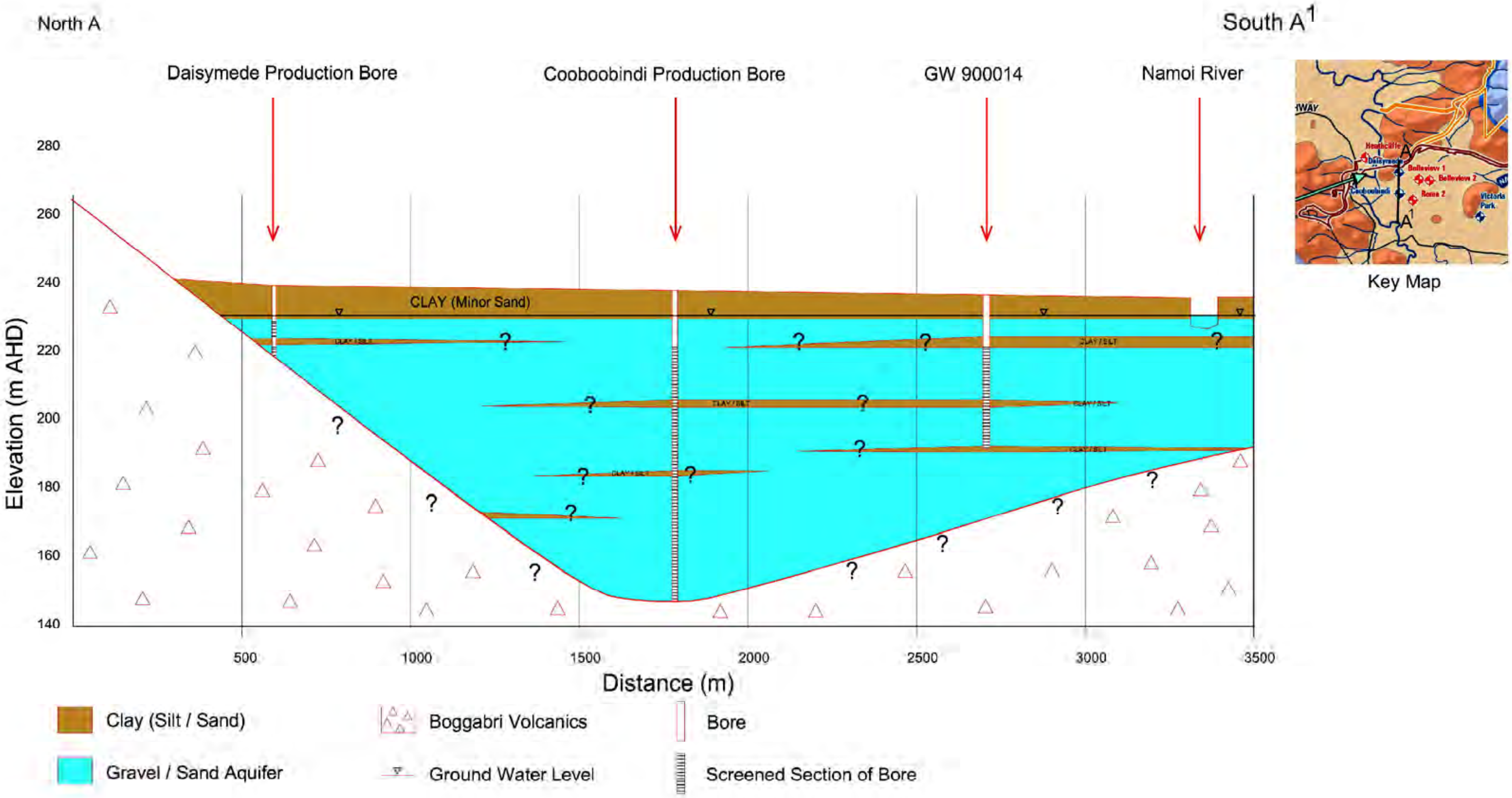
A) Alluvium aquifer

The gravel and sand layers within the alluvium comprise the aquifer zone of stream channel deposits with interlayers of clay and silt representing floodplain sediments. The gravel-sand layers of the aquifer are variable in distribution with the thickest most productive aquifer layers occurring within a few kilometres of the Namoi River. Towards the margins of the alluvial plain the gravels and sand aquifer layers are thinner, less numerous, less yielding and may be absent. Modelling undertaken by CSIRO (2007) for the alluvial aquifer incorporated two aquifer layers of the basal Gunnedah Formation and the surficial Narrabri Formation. The Gunnedah Formation consists of sands and gravels with interbedded clays and is conceptualised as a high yielding aquifer with good quality water. The overlying Narrabri Formation is conceptualised as a lower yielding aquifer composed generally of clays with some sand and gravel.

B) Bedrock aquitard

The Boggabri Volcanics, which underlies the alluvium and bounds the plain on the eastern and western side has a primary porosity (rock matrix) characterised as of low permeability. Groundwater may occur within secondary porosity features such as open or weathered joints and faults and provide a fractured aquifer resource in places. Where this occurs the groundwater yield is dependent on the extent of connecting fracture networks and permeability. In general the yields from the fractured system are limited and the Boggabri Volcanics is a poor groundwater resource. Overall the Boggabri Volcanics is characterised as an aquitard.

A conceptual hydrogeological N-S cross-section which extends from Daisymede production bore through Cooboobindi test production bore to the Namoi River is provided in Figure 5.1.



Map: 2200555A_GIS_025_A1_Fig5-1	Author: P Jayasinghe
Date: 30/06/2015	Approved by: - D Whiting

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine

Figure 5.1

Conceptual hydrogeological N-S cross-section of the Alluvial Aquifer

5.2 Alluvium aquifer

5.2.1 Description

The gravel and sand layers of the aquifer are variable in distribution as occurs with a meandering fluvial channel system and comprise interlayers of clay silt floodplain deposits. The thickest layers of gravel – sand aquifer sediments commonly occur within a few kilometres of the Namoi River and provide the most productive bore yields. A review of registered borelogs located on the Namoi River floodplain and in the location of the Cooboobindi and Roma test production bore provide a sequence of gravel and sand aquifer layers over 60 m thick and is likely to be part of a deep palaeochannel system in this locality. Towards the margins of the alluvial plain, the gravel and sand aquifer layers are thinner, less numerous and may be absent in places with the majority of sediments comprising floodplain clays and silt. This was evident within test investigation holes located on the Belleview property, near Belleview 1 and 2 test production bores (AFGES, 2013). A deeply incised palaeochannel occurs along the course of the Namoi River in the northern part of Namoi Alluvial Groundwater Source Zone 4 and extends into Zone 5.

Test pumping results for individual production bores installed for the BCOPL borefield indicate that the groundwater system behaves as a confined to leaky-confined aquifer system. This is due to the thick blanket of low permeable clay sediments that overlie the sands and gravels.

The constriction of floodplain sediments in the area known as Gin's Leap by the outcropping Boggabri Volcanics rock is thought to provide a natural barrier restricting groundwater movement flow to the north and may pond aquifer water behind this barrier.

5.2.2 Hydraulic properties

The gravel and sands of the alluvium aquifer in the borefield region is relatively permeable with hydraulic conductivity (K) estimates ranging from about 13 to 35 m/d, derived from test pumping data of BCOPL bores in the borefield. The K estimates were derived from transmissivity results and interpretation of aquifer unit thickness. The confined–semi confined aquifer provided storativity estimates ranging from 3 x 10^{-3} to 1 x 10^{-5}. In general the high storativity values were evident in the most productive bores with greatest aquifer thickness comprising the Cooboobindi and Roma test production bores. The results for each bore are provided in Table 5.1.

Table 5-1 Hydraulic properties derived from test pumping results for BCOPL Borefield

Bore	Transmissivity estimates (m^2/d)	Derived Hydraulic conductivity estimates (m/day)	Storativity
Cooboobindi	1410 - 1895	18.1 – 24.3	2.1 x 10^{-3} – 2.7 x 10^{-3}
Victoria Park (VP02)	180 - 240	13.7 – 18.5	3.00 x 10^{-3}
Daisymede (DM1)*	200 - 280	25.3 – 35.3	1.22 x 10^{-4} – 1.00 x 10^{-5}
Roma	910 - 1300	13.8 – 19.7	1.0 x 10^{-3} – 1.3 x 10^{-3}
Heathcliffe (HC01)	230 - 235	17.7 – 18.1	2.00 x 10^{-4}
Belleview 1(BCBF8)	300 - 335	25.1 – 27.9	1.61 x 10^{-4}
Belleview 2(BCBF10)	125 - 140	25.2 – 28.0	6.02 x 10^{-5}

* Data have been reassessed for this report. References of test pumping reports for the above bores are provided in Section 1.1

5.2.3 Groundwater levels and flow

Groundwater levels are typically 7 to 10m below the ground surface on the alluvial plain, but can be deeper in places upslope towards the outcropping Boggabri Volcanics (11.2 m at Victoria Park test bore). Groundwater levels are shallower in the vicinity of drainage depressions and creeks, particularly during wetter months when they contain surface water.

A network of monitoring bores has been installed within the Namoi alluvium by the NSW government. Many of the bores have been routinely monitored since the mid 1970s providing a long record response to climatic conditions and pumping from landholders. The groundwater levels within these monitoring bores show a general decline of 1.5 to 2m since the late 1970's, although groundwater levels appear to have steadied off and in some instances recovered slightly since the mid 2000s. This may coincide with the introduction of the restrictions on groundwater allocations and commencement of the Upper Namoi Groundwater Resource Water Sharing Plan in 2006. Variations in the water levels occur seasonally and also across several years, possibly relating to wetter and drier periods.

Alluvium groundwater levels for five NOW monitoring bores located in the borefield region and the CDFM are presented as time-series hydrographs in Figure 5.2. There is a relatively strong correlation of rising and falling groundwater levels to the CDFM as indicated in the NOW monitoring bore records for registered bores GW03070, GW030471 and GW030468 and is indicative of direct rainfall recharge. However, the correlation between groundwater levels of registered bores GW030472 and GW036008 and the CDFM is not so distinctive and shows a subdued response. This indicates poor connectivity associated with rainfall recharge and possibly the groundwater level response is compounded by interference effects from pumping bores.

Several of the NOW monitoring sites have multilevel piezometers installed within the shallow and deeper parts of the aquifer units and commonly show similar groundwater trends and level response to rainfall recharge events. The similar responses are indicative of a good vertical hydraulic connection through the aquifer. The water levels in the NOW monitoring bores also show fluctuations in groundwater level due to pumping for irrigation and water supply (refer to Figure 5.3). Monitoring bore GW030050, located east of Boggabri township and about 1.4km east of the town water supply bore, shows an increase in the magnitude of short term water level variations from the 1970's through to recent which is likely a response to increased pumping activity of nearby irrigation bores. The location of the NOW monitoring bores is provided on Figure 5.4.

The direction of groundwater flow is towards the Namoi River which is in hydraulic connection with the aquifer. The hydraulic gradient on the plain is generally quite flat reflecting the high transmissivity of the alluvial aquifer.

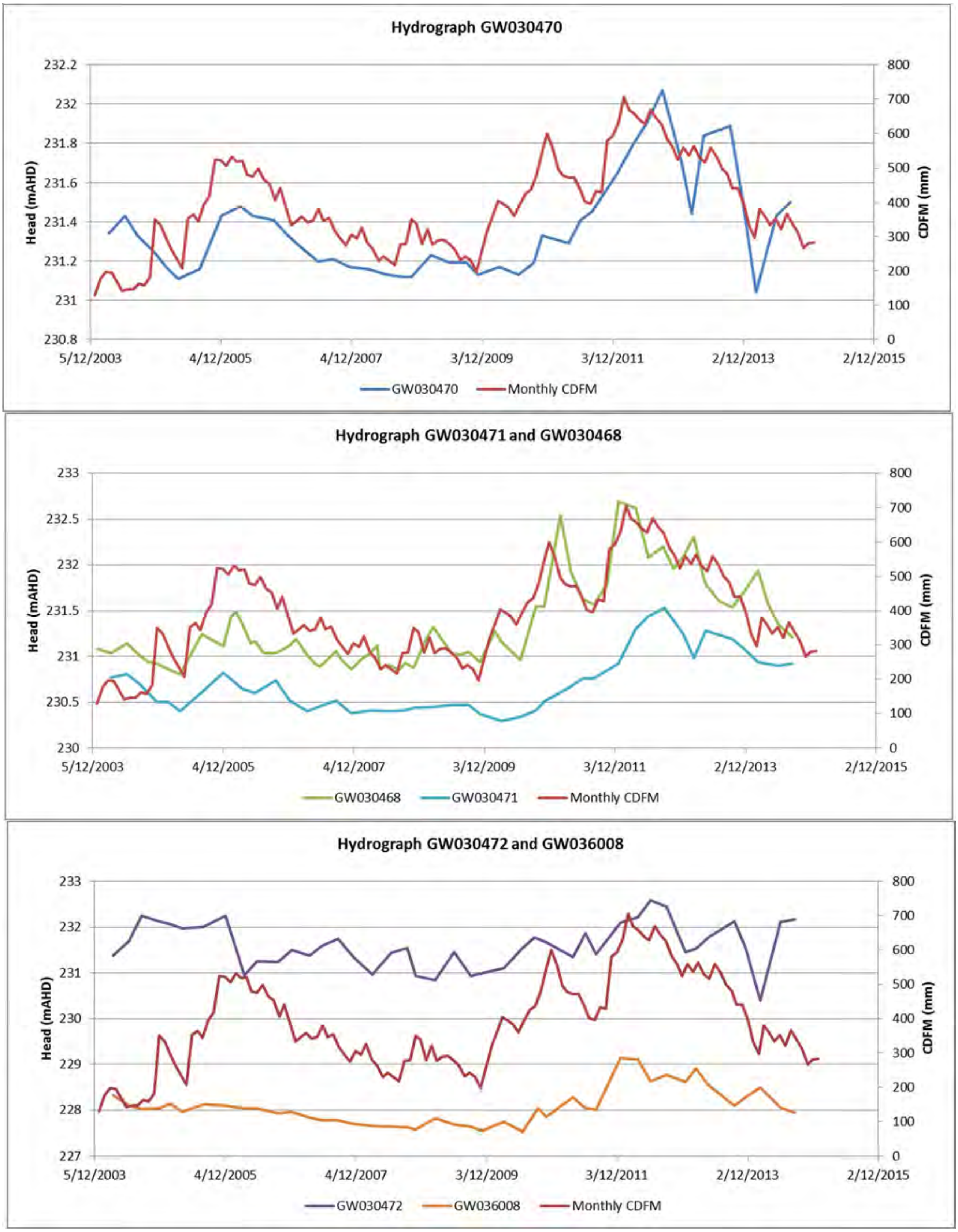


Figure 5-2 Hydrographs of NOW monitoring bores compared with monthly rainfall CDFM

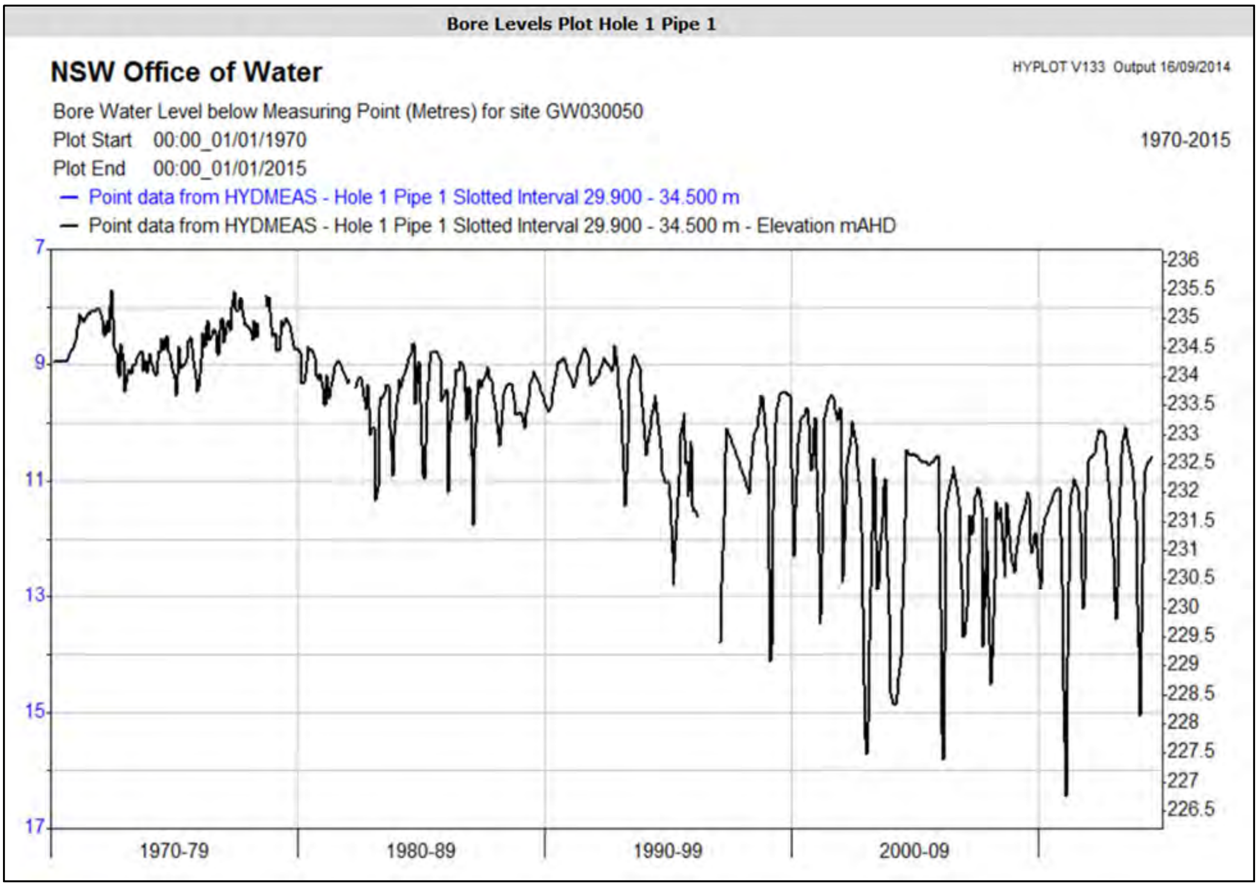


Figure 5-3 **Bore hydrograph (NOW source) for GW030050 as an example for effects on the groundwater level due to pumping for irrigation or town water supply**

5.2.4 Recharge and discharge

The main sources of recharge to the Upper Namoi Alluvium are as follows:

- infiltration of rainfall and runoff from surrounding hills onto the alluvium
- leakage from streams during high flow and flooding
- irrigation return flow and
- leakage from Permian bedrock

Groundwater discharge occurs predominately through abstraction from pumping, discharge into streams and outflow to surrounding aquifers in the Lower Namoi (CSIRO, 2007). The surface – groundwater interaction of the Namoi River is influenced by river level compared to groundwater level as influenced by seasonal changes in runoff/rainfall recharge and pumping activity. During extended dry periods the groundwater level decreases. The Namoi River generally will gain groundwater discharge unless the groundwater level decreases below the river bed during extended dry periods or from drawdown of levels from pumping activity.

5.2.5 Water quality

Groundwater in the Upper Namoi Alluvium has a pH close to neutral and generally fresh to marginal shown by electrical conductivity (EC) values less than 1500 µs/cm, with areas of slightly saline groundwater with EC readings of up to 7000 µs/cm (Barrett, 2012).

5.3 Sensitive receptors

Sensitive receptors which have been considered for this modelling drawdown assessment include landholder groundwater works (bores and wells) and groundwater dependant ecosystems.

5.3.1 Landholder bore census

BCOPL conducted a survey (hydrocensus) of registered groundwater works (bores and wells) on land holdings within 4 to 5 km of the borefield region (Parsons Brinckerhoff, 2015d) from March to May 2015. Excluded were registered groundworks on BCOPL land tenure. The study included a desktop assessment and a site hydrocensus arranged in consultation with landholders. Information of aquifer source, groundwater levels and quality, usage and bore construction details were identified for 55 registered bores in the borefield hydrocensus area of which 52 bores were in alluvium and three bores in fractured bedrock. Groundwater usage is for crop irrigation, stock, domestic and municipality water supply.

The desktop assessment comprised information sourced from the NOW Pinneena database of registered groundwater works for geological logs, construction details and historic groundwater data. In addition the NOW dataset of metered usage from irrigation bores in the hydrocensus region and previous hydrocensus information from the neighbouring Whitehaven coal mines were consulted.

A total of 17 private landholders were approached and access to groundwater works on properties was granted by 14 of these landholders. The Narrabri Shire Council was also consulted for usage from the Boggabri town water supply bore. The site visit included an inspection of the groundwater works, acquiring groundwater information of water levels and quality, activity status and usage (rates and frequency) of the bores and wells. Of the 55 registered groundwater works in the borefield region: 24 are currently active, 10 are not currently used, nine are abandoned or entitlements have been sold to BCOPL, and there is no information on usage for 12 bores (landholder unavailable to comment). There is 11 active irrigation bores, six irrigation bores not currently used or have unknown status details and one municipality water supply bore for the Boggabri township.

The collated information from the hydrocensus was applied in the groundwater modelling assessment (section 7) to quantify potential drawdown impacts on landholder bores and wells. A plan showing the location of these registered groundwater works within the hydrocensus region is provided in Figure 5.4.

5.3.2 Groundwater dependent ecosystems

Groundwater dependent ecosystems (GDEs) are communities of plants, animals and other organisms that depend on groundwater for survival (Department of Land and Water Conservation, 2002). A GDE may be either entirely dependent on groundwater for survival, or may use groundwater opportunistically or for a supplementary source of water (Hatton and Evans, 1998). GDEs can potentially include wetlands, vegetation, mound springs, river base flows, cave ecosystems, playa lakes and saline discharges, springs, mangroves, river pools, billabongs and hanging swamps and near-shore marine ecosystems.

The GDE Atlas (Bureau of Meteorology, 2015) categorises groundwater dependent ecosystems into three classes:

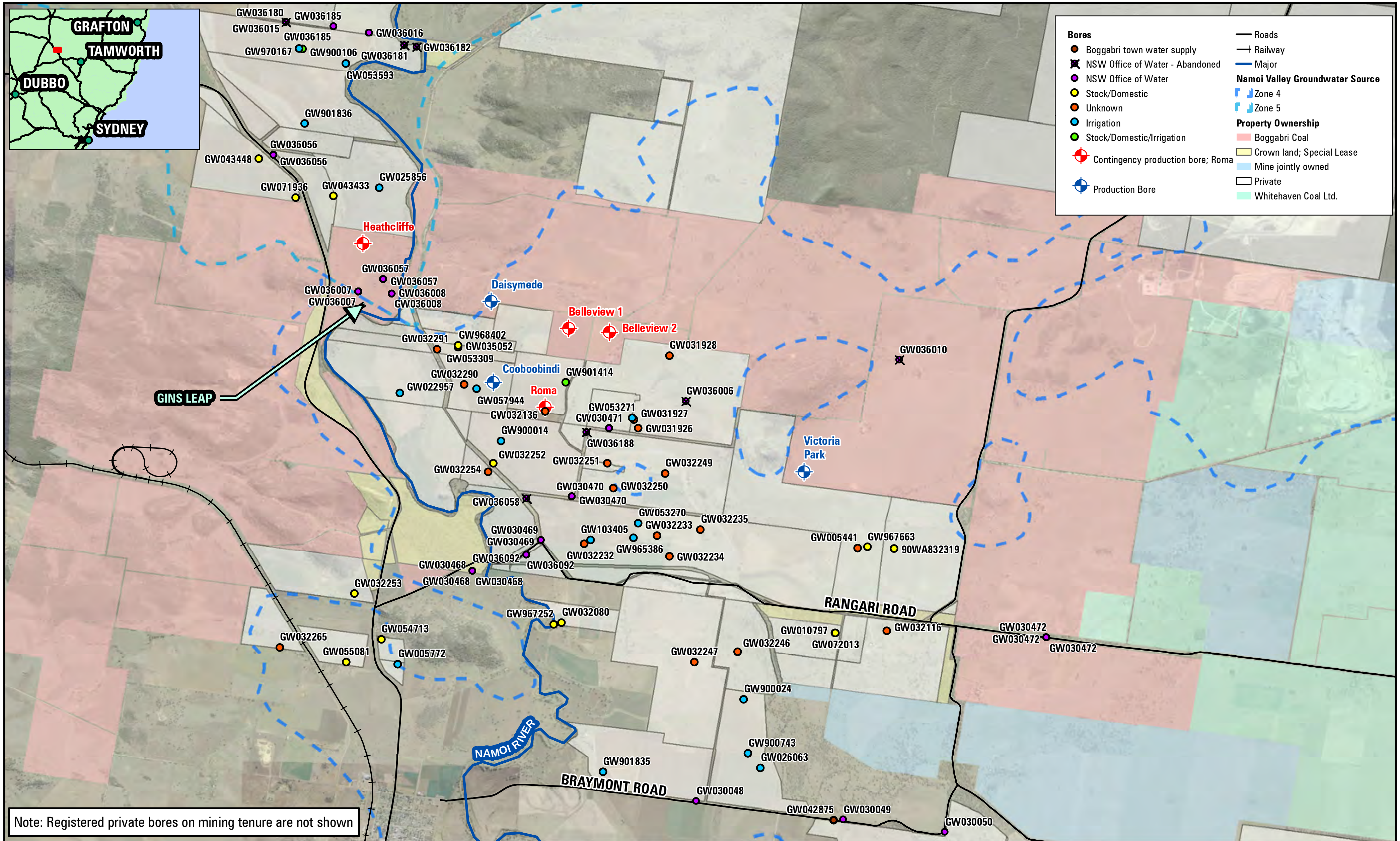
- Ecosystems that rely on the surface expression of groundwater – this includes all the surface water ecosystems which may have a groundwater component, such as rivers, wetlands and springs. Marine and estuarine ecosystems can also be groundwater dependent.
- Ecosystems that rely on the subsurface presence of groundwater – this includes all vegetation ecosystems.
- Subterranean ecosystems – this includes cave and aquifer ecosystems.

The Water Sharing Plan for the Upper and Lower Namoi Groundwater Sources (NSW Government 2003) notes that ‘there are no high priority groundwater dependent ecosystems identified and scheduled at the commencement of this Plan’ in Upper Namoi Groundwater Source. The water table of the alluvial plain is typically greater than 2m depth and therefore unlikely to support stands of groundwater dependant vegetation (CSIRO, 2007).

The GDE Atlas (Bureau of Meteorology, 2015) desktop assessment shows some areas on the alluvium plain and along the Namoi River, notably south of Heathcliffe bore and north of Gins Leap, which have low to moderate potential for vegetation reliant on subsurface groundwater (refer to Figure 5.5). These areas would comprise River Red Gum open forest, Pilliga Box – Poplar Box – White Cypress Pine grassy open woodland and Plains Grassland communities (Parsons Brinckerhoff 2009a). The Pilliga box – Poplar Box – White Cypress Pine grassy open woodland and Plains Grassland communities are considered to be primarily associated with perched water tables not likely to be dependent on sub surface groundwater and are thus not included within the GDE classification of (Eamus et al. 2006).

The River Red Gum open forest is likely to be directly associated with the Namoi River. A characteristic of river red gums is the rapid development of an extensive and deep taproot system. The dense surface root system of a mature river red gum extends at least 20 m in the horizontal direction and greater than 10 m vertically (Davies 1953). River red gums can therefore have a water uptake area of greater than 4000 m^3, with potential for element uptake via their roots from the adjacent stream sediments, the shallow ground water aquifers within the alluvial sediments and buried bedrock. Therefore this community will have proportional dependence upon the subsurface groundwater. It is unlikely that this GDE would be a high priority groundwater dependent ecosystem due to the proportional use of the groundwater as opposed to being entirely dependent upon the groundwater.

In summary none of the vegetation communities within the vicinity of the borefield would be considered to be high priority GDEs as they are not entirely dependent upon subsurface groundwater, for their water requirements.



Map: 2200555A_GIS_005_A2_Fig5-4	Author: M Goganovski	
Date: 26/08/2015	Approved by: D. Whiting	

Data source: - LPI, Murray Darling Basin Authority

0 0.75 1.5 Km

1:75,453

Coordinate system: GCS GDA 1994

Scale ratio correct when printed at A4

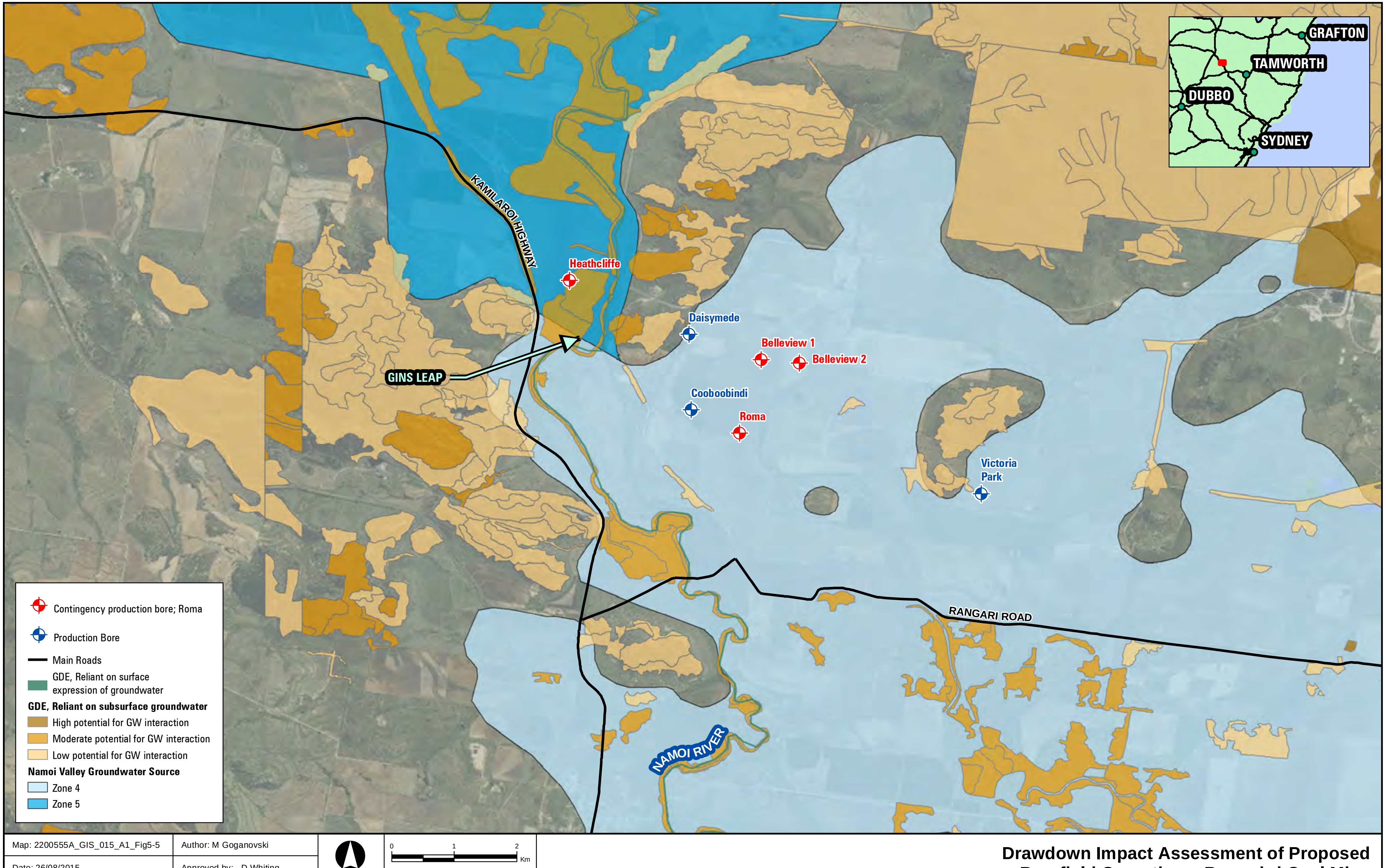
WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine

Figure 5.4

Registered landholder bores (wells) in borefield region

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.



Map: 2200555A_GIS_015_A1_Fig5-5	Author: M Goganovski
Date: 26/08/2015	Approved by: - D Whiting

Data source: - GDE mapping sourced from 2015 BOM Atlas - Desktop Assessment

1:80,000

Coordinate system: GCS GDA 1994

Scale ratio correct when printed at A4

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine

Figure 5.5

Groundwater Dependent Ecosystem Mapping in Borefield Region

6. Water demand forecasts

6.1 Project water balance and borefield demand

6.1.1 Project water demand

Based on projections by BCOPL, a project water demand of 9 ML/day is needed for the upgrade in coal throughput of five to seven million tonnes and excludes use of recycled water. In addition there is approximately 0.4ML/day of evaporation from storages, which provides a total requirement of 9.4 ML/day. A simplified breakdown of project water outputs is provided in Table 6-1.

Water inputs into the coal operations will result from runoff and direct rainfall, pit inflow, groundwater extraction from the alluvium borefield and recycled water. Runoff and direct rainfall within the coal mining area will be guided into surface storage dams, and pit groundwater inflows will also be pumped to the surface site storages. The contribution of surface water to the overall project input will be influenced by seasonal conditions of rainfall and this has been assessed using Goldsim modelling within the site water balance for the upgrade modification (Parsons Brinckerhoff, 2015a).

Table 6-1 Project water outputs

Output	Volume (ML/day)
Mine Water Cart	4
CHPP & Bypass	4
MIA & Potable	1
Evaporation	0.4
TOTAL	**9.4**

Source: BCOPL water demand summary spreadsheet with exception of evaporation total which was derived from site water balance model by Parsons Brinckerhoff (2015a). Total excludes recycled water usage.

Weather conditions are expected to fluctuate during the life of the mine, and therefore, the requirement for imported water to make up a site water deficit will change depending on water availability and rainfall. During extended dry periods the surface water contribution is expected to be reduced to nil and the input will come from the borefield with minor contribution from groundwater inflow into the pit.

Based on site water balance data, an estimation of imported project water requirements for average weather conditions (represented by modelled projected 50th median percentile) is 2080 ML/year (5.7 ML/day). This estimation is the peak amount projected from mine planning in year 2017. The remaining makeup of water to meet project demand would be from site surface water storage and groundwater inflow. The site water balance model has incorporated evaporation from site storages when calculating the imported water requirements of 2080 ML/year. The peak evaporation rate of 0.4 ML/day was calculated from the site water balance model for borefield input water storages, including dams SD10, SD12, MD2 and MD5.

6.1.2 Determining extended dry condition

Statistical percentiles of below average annual rainfall quantities for the Boggabri rainfall station 055007 and a data drill interpolation of rainfall for Boggabri Mine from 1989 to 2015 (Parsons Brinckerhoff, 2015a) are provided in Table 6.2. The rainfall statistical percentiles of rainfall are higher for data drill interpolation at the Boggabri mine and this may be due to either: a) the BOM data is missing rainfall data records for some periods or b) there is noticeably greater rainfall distribution within the hills at the Boggabri Mine compared to the flatter lower area of the township of Boggabri.

Table 6-2 Annual rainfall percentiles at Boggabri PO rainfall station

Percentile	Annual rainfall (mm/yr) data drill interpolation	Annual rainfall (mm/yr) BOM 055007
minimum	319	235
5th percentile	363	328
10th percentile	423	394
25th percentile	526	465
50th percentile	658	592

From a review of the rainfall records from BOM rainfall station (055007) at the Boggabri Post Office (PO) from 1884 to 2015, the longest extended period of dry conditions below the 25th percentile was from 1922 through to 1929. However, in this 8 year period there were three years with rainfall above the 25th percentile. This is a similar case with the drill interpolated data for Boggabri Mine for the period from 1922 to 1929, although the rainfall amounts for the percentiles are higher. The most noticeable rainfall deficit below 10% during this period was two consecutive years in 1918 -1919 when rainfall is interpolated below the 5% percentile. Therefore, it can be deduced from historical rainfall records and Boggabri PO records that extreme extended dry (prolonged drought) conditions will be experienced at Boggabri when there are four sequential years of low rainfall (less than the 10th percentile). A worst case and conservative approach would assume little to no available water from runoff from the site and storages would be close to empty. Following this, for the purposes of this groundwater assessment the conservative worst case scenario of extended dry period is defined as below:

- A four year period where water supply for the project is sourced from the alluvium borefield with no input from surface site storage, no pit inflow contribution and additional requirements to meet evaporation from surface water storage. Therefore, a water supply requirement of 9.4 ML/day from the borefield will be required (which excludes site recycled water contribution).

7. Numerical groundwater model

7.1 Introduction

Numerical groundwater modelling was carried out to estimate the effects of pumping from the proposed borefield on groundwater levels in the aquifer and for assessment of impacts to sensitive receptors and potential interaction with surface water bodies. The modelling objectives were:

- identifying upper and lower thresholds of impacts to groundwater levels from borefield operations for average weather conditions and for extended dry seasons where there is required peak demand for mine operations from the borefield
- quantifying the potential drawdown impacts from borefield operations to regional stakeholder groundwater works and interaction with Namoi River
- optimising pumping rates from production bores with respect to meeting required water supply demand and limiting environmental impacts and drawdown to landholder groundwater works
- the provision of contingency bore scenarios, where backup bores will be used in the circumstance the production bore fails
- assessing recovery of groundwater levels and potential residual impacts at the cessation of borefield operations
- assessing the influence of predicted cumulative drawdown impacts from the Boggabri – Tarrawonga and Maules Creek (BTM) mine complex and borefield drawdown assessment on the alluvial aquifer resources.

The model was specifically constructed and calibrated to meet these objectives and the results should not be applied for any other purpose.

7.2 Model software and complexity

Parsons Brinckerhoff developed a three-dimensional finite difference model using the Groundwater Vistas user interface. MODFLOW (McDonald & Harbaugh, 1988) was used in conjunction with MODFLOW 2005. MODFLOW and its related programs are well documented and internationally widely used for hydrogeological analysis, being widely accepted by NSW government regulators as industry standard.

Groundwater modelling in Australia is undertaken according to industry supported guidelines (Barnett et al., 2012). The Australian groundwater modelling guidelines recommend adoption of confidence level classifications to recognise the different quality of data required for models used for variable purpose (Barnett et al., 2012).

The confidence level classification comprises three classes, in order of increasing confidence level: Class 1; Class 2; and Class 3. The classification is based on a number of criteria, but is mainly related to the availability of data against which the model is calibrated and the timeframe of the predictions relative to the calibration period. In practice, the adoption of a confidence level classification is often constrained by the availability of data, budget and/or time. Class 1 models, in which data are not sufficient for transient model calibration, are often useful to provide initial assessments or to demonstrate processes and relationships based on the conceptual model and reasonable parameter estimates. Most mine impact studies fall into Class 1 or Class 2. The numerical groundwater model developed for this study has been classified as ‘Class

2 to 3'. The table used in the modelling guidelines for assessment of model class is provided in Appendix A. The key indicators met by this model are highlighted in red.

7.3 Model extent and grid

The model domain extends over an area 12.1 km x 17.3 km (209.33 km^2) and is presented in Figure 7.1. The model comprises three layers and the proposed borefield area is located in the centre of the model domain. The model area was divided into 242 rows and 346 columns, resulting in 83,732 cells per layer, and 251,196 cells in the entire 3-layer model. The resulting grid is uniform comprising 50 m x 50 m spacing.

7.4 Model layers and geometry

The surface elevation used for the groundwater flow model was derived by 2 m DTM contour data (Geoscience Australia 2011). Hydrogeological units are represented by 3 model layers as summarised in Table 7.1.

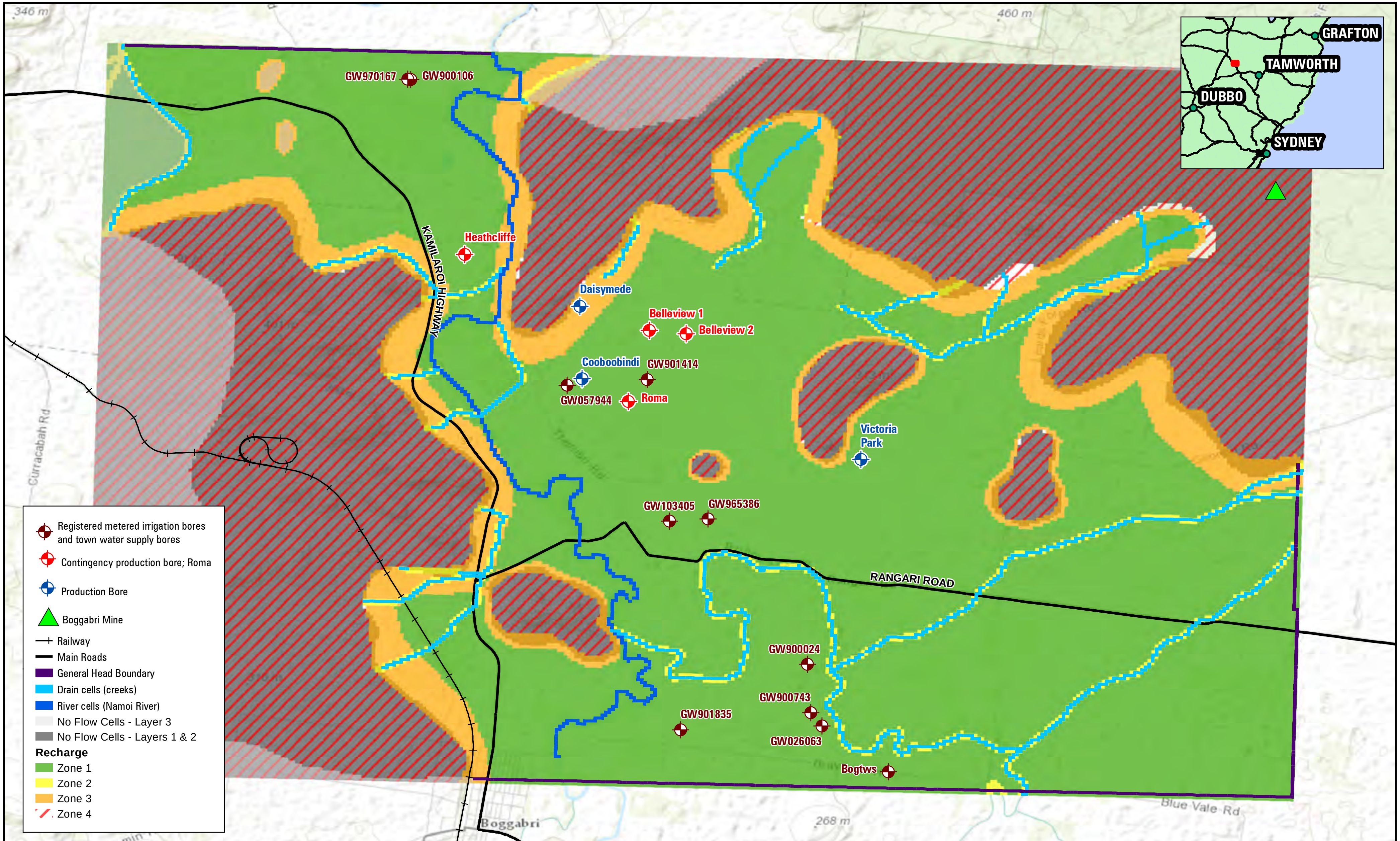
Table 7-1 Model layer summary

Layer	Stratigraphic unit	Lithology	Hydrogeology
1	Narrabri Formation (Alluvium)	Clay with some silt, sand and gravel	Low yielding unconfined aquifer
2	Gunnedah Formation (Alluvium)	Sand, Gravel with silt and clay lenses	High yielding, semi confined aquifer
3	Boggabri Volcanics	Rhyolitic to dactitic lava, trachytes, and andesitic and ashflow tuffs.	Aquitard

Layer elevations were created in Surfer© using kriging and are based on:

- 29 selected bores from the NOW database of which 26 were fully penetrating the alluvium
- 16 bores drilled as part of the borefield investigation of which 13 were fully penetrating the alluvium
- geological map (Pratt, 1998).

A geological map is provided in Figure 4.2 and the bores used for interpretation of geological unit elevations are shown on Figure 7.2. Layers are not continuous throughout the model domain (except layer 3). Where a layer is absent, a minimum thickness of 1 m was kept and the layer was parameterised according to the outcropping geology. The base of the model was set at 125 mAHD. Layer thicknesses are provided as contours in Figure 7.2 for Layer 1 and 2.



Map: 2200555A_GIS_001_A2	Author: M Goganovski
Date: 26/08/2015	Approved by: -

Data source: -

0 750 1,500 m

1:84,000

Coordinate system: GCS GDA 1994

Scale ratio correct when printed at A4

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine

Figure 7.1

Model domain and boundary conditions

WSP | PARSONS BRINCKERHOFF

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

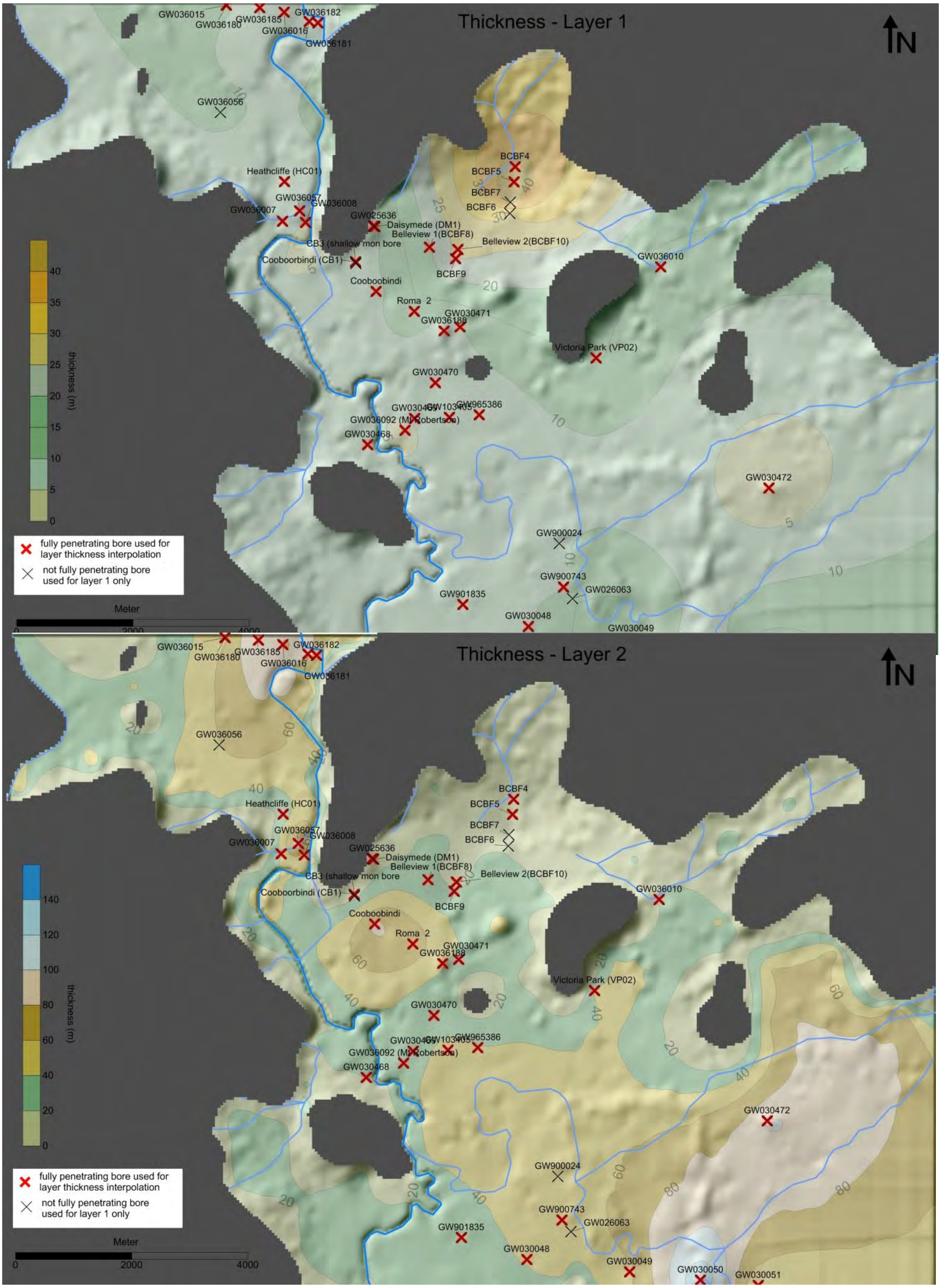


Figure 7-2 Thickness of layer 1 (upper plot) and layer 2 (lower plot) and bores used for interpolation

7.5 Boundary conditions

7.5.1 No flow boundaries

A total of 80,822 model cells have been assigned as no flow cells representing the outcropping geology of the Boggabri Volcanics in Layers 1 and 2. In layer 3 no flow cells were assigned according to potential water divides.

7.5.2 Surface drainage

The MODFLOW RIVER package has been adopted to represent the Namoi River (Figure 7.1). The river stage was set based on the levels and gradient between river gauging stations 419012 (Namoi River at Boggabri) and 419023 (Namoi River at Turrawan). The Namoi River is incised within the alluvial plain by several meters (assumed 6-9m), Therefore, RIV cells have been assigned to layer 1 and 2 according to the river bed elevation. The river bed conductance was set between 0.6 m^2/day and 21.6 m^2/day (depending on river length in any given cell, a width of 15m, a hydraulic conductivity of 0.02 m/day) and adjusted during calibration.

Creeks have been included in the model using the MODFLOW DRAIN package and are consistent with the conceptualisation. This simulates the groundwater discharge to creeks as baseflow during times of increased recharge (rainfall). To account for increased recharge along the creeks, zones of higher recharge were assigned. The drain elevation was set at 4 m below topography to account for incised creek beds.

7.5.3 Recharge and evaporation

Aquifer recharge was simulated using the MODFLOW RECHARGE package. Rainfall recharge is conceptualised as a fraction of rainfall measured at BOM station 055007 (Boggabri Post Office). The model domain was split into four different zones which were adjusted during calibration representing:

1. Alluvial aquifer
2. Slope wash zone along slopes of outcropping Boggabri Volcanics
3. Ephemeral creeks in order to account for increased infiltration during rainfall events
4. Boggabri Volcanics.

Evapotranspiration was applied using the MODFLOW EVT package. The mean annual evaporation at BoM station 055024 (Gunnedah Resource Centre) is 1,750 mm/year. Evaporation was set at 50% of pan evaporation with an extinction depth of 3.5 m.

7.5.4 General head boundaries

In order to simulate cross boundary flows, a MODFLOW GENERAL HEAD boundary was included along the northern, southern and south-eastern boundaries in all layers. The heads were set based on regional water tables contoured from available data (NOW database). The conductance of each cell was calculated from cell hydraulic parameters and saturation.

7.5.5 Groundwater abstraction

This alluvial aquifer is used extensively for irrigation, town water supply and stock and domestic purposes imposing existing stresses to the system. Analytical element wells have been included where known significant abstraction occurs (registered metered use with information collated during the bore census). Considered bores are:

- Boggabri town water supply bore (0.65ML/day)
- 10 Irrigation bores with varying metered data available

Bores considered for the model are shown on Figure 7.1.

7.6 Hydraulic parameters

7.6.1 Hydraulic conductivity

The initial horizontal hydraulic conductivity (k_x) for layers 1 and 3 was based on literature values (AGE 2010; Heritage Computing, 2012a). The hydraulic conductivity for layer 2 was included as a heterogeneous field based on derived estimates from test pumping data of BCOPL borefield bores as provided in Table 5.1. The values were contoured (by kriging) and imported into the model.

For alluvial sediments the initial vertical hydraulic conductivity (k_z) was assumed to be 10% of the horizontal permeability. During the model verification process using recent pump out test data for the Cooboobindi test production bore (refer to section 7.8), a ratio of 0.01 resulted in a better fit of modelled values compared to observed values. This is consistent with the value applied by Heritage Computing (2012a) in the numerical groundwater model for the Tarrawonga Coal Project located nearby. This rationale accounts for the lateral and vertical heterogeneity (i.e. clay lenses). Table 7.2 summarises the initial adopted hydraulic parameter for each layer.

7.6.2 Aquifer storage

Groundwater storage parameters are less well constrained by test data than hydraulic conductivity. However, the model has adopted values for storage derived from pump out tests where sufficient information was available to assess storage characteristics of the aquifer. Storage parameters are only sensitive in transient models. Initial values adopted in the model are summarised in Table 7.2.

Table 7-2 Initial hydraulic parameters

Layer	Initial k_x (m/day)	Initial k_z (m/day)	Specific yield	Specific storage
1	0.5	5×10^{-3}	0.06	2.47×10^{-4}
2	13.7 – 35.30	0.14 –0.35	0.06	2.47×10^{-5}
3	5×10^{-4}	5×10^{-4}	0.001	1×10^{-6}

7.7 Calibration

Numerical models are calibrated to the natural system by comparing simulated results with observed results over a given area of interest and period of time. Model parameters are then altered (within the bounds of reasonable values) to achieve the best possible fit between the simulated and observed results.

7.7.1 Methodology and calibration targets

An initial steady state sensitivity analysis was performed (Appendix B) to identify the most sensitive model parameters:

- hydraulic conductivity
- recharge
- river bed conductance
- aquifer storage.

Variation of these parameters was undertaken during the calibration process. PEST (Doherty, 2003) was used to produce the optimal parameter fields for hydraulic conductivity and aquifer storage for Layer 2, constrained by pilot points. With this technique, PEST assigns optimised values for each parameter to discrete points within the model domain. A value for each calibration parameter is then assigned to every cell of the model grid using a spatial interpolation algorithm. One pilot point was included in Layer 1 and layer 3, resulting in a homogenous bulk value for the entire layer. For recharge and river bed conductance no pilot points were included as different recharge zones were assigned based on geology and topography.

The variation of calibration parameters using PEST can be constrained to within reasonable bounds using pilot points and zones. Each pilot point and zone is assigned a target value and a minimum and maximum boundary across which the calibration parameter may be varied. The number and placement of pilot points as well as the final target and bounding values assigned to each point are provided in Table 7.3. The bounding values for Layer 2 are set based on pumping test results for seven production bores. An additional 27 horizontal hydraulic conductivity (Kx) pilot points for Layers 1, 2 and 3 have been set between head targets along the direction of groundwater flow with minimum and maximum bounds of 4m/day and 40 m/day respectively.

Verification after the first steady state and transient calibration identified that changing the anisotropy ratio between horizontal and vertical hydraulic conductivity from 0.1 to 0.01 improved model calibration. The model was subsequently recalibrated, applying this ratio produced better calibration and verification results.

Table 7-3 Summary of targets and pilot points

ID	x	y	Layer	Steady state target value (m AHD)[1]	K_x lower bound (m/day)[2]	K_x upper bound (m/day)[2]	Ss lower bound[3]	Ss upper bound[3]
Victoria Park (VP02)	221961	6605011	2	n/a	12	15	6.2×10^{-5}	6.55×10^{-5}
Daisymede (DM1)	217880	6607431	2	n/a	34	36	n/a	n/a
Cooboobindi TPB	217917	6606240	2	n/a	19	21	1.2×10^{-5}	1.4×10^{-5}
Roma TPB	218612	6605874	2	n/a	14	16	1.5×10^{-5}	1.7×10^{-5}
Belleview 1(BCBF8)	218884	6607055	2	n/a	25	28	1.24×10^{-5}	1.44×10^{-5}
Belleview 2(BCBF10)	219408	6607016	2	n/a	25	28	8×10^{-5}	1×10^{-4}

ID	x	y	Layer	Steady state target value (m AHD)[1]	K_x lower bound (m/day)[2]	K_x upper bound (m/day)[2]	Ss lower bound[3]	Ss upper bound[3]
Heathcliffe (HC01)	216209	6608260	2	n/a	15.9	19.9	1×10^{-5}	1.2×10^{-3}
GW030048D	220712	6600066	2	232.24	n/a	n/a	1×10^{-5}	5×10^{-4}
GW30049M	222609	6599838	2	231.2	n/a	n/a	1×10^{-5}	5×10^{-4}
GW30050M	223918	6599686	2	231.21	n/a	n/a	1×10^{-5}	5×10^{-4}
GW30468	217748	6603410	2	231.34	n/a	n/a	1×10^{-5}	5×10^{-4}
GW30469	218614	6603895	2	231.37	n/a	n/a	1×10^{-5}	5×10^{-4}
GW30470S	218997	6604552	1	231.34	5×10^{-3}	5×10^{-1}	(Sy) 0.03	(Sy) 0.15
GW30470D	218997	6604552	2	231.35	n/a	n/a	1×10^{-5}	5×10^{-4}
GW30471M	219450	6605581	2	230.67	n/a	n/a	1×10^{-5}	5×10^{-4}
GW30472M	225148	6602615	2	231.48	n/a	n/a	1×10^{-5}	5×10^{-4}
GW36007M	216174	6607530	2	228.44	n/a	n/a	1×10^{-5}	5×10^{-4}
GW36008	216601	6607510	2	228.03	n/a	n/a	1×10^{-5}	5×10^{-4}
GW36015	215136	6611509	2	226.61	n/a	n/a	1×10^{-5}	5×10^{-4}
GW36016M	216205	6611383	2	224.85	n/a	n/a	1×10^{-5}	5×10^{-4}
GW36056	215028	6609534	2	226.86	n/a	n/a	1×10^{-5}	5×10^{-4}
GW36057S	216488	6607723	2	228.43	n/a	n/a	1×10^{-5}	5×10^{-4}
GW36092	218434	6603674	2	231.38	n/a	n/a	1×10^{-5}	5×10^{-4}
GW36185	215750	6611464	2	224.4	n/a	n/a	1×10^{-5}	5×10^{-4}
MB6	22546	6608059	2	259.93	n/a	n/a	1×10^{-5}	5×10^{-4}
L3	225466	6608059	3	n/a	5×10^{-5}	5×10^{-3}	1×10^{-6}	1×10^{-4}

1 averaged based on water level observations between January 2004 and January 2015

2 k_z/k_x ratio of 0.1 maintained

3 Sy for Layer 1

7.7.2 Steady state calibration

For the steady state calibration, averages of data collected between 1 January 2004 and 31 December 2014 were considered for:

- rainfall
- evaporation
- the measured heads of 18 head targets; comprising predominantly NOW monitoring bore records and select additional BCOPL or landholder bores
- Namoi River stage
- groundwater abstraction from town water supply and metered irrigation bores.

The calibration statistics are presented in Table 7.4 and a graph showing modelled versus observed average heads is provided in Figure 7.3.

Table 7-4 Steady state calibration statistics

Calibration statistics	Value
Number of data	18
Root mean square	0.5
Scaled root mean square (%)	1.4
Residual mean (m)	0.15

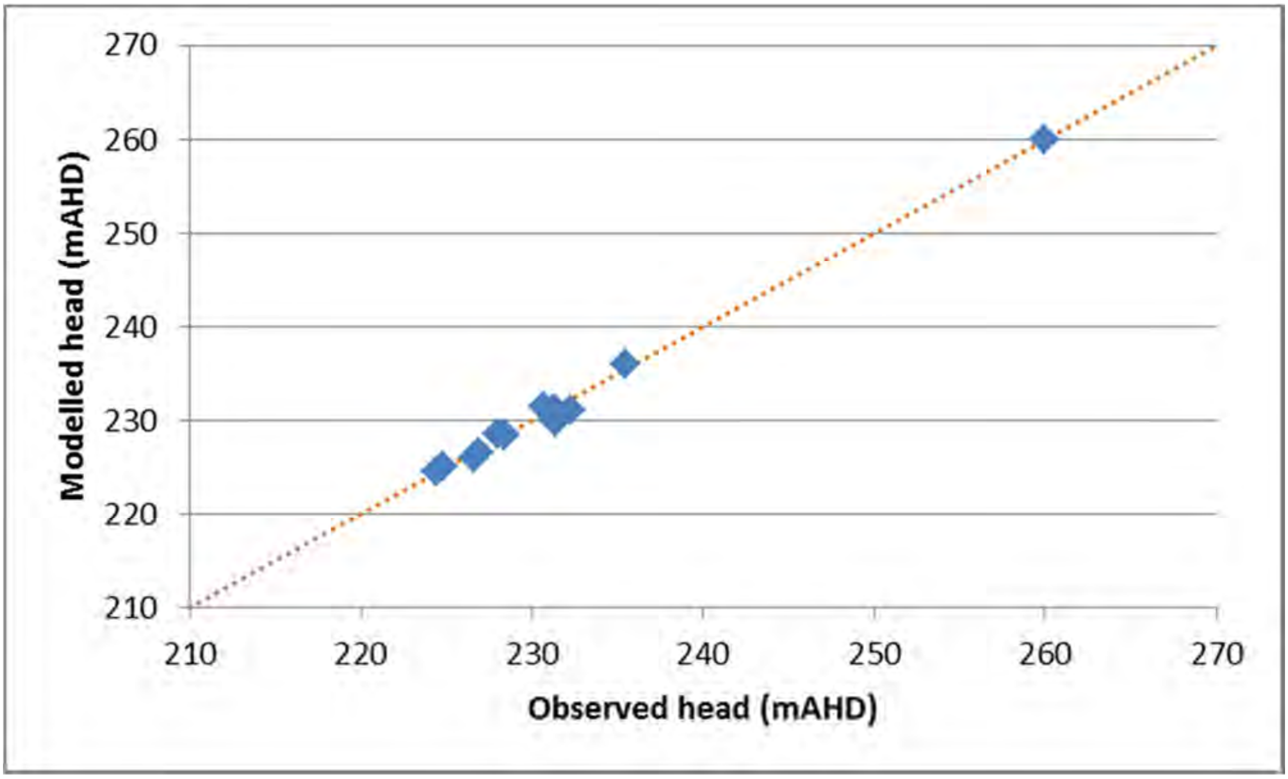


Figure 7-3 Modelled versus observed heads

Steady state calibrated hydraulic parameters are presented in Table 7.5. The steady state calibrated values for rainfall recharge expressed as percentages of rainfall are:

- Alluvial aquifer: 1.5%
- Slope wash zone: 15%
- Ephemeral creeks: 15%
- Volcanics: 0.5%

Table 7-5 Steady state calibrated parameter

Layer	Lithology	K_x (m/day)	K_z (m/day)	River Cond (m^2/day)
1	Clayey sand and gravel	0.5	0.005	9.3
2	Sand and gravel with clay lenses	3.48 – 39.72	0.034 – 0.4	23.3
3	Volcanics	1×10^{-4}	1×10^{-4}	N/A

The steady state water balance (Table 7.6) indicates:

- Within the model domain, the Namoi River is predominantly a gaining stream
- Main inflow mechanism are cross boundary flow and rainfall infiltration

Table 7-6 Steady state simulated water balance for model domain

Component	Groundwater inflow (m^3/day)	Groundwater outflow (m^3/day)
Rainfall recharge	9,229	
Evapotranspiration		39
Namoi River	17	3,135
Creeks		2
Abstraction bores		5,980
Boundary Flow	20,773	20,878
Total	29,853	29,888
Error	-15	

7.7.3 Transient calibration

For transient calibration a total of 44 quarterly stress periods was included to represent the time between 1 January 2004 and 31 December 2014. Recharge multipliers were used for each stress period according to the actual measured rainfall. The Namoi River was represented as a time-varying boundary condition with an average river stage over each quarter used each stress period. The general head boundaries in the north and south were kept at a steady state height (and the head targets de-weighted to 0.1) as they are considered far enough from the proposed abstraction field. Evapotranspiration was kept constant due to low sensitivity. Well abstraction rates for the irrigation bores were interpolated using provided meterage data.

Transient calibrated hydraulic parameters are presented in Table 7.7. The calibrated distribution of hydraulic conductivity and specific storage are shown in Figure 7.4 and Figure 7.5. The transient calibrated values for rainfall recharge expressed as percentages of rainfall are:

- Alluvial aquifer: 2.1%
- Slope wash zone: 10.7%
- Ephemeral creeks: 12.4%

Table 7-7 Transient calibrated parameter

Layer	Lithology	K_x (m/day)	K_z (m/day)	River Cond (m^2/day)	Sy	Ss (1/m)
1	Clayey sand and gravel	0.5	0.005	10.0	0.15	2.98×10^{-4}
2	Sand and gravel with clay lenses	3.85 – 39.79 (Mean: 21.23)	0.034 – 0.4	19.9	n/a	1.2×10^{-5} – 5.4×10^{-4}
3	Volcanics	1×10^{-4}	1×10^{-4}	N/A	n/a	1×10^{-6}

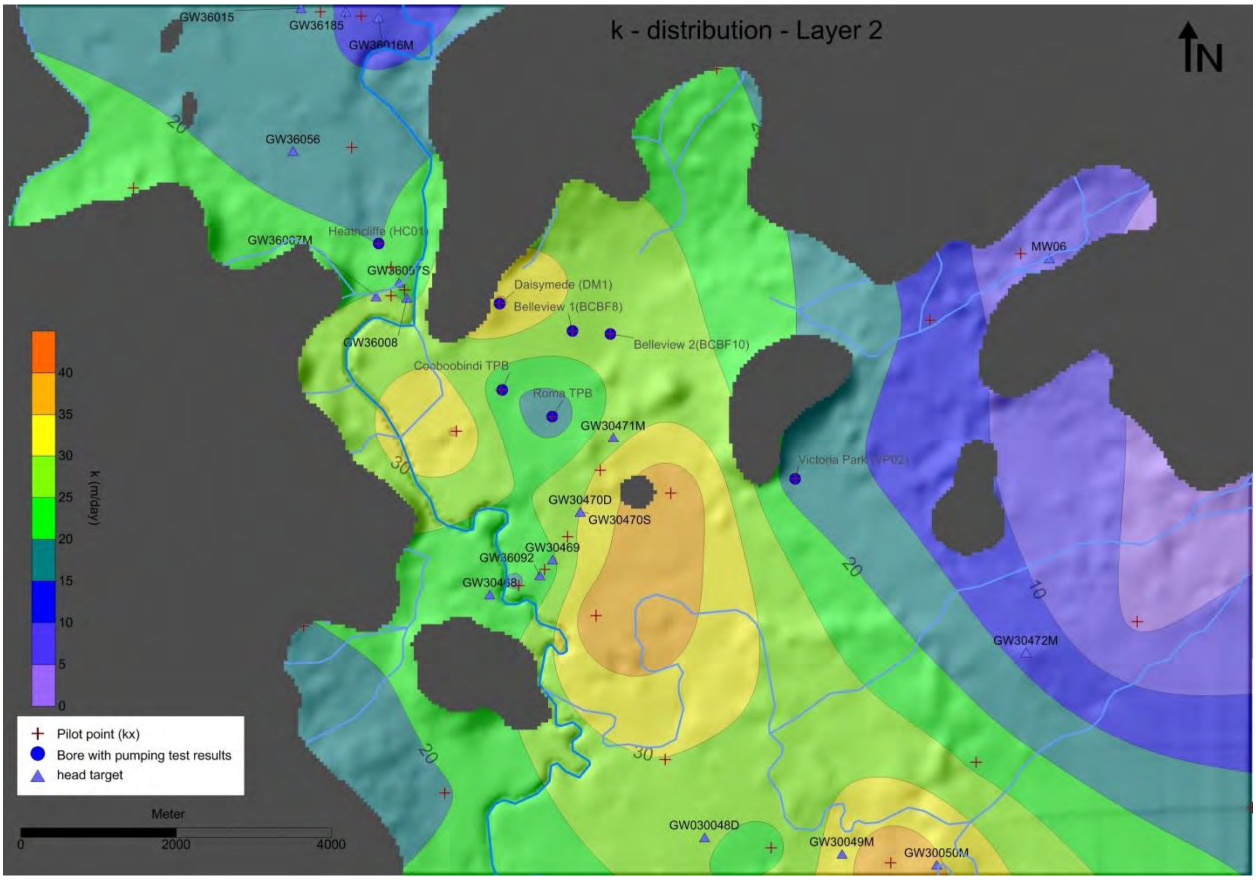


Figure 7-4 Distribution of horizontal hydraulic conductivity in layer 2

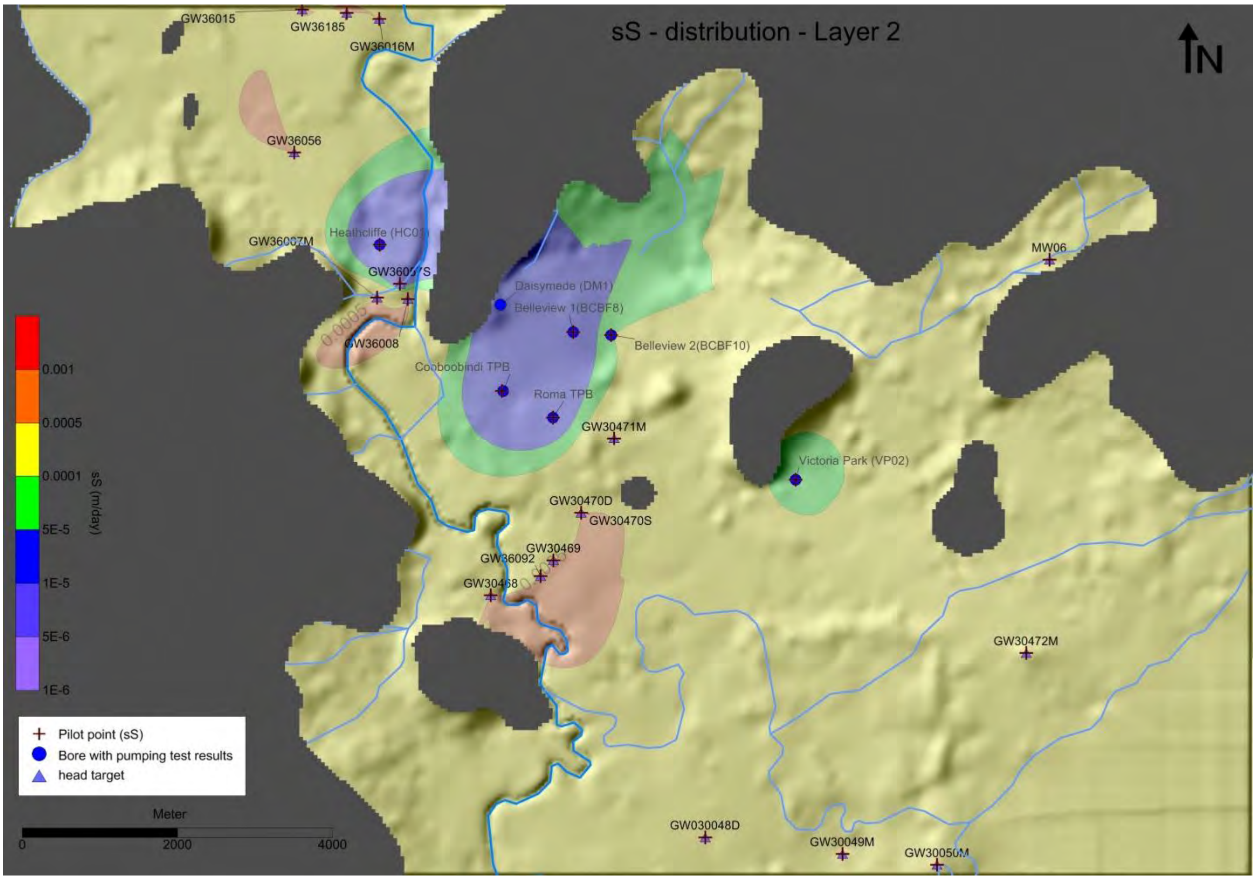


Figure 7-5 Distribution of calibrated specific storage in layer 2

The calibration statistics are presented in Table 7.8 and a graph showing modelled versus observed heads is provided in Figure 7.6. Hydrographs showing modelled and observed heads are provided in Appendix C. Observed head data are from NOW longterm monitoring bore records.

Table 7-8 Transient calibration statistics

Calibration statistics	Value
Number of data	757
Root mean square	0.55
Scaled root mean square (%)	1.4
Residual mean (m)	0.12

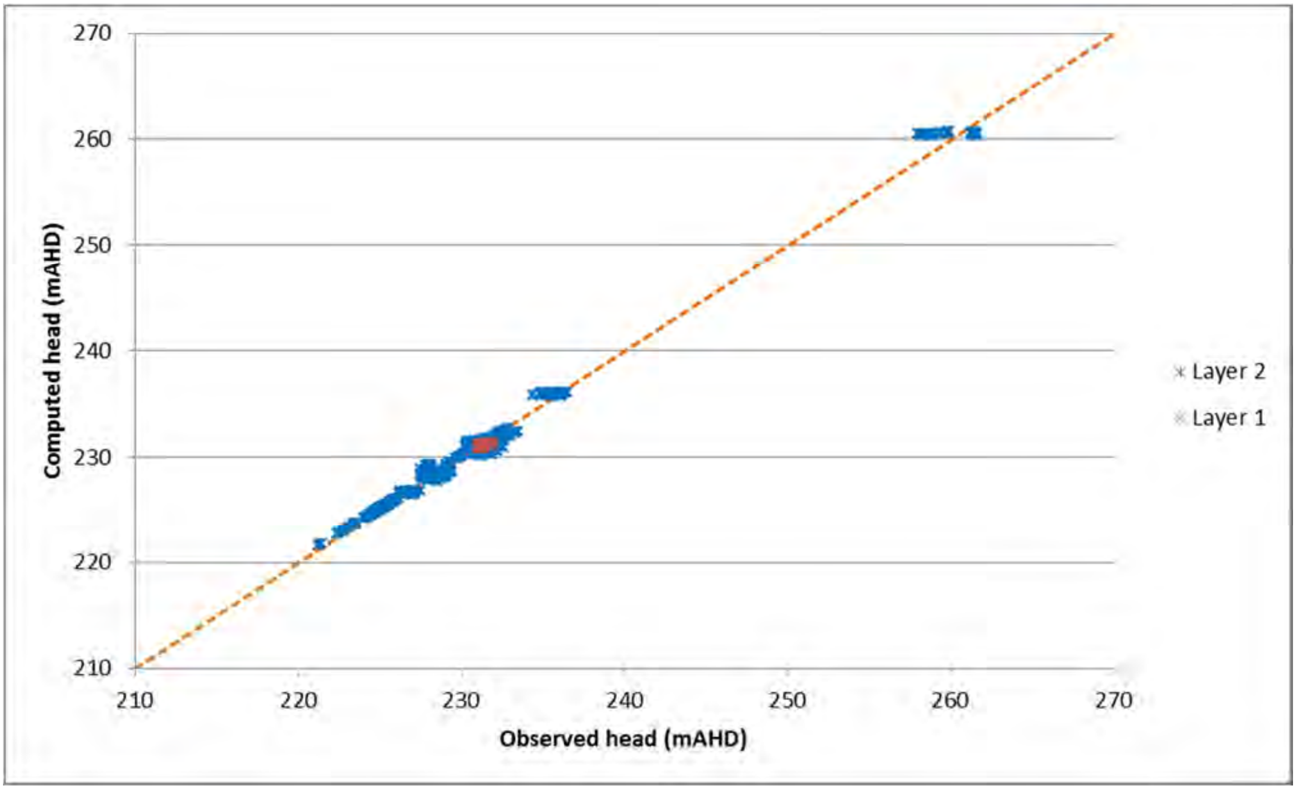


Figure 7-6 Modelled versus observed heads (transient)

The transient mass balance (Figure 7.7) shows:

- the wetter summers and dryer winters are represented in the model
- depending on weather and abstraction, the Namoi River alters between receiving and loosing stream
- during the summer months groundwater abstraction is the major outflow mechanism
- creeks remain predominantly disconnected from the groundwater
- evapotranspiration from the water table is low due to the depth to groundwater and vegetation (few plants with deep rooting).

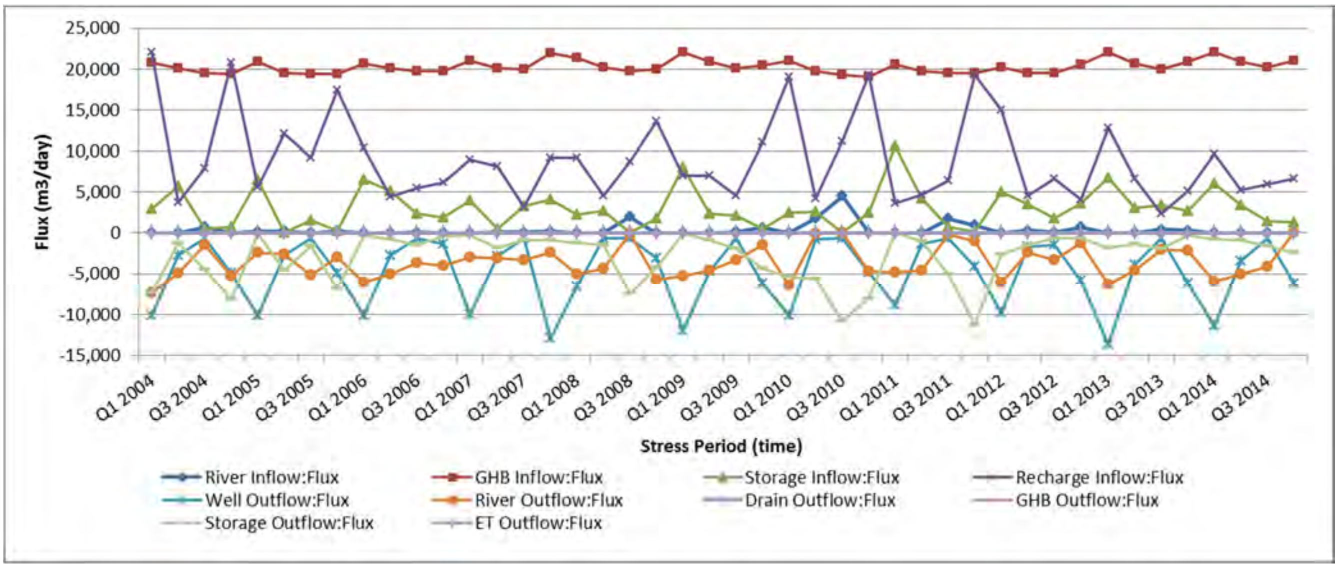


Figure 7-7 Transient mass balance

7.8 Model verification

The verification was done using recent pump out test data from the Cooboobindi test production bore (CBTPB) constant rate test (Parsons Brinckerhoff, 2015b). Drawdown targets were included for the Roma monitoring bore (RMB), Cooboobindi monitoring bore (CBMB) and GW032291. The calibrated model replicates the observed drawdown within 10% (CBMB) and 4% (RMB) as shown in Figure 7.8.

The verification is considered successful, indicating that the realisation of model parameters is appropriate for predictive purposes.

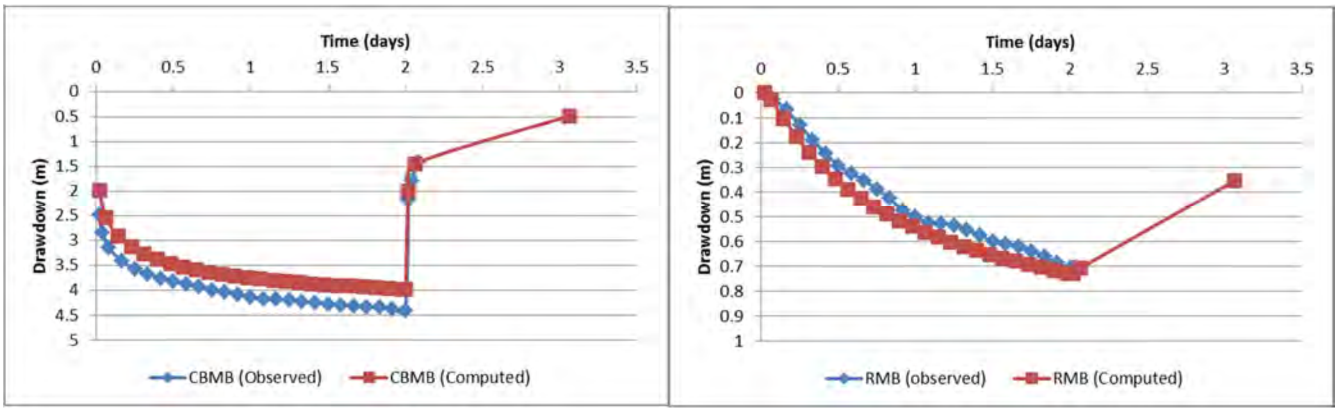
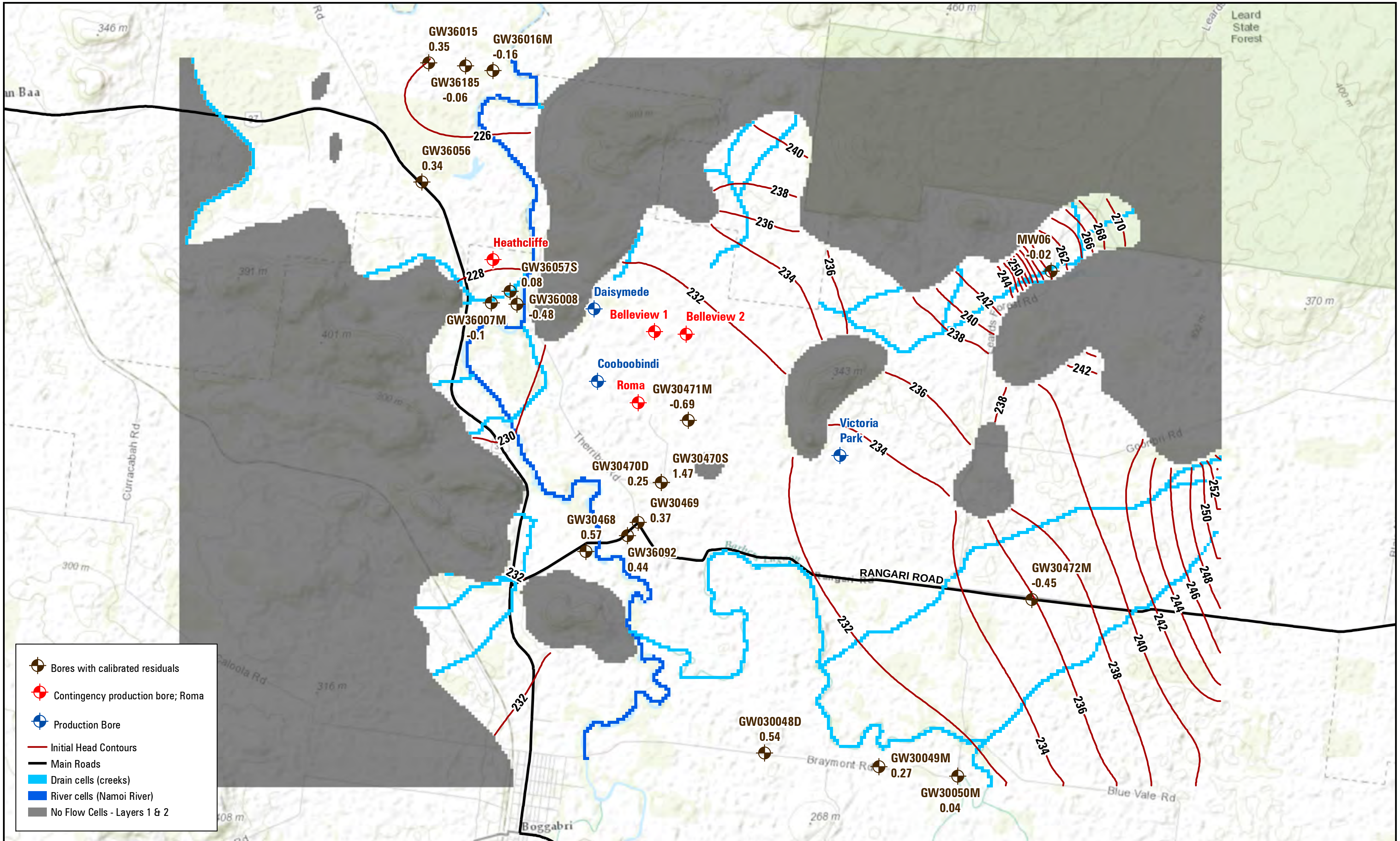


Figure 7-8 Observed and modelled drawdown for Cooboobindi pumping test monitoring bores

7.9 Predictive simulations

7.9.1 Initial conditions

In order to arrive at drawdown induced by the proposed groundwater abstraction, the initial conditions for the predictive runs were set based on average conditions for rainfall, river stage and groundwater abstraction from other beneficial users as applied for steady state calibration. For the A-scenarios the maximum drawdown can be observed at the end of pumping. For drawdown calculations of the dry periods (B-scenarios), the same initial heads were taken, but corrected by subtracting the apparent drawdown due to natural variations. To estimate the drawdown caused by changes to the boundary conditions, the B-scenario model was run without pumping stresses from the Boggabri production bores (last plot in Appendix E). The initial head, including the steady state residuals, is shown in Figure 7.9.



Map: 2200555A_GIS_014_A1_Fig7-9	Author: M Goganovski
Date: 26/08/2015	Approved by: - S Focke

Data source: -

0 750 1,500 m

1:84,000

Coordinate system: WGS 1984 UTM Zone 56S

Scale ratio correct when printed at A4

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine

Figure 7.9

Initial head and steady state calibrated residuals

7.9.2 Optimisation of abstraction rates

In order to minimise impacts on other beneficial users due to groundwater abstraction from the three production bores (Victoria Park, Cooboobindi, Daisymede), abstraction rates were optimised using the following methodology:

- Landholder bores were imported as head targets into the model.
- The dry weather condition model (see below) was used while changing modelled abstraction rates for the individual bores (but always totalling 5.7 ML/day and 9.4 ML/day for mean and dry weather conditions respectively).
- The following measures were used to identify optimised abstraction rates:
  - number of bores with >1m drawdown
  - number of bores with >2m drawdown
  - sum of maximum drawdown of all bores
  - calibration statistics.

Assessed optimised abstraction rates for each bore is summarised in Table 7.9.

Table 7-9 Optimised abstraction rates for utilised production bores

Bore	Rate – mean weather conditions (ML/day)	Rate – dry weather conditions (ML/day)
Daisymede	0.8	0.9
Cooboobindi	3.0	5.5
Victoria Park	1.9	3.0
Total	5.7	9.4

7.9.3 Model scenarios

All model scenarios include a 17 years pumping period, in which the production bores were continuously abstracting groundwater, followed by a 10 year recovery period. The base case scenarios are for the pumping of the three production bores – Cooboobindi, Daisymede and Victoria Park and are as follows:

1A) Base case - comprises average weather conditions with water input to site operations originating from mine site sources (surface water collection from direct rainfall and runoff and groundwater inflow into the pit) as well as input from the alluvial borefield (scenarios 1A, 2A, 3A and 4A) for the duration of 17 years pumping from the borefield.

1B) Base case extended dry conditions - which includes the following sequence:

- years 1 – 10 is average weather conditions
- years 11 – 14 is extended dry period with all water inputs to mine coming from the borefield
- years 15 – 17 is average weather conditions.

Scenarios 2 – 4 (2A/B, 3A/B and 4A/B) include the utilisation of contingency bores (Roma, Heathcliffe or Belleview 1 and Belleview 2) for a period of 3 months, giving sufficient time to repair/replace the failed production bore. The 2A/3A/4A scenarios utilise average weather conditions while the 2B/3B/4B utilise the contingency bore for a period of 3 months during the extended dry period for years 11 – 14 of borefield operations.

Details of pumping rates for the model scenarios are provided in Table 7.10. Registered bores were included in the model as drawdown targets so as to estimate the drawdown for the borefield pumping scenarios.

Table 7-10 Model scenarios (pumping rates in ML/day)

Scenario	1A	1B	2A	2B	3A	3B	4A	4B
Production Bores	Base Case	Base Case dry weather	CB fails	CB fails, dry weather	VP bore fails	VP bore fails, dry weather	DM fails	DM fails, dry weather
Daisymede	0.8	0.9	0.8	0.9	0.8	0.9		
Victoria Park	1.9	3	1.9	3			1.9	3
Cooboobindi	3	5.5			3.5	7	3	5.5
Roma			3	5.5				
Roma								
Heathcliffe					1.4	1.5		
Bellevue BCBG8							0.4	0.5
Bellevue BCBF10							0.4	0.4

Note: DM = Daisymede; VP is Victoria Park, CB is Cooboobindi

For the dryer periods the following changes to the steady state boundaries were made:

- River stage was set to the 25th percentile for years 11 and 14 and to the 10th percentile of river height for years 12 to 13.
- The head of the GHB was lowered by 0.5 m for years 11 and 14 and 1 m for years 12 and 13 of the simulation, according to groundwater monitoring data in the vicinity of these boundaries.
- The recharge was reduced to the 25th percentile of long term mean for years 11 and 14 and to the 10th percentile for years 12 and 13.

7.10 Results and impact assessment

7.10.1 Introduction

Results are presented as drawdown plots (Appendix D) and drawdown hydrographs for four selected long term NOW monitoring bores as well as the three production and four contingency bores (Appendix E). **The drawdown on the plots represents the LOM (life of mine) drawdown which reflects the maximum drawdown at any location at any time during abstraction.** The minimum drawdown contour plotted is 1m. In addition to the LOM plots, time snap shots for 4month, 2.5 years, 10 years and 17 years of pumping and 2.5 years of recovery are provided for Scenario 1A (Appendix 1a to 1e). As the first ten years of pumping are identical for scenarios 1A and 1B, for scenario B plots for 13 years (end of driest period) and 14 years (end of dry period), 17 years *end of pumping) as well as after 2.5 and 10 years recovery (Appendix 2a to 2e). It can be seen that:

- The extent of the 1m LOM drawdown contour is similar for all A-scenarios
- The extent of the 1 m LOM drawdown contour is similar for all B-scenarios
- Due to increased abstraction rates, the drawdown for the B-scenarios extend over a further distance and maximum drawdown is spatially more extensive compared to the A-scenarios
- A cone of depression develops around the pumping bores with likely interference between Cooboobindi and Daisymede and, to a lesser extent, Victoria Park
- Recovery after abstraction ceases is relatively quickly with less than 1m residual drawdown after 2.5 years for Scenario 1A and 10 years for Scenario 1B in areas where registered landholder bores or wells are located.

From review of the hydrographs it can be seen that:

- The development of the cone of depressions is identical for the A- and B-Scenarios for the first 10 years
- For the A-scenarios close to steady state conditions have developed after 17 years with the slope of the graphs tending towards zero
- The bores utilised for abstraction show the biggest drawdowns
- Residual drawdown after 10 years of recovery is less than 0.5 m for all bores and scenarios
- The increased drawdown due to increased abstraction rates from year 11 to 14 is clearly visible
- Maximum drawdown for A-scenarios is reached at the end of year 17 (end of pumping)
- Maximum drawdown for B-scenarios generally occurs at the end of year 13, at the end of the period for which the recharge and river stage are reduced to the 10th percentile).

7.10.2 Drawdown and bore performance

Groundwater drawdown due to pumping at each of the active wells will contribute to drawdown in the water level in the other wells (well interference). Well interference can lead to a decline in bore yields, particularly if the available drawdown in the well water column is limited (as is the case at Daisymede bore and Heathcliffe bore).

Estimated total drawdown at each bore, which includes pumping and interference from other active pumping bores, was calculated from the MODFLOW cell drawdown values for each pumping cell and for each scenario using the approach of Anderson and Woessner (1992). Drawdown at MODFLOW pumping well cells often underestimates the drawdown in the well itself because the effective radius of the model cell is typically far larger than the actual bore radius The Anderson and Woessner (1992) approach uses the Thiem equation (Thiem, 1906) to correct for this effect (Table 7.11). Bores at which the estimated drawdown exceeds 50% of the available drawdown are highlighted (Daisymede bore and the contingency bore, Heathcliffe). It will be important to monitor water levels in these bores, particularly Daisymede Bore for performance and refining pumping rates for management of borefield operations.

It should be noted that these drawdown results are for bores operating continuously 24 hours a day and are therefore conservative. Realistically bore pumping may be stopped at times due to filling of site storages at the mine or maintenance and this will allow time for water levels to recover.

Table 7-11 Estimated total interference drawdown at each pumping bore (metres)

Scenario			1A	1B	2A	2B	3A	3B	4A	4B
Production Bores	Proposed Pump Level (m bgl)	Available Drawdown (m)	Base Case	Base Case dry weather	CB fails	CB fails, dry weather	VP bore fails	VP bore fails, dry weather	DM fails	DM fails, dry weather
			Drawdown (m)							
Cooboobindi	46 (blank within screens)	36.5	5.6	11.2	1.9	4.2	6.4	13.7	5.5	11.1
Victoria Park (VP02)	49 (top of lower screen)	37.8	5.6	9.9	5.6	9.9	1.4	3.0	5.6	9.9
Daisymede (DM1)	19 (top of lower screen)	11.3	4.9	7.6	4.7	7.2	5.1	8.2	2.3	4.6
Roma	42 (blank within screens)	32.3	1.9	4.3	6.0	11.7	2.0	4.9	1.9	4.3
Heathcliffe (HC01)	16.5 (top of upper screen)	7.05	0.3	2.0	0.3	1.8	3.2	5.5	0.3	1.9
Belleview1 (BCBF8)	22 (top of screen)	12.2	2.1	4.2	2.1	4.1	2.2	4.6	2.8	5.0
Belleview 2 (BCBF10)	27 (top of screen)	18.2	1.9	3.7	2.0	3.8	2.0	4.0	2.8	4.6

Note: Proposed location of pump inlet is from review of bore construction logs and recommendations provided in test pumping reports (refer to section 1.1 for list of reports).
Drawdown highlighted in bold exceed 50% of available drawdown between groundwater level and pump level.

7.10.3 Predicted impacts on water users

The cone of depression will cause water levels in landholder bores (includes concrete lined wells) to decline. For each scenario, the modelled drawdown at affected landholder registered bores was identified. The Aquifer Interference Policy (AIP) quotes a threshold for key minimum impact considerations of 2m for groundwater supply works.

More bores are effected for the dry weather scenarios due to increased abstraction rates. A summary of impacts for drawdown for the differing scenarios is provided in Table 7.12 and Figure 7.10.

Table 7-12 Summary of impacts on registered landholder bores

Scenario	Number of bores with DD > 1m	Number of bores with DD > 2m	Number of bores with DD > 5m
1A	22	6	0
2A	22	7	0
3A	22	6	0
4A	22	6	0
1B	34	20	0
2B	34	20	1
3B	35	20	1
4B	34	20	0

Note: DD is drawdown; LOM is Life of Mine

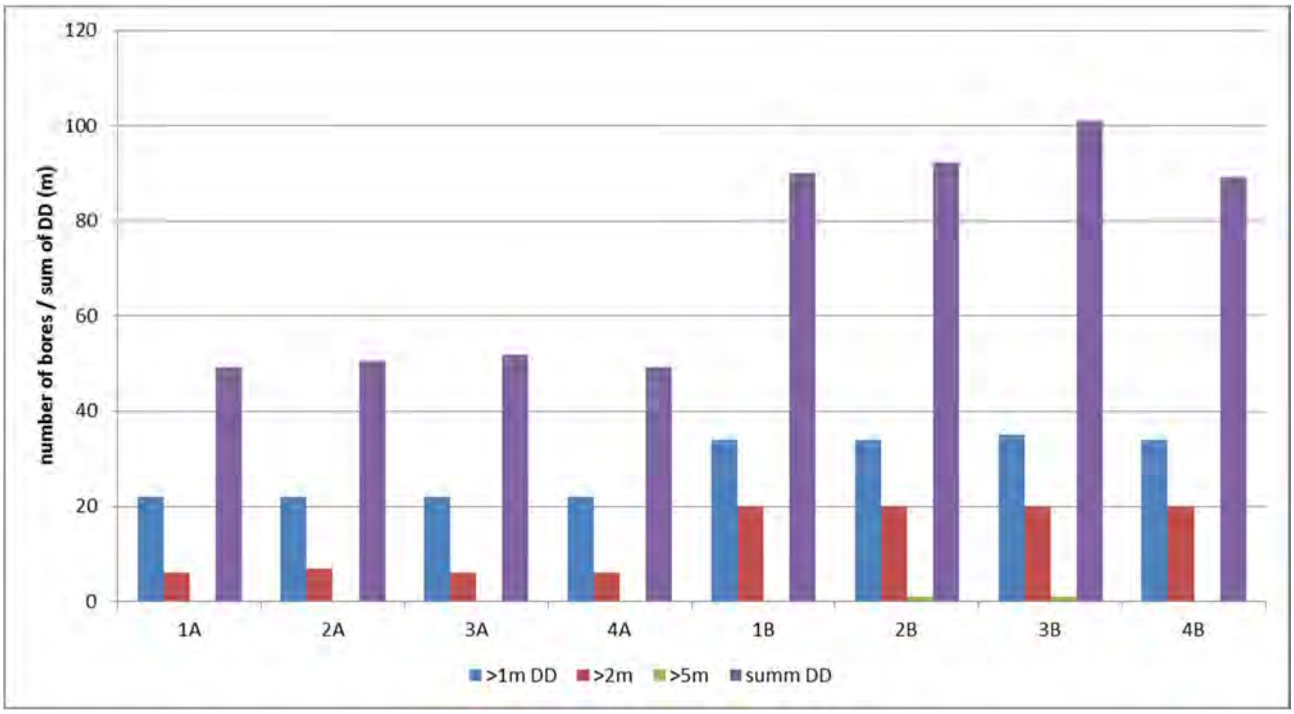


Figure 7-10 Number of bores affected and sum of total modelled drawdowns in landholder bores

For the A-scenarios of mean weather conditions the likely number of active landholder bores exceeding 2m drawdown, without entitlements sold to BCOPL is limited to 2 bores on the Cooboobindi and Roma properties. Four of the five groundwater bores are on the Cooboobindi property and are either decommissioned, unlicensed or entitlements have been sold to BCOPL. This number would reduce further if wetter than average conditions cause less required abstraction and increased recharge. Details of these bores are provided in Table 7.13.

Table 7-13 Bores in Scenario 1A with predicted drawdown greater than 2m

Bores	property	Description	Status	Predicted DD (m)
GW032290	Cooboobindi	irrigation	Decommissioned (cement plug)	2.12
GW035052	Cooboobindi	irrigation	License cancelled; not used	2.2
GW053309	Cooboobindi	stock/domestic	Last used in 2008; license lapsed	2.2
GW057944	Cooboobindi	Adjacent Cooboobindi production bore	Entitlement sold to BCOPL	2.29
GW901414	Roma	Irrigation bore	Active	2.05
GW968402	Cooboobindi	House domestic bore	Entitlement sold to BCOPL	2.22

The B-scenarios are considered worst case scenarios with increased pumping and reduced recharge. For these scenarios, 20 registered landholder bores or wells would experience a drawdown between 2 and 5 m. Some of these groundwater works are predicted to become dry. However, from the recent hydrocensus, there was identified only 6 active (or presumed active) bores and wells, with the remaining dry, abandoned, inactive, or entitlements sold to BCOPL. Details of these bores and estimated drawdown quantities are provided in Table 7.14.

Table 7-14 Bores in Scenario 1B with predicted drawdown greater than 2m

Bores	property	Description	Status	Predicted DD (m)
GW032290	Cooboobindi	irrigation	Decommissioned (cement plug)	4
GW035052	Cooboobindi	irrigation	License cancelled; not used	4.03
GW053309	Cooboobindi	stock/domestic	Last used in 2008; license lapsed	4.03
GW057944	Cooboobindi	adjacent BCOPL Cooboobindi production bore	Entitlement sold to BCOPL	4.27
GW901414	Roma	irrigation bore	Active	3.49
GW968402	Cooboobindi	domestic bore	Entitlement sold to BCOPL	4.04
GW005441	Lot21/DP618032	stock - domestic ?	unknown	2.11
GW022957	Bullock Paddock	irrigation	Not used since 2002/ bore screen damage/ traded in licence	2.78
GW031926	Roma	unknown	Licence inactive, not used cement lined well, possibly dry/backfilled	2.73
GW031927	Roma	unknown	Not used cement lined well, possibly dry/backfilled	2.79
GW031928	Roma	stock	Not used, salty water - recorded TDS of 3000 - 7000 ppm	2.75
GW032136	Roma	Adjacent BCOPL Roma production bore	Not used	3.47
GW032249	Glenhope	domestic and stock	Active - house well	2.21
GW032251	Glenhope	stock	Dry; Not used since early 1990's	2.63
GW032252	Billabong	stock	Dry	2.89
GW032254	Billabong	domestic	Active - used by current caretakers	2.78
GW032291	Cooboobindi		Inactive concrete well	3.47
GW053271	Roma	domestic	Active - house bore	2.81
GW900014	Billabong	irrigation	Currently not used	3.24
GW967663	Lot21/DP618032	stock - domestic ?	unknown	2.1

NA – Not Available.

Bore or wells highlighted in yellow are active or unknown but presumed active.

Bores highlighted in green have entitlements sold to BCOPL

There are five shallow active concrete lined landholder wells or bores, which would experience less than 2m drawdown, however they have a limited saturated water column depth and will become dry or supply will potentially be adversely affected for both A and B scenarios. These groundwater works are located on the Brighton, Glenhope, Billabong and Nardeenean properties. Table 7.15 provides a list of bores and wells which are predicted to have greater than 50% reduction in water column depth for scenario 1A and Scenario 1B (excludes existing dry bore/wells).

Table 7-15 Bores and wells predicted greater than 50% reduction in water column height for Scenarios 1 and 1B

Bores/well	Property	Current Status	Scenario 1A: >50 % reduction water column height	Scenario 1B: >50 % reduction water column height
GW005441	Lot21/DP618032	unknown	N	Y
GW010797	Nardeeneen	decommissioned ?	N	Y
GW032116	Lot143/DP754926	active	N	Y
GW032136	Roma	not used (adjacent BCOPL Roma production bore)	Y	Y
GW032233*	Brighton	active	Y	Y
GW032235*	Brighton	opportunistic use , commonly dry	Y	Y
GW032246	Hopeton Park	destroyed	N	Y
GW032249*	Glenhope	active	N	Y
GW032254	Billabong	active	Y	Y
GW032290	Cooboobindi	decommissioned	N	Y
GW032291*	Cooboobindi	not used	Y	Y
GW035052	Cooboobindi	not used, license cancelled	N	Y
GW043433	Horse Shoe	unknown	N	Y
GW043448	Rosewood	unknown	Y	Y

* = concrete lined well

Additional tabulated information details of predicted drawdown and water column reduction for all registered landholder groundwater works for modelling scenarios is provided in Appendix F.

7.10.4 Predicted impacts on flow towards Namoi River

The cone of drawdown will spread to the west and reach the Namoi River for all Scenarios. At least 1m drawdown is predicted along 1.45 km of river reach in Scenario 1A, and > 2 m drawdown along approximately 3.8km of river reach in Scenario 1B during the extended dry period. This will reduce the volume of groundwater discharging into Namoi River and increase river loss into the groundwater within the zone of influence, assuming that the river is hydraulically well-connected to the aquifer. Water balance results from the model indicate that:

- For all Scenarios the net groundwater discharge to Namoi River within the zone of influence decreases within the first 10 years of pumping and continues for the duration of pumping.

- After pumps are switched off, groundwater discharge to the river recovers to 88.2% (Scenarios A) and 83.3% (Scenarios B) of pre-development rates within 10 years.

According to the NSW Aquifer Interference Policy, any induced net loss from a surface water source is considered to be an indirect take from that surface water source and needs to be accounted for by relevant water access licences. BCOPL has existing WALs for the Namoi River and where necessary will obtain further WALs to cover licensing shortfall for the quantity of take from the River. Table 7.16 summarises the model estimates of the reduction in groundwater discharge (baseflow) to the Namoi River as a result of pumping from the borefield under scenarios 1A and 1B.

The Boggabri flow gauging station (419012) records from 1980 to 2014 provide an average yearly flow of 611 GL. The estimated loss of water from the Namoi River represents less than 0.2% of the average annual flow for Scenarios 1A and 1B as shown in Table 7.16. The 10th percentile annual river flow (132.5 GL) is taken to reflect an extended dry period. Under these conditions, the induced river loss from pumping represents 0.6% to 0.9% of annual river flow under those conditions.

Table 7-16 Estimated loss of baseflow to the Namoi River as a result of borefield operation

	Scenario 1A		Scenario 1B	
Years of operation	Reduction in net flux to river (ML/y)	Percentage of average annual flow	Reduction in net flux to river (ML/y)	Percentage of average annual flow
1 to 10	860	0.14 %	860	0.14 %
11 to 14	965	0.16 %	1,133	0.19 %
15 to 17	975	0.16 %	769	0.13 %
18 to 27	232	0.04 %	314	0.05 %

Note: 18 to 27 years net river flux estimates are during recovery of groundwater levels following borefield pumps ceasing operations.

7.10.5 Cumulative drawdown

Three coal mines operating in the hills over 5km east to northeast of the alluvial borefield (refer to Figure 1.1) have potential to cause drawdown to extend into the alluvium from development of the pit voids. These coal mines are:

- Maules Creek
- Tarrawonga
- Boggabri.

Previous modelled cumulative drawdown impact assessments for the Boggabri, Tarrawonga and Maules Creek coal operations undertaken by Heritage Computing (2012b) and AGE (2011) show drawdown extending into the alluvium at the base of the foothills east to northeast of the borefield (refer to Appendix G for plans). The more conservative cumulative modelling outcomes (AGE, 2011) provide 1m drawdown contour after 21 years extending to within 500m to 1000m of the Victoria Park, Belleview and Daisymede bores. These production bores are therefore likely to experience minor drawdown (< 1m) from mine dewatering, which, when compounded from pumping interference effects, is unlikely to affect the sustainability of pumping rates in these bores, with the exception of possibly the Daisymede bore. The contribution of longterm pumping from the borefield on cumulative drawdown impacts is estimated to be an additional 1-2m (Scenarios A) and 1-3m (Scenarios B) drawdown in the alluvium to the east and northeast of the borefield where mine cumulative drawdown is experienced.

7.11 Sensitivity analysis

A sensitivity analysis was undertaken to assess the model predictions to variations in input parameters. The parameters with the highest uncertainty are recharge and river cell conductance. Although hydraulic conductivity is reasonably restrained by pumping test results, it was included in the sensitivity analysis. The calibrated specific storage is about one order of magnitude lower in areas where it is constrained by pumping test data than in the areas where the pilot points where less constrained. Therefore a sensitivity run was done with a consistent lower specific storage in layer 2. The following changes to these parameters were assessed in the sensitivity analysis:

- A +/- 25% change of kx and kz in Layer 2
- A +/- 25% change of recharge to all zones
- A +/- 50% change of the river cell conductance in layers 1 and 2
- Applying a consistent Ss of 1.5 x 10^{-5} in Layer 2.

Baseline scenario 1B was used. Table 7.17 summarises the variations of important model outputs as a response to the changes of the listed parameters. It can be seen that:

- drawdown in landholder bores appears to be most sensitive towards changes to the hydraulic conductivity
- fluxes in and out of Namoi River appears to be most sensitive towards recharge and river cell conductance
- applying a lower than calibrated specific storage regionally in layer 2 increases the effects on landholder bores by some 10% and reduces the river discharge by some 15%.

Table 7-17 Sensitivity analysis summary

	Units	Baseline	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
Parameter			Kh and Kv -25%	Kh and Kv +25%	Rech -25%	Rech +25%	Riv Cond -50%	Riv Cond+50%	Constant Ss (1.5 x 10^{-5})
SRMS (transient)		0.014	0.03	0.017	0.021	0.017	0.014	0.016	0.015
Residual Mean	m	0.12	0.03	0.03	0.38	-0.07	-0.07	0.17	0.09
SS Rech	ML/day	8,707	8,707	8,707	6,530	10,883	8,707	8,707	8,707
SS Riv In	ML/day	210	184	226	267	163	247	244	184
SS Riv Out	ML/day	2,735	2,650	2,798	2,048	3,410	2,210	2,978	2,650
SS GHB In	ML/day	20,605	16,159	24,822	21,187	20,077	20,448	20,680	16,159
SS GHB Out	ML/day	20,788	16,344	24,967	19,948	21,641	21,091	20,655	16,344
Landholder bores DD>2m		20	28	17	23	20	27	20	22
Landholder bores sum of max DD	m	90.22	111.19	76	101.5	88.24	107	85.64	101.06

	Units	Baseline	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
Average Riv Out	ML/day	549	535	674	334	913	462	662	572
Average Riv In	ML/day		1,104	926	1,333	783	690	1,250	930

Note: landholder bores mentioned in Table 7.16 refer to all registered active, non active or decommissioned bores/ wells.

7.12 Model limitations and assumptions

Numerical groundwater models represent an approximation or simplification of interacting natural systems. It is generally accepted that no single 'true' model replicates all the systems and therefore models are constructed to address specific management objectives. As a consequence model predictions are subject to uncertainty which arise from a number of sources, including (Barnett et al., 2012):

- Error and/or paucity in field measurements.
- Failure to capture the important details in the natural system, or incorrect conceptualisation of parts of the system.
- Inability to provide accurate parameterisation across the model domain (uncertainty in parameters).

These limitations are common to all numerical groundwater models. More specifically, the following limitations should be noted in relation to this model:

- the productive alluvial aquifer consists of one layer (Layer 2), not incorporating smaller scale geological and hydrogeological features such as clay lenses
- Unmetered groundwater take for stock and domestic, irrigation or other purpose was not included
- upward leakage from the Volcanics is limited due to a low hydraulic conductivity, no faults or other structures have been included which would have the potential to increase upward leakage
- no seasonality for evapotranspiration was incorporated as this parameter is insensitive
- it was assumed that landholder bores are all screened in layer 2. In the absence of reliable data this approach is considered conservative
- for predictive purposes, steady state calibrated recharge, evapotranspiration rates and river stages were applied to all stress periods neglecting seasonality for these parameters to arrive at likely drawdowns caused by the project abstraction only

The model relies on data collected from a finite number of locations over a discrete time interval. Due to natural geological and climatic variations, there is significant uncertainty regarding the properties of the groundwater system in locations where data have not been collected and under conditions not encountered during the monitoring period.

8. Summary

8.1 Model Results

The following points concerning potential drawdown impacts from the modelling assessment are noted:

- The model results are based on the LOM drawdown in the borefield and assume continuous pumping from active bores. The model results are therefore conservative.
- Estimated total drawdown at each bore, which includes pumping and interference from other active pumping bores, was calculated from the MODFLOW cell drawdown values. Bores that experience over 50% reduction in available drawdown occur within B scenarios of extended dry conditions and include Daisymede bore and the contingency bore, Heathcliffe.
- For average weather conditions (A-scenarios), the number of active landholder bores, at which more than 2m drawdown is predicted, is limited to 2 bores on the Cooboobindi and Roma properties. The maximum drawdown can be observed at the end of pumping in year 17.
- For extended dry periods (B-scenarios), pumping rates are assumed to be higher and recharge lower. For these scenarios, 20 registered landholder bores or wells would experience a drawdown between 2 and 5 m. Some of these groundwater works are predicted to become dry. However, from the recent hydrocensus, there was identified only six active (or presumed active) bores and wells, with the remaining dry, abandoned, inactive, or entitlements sold to BCOPL.
- Five shallow active bores or wells are predicted to receive less than 2m drawdown and will be adversely affected due to the limited depth of the water column for both A and B scenarios; in some instances these groundwater supplies are predicted to dry up. These groundwater works are located on the Brighton, Glenhope, Billabong and Nardeeneen properties.
- For A and B scenarios the drawdown is projected to intersect the Namoi River. Estimated loss of baseflow into the river is calculated as reaching approximately 975 ML/yr in years 15 - 17 for 1A scenario and 1133 ML/yr in 1B scenario during the extended dry period. This follows the assumption that the river is hydraulically well-connected to the aquifer. Under average conditions, this loss of river flow equates to less than 0.2% of the average annual flow in the Namoi River. Under the dry condition scenario, the river loss equates to less than 0.9% of the 10th percentile average annual flow in the Namoi River.
- Previous modelled cumulative drawdown impact assessments of mine void development at the Boggabri, Tarrawonga and Maules Creek coal operations show drawdown extending into the alluvium at the base of the foothills east to northeast of the borefield. The more conservative cumulative modelling outcomes (AGE, 2011) provide 1m drawdown contour after 21 years extending to within 500m to 1000m of the Victoria Park, Belleview and Daisymede bores. These production bores are therefore likely to experience minor drawdown (< 1m) from mine dewatering which when compounded with borefield pumping interference is unlikely to affect the sustainability of pumping rates in these bores, with the possible exception of Daisymede bore. The contribution of long-term pumping from the borefield on cumulative drawdown impacts is estimated to be an additional 1-2m (Scenarios A) and 1-3m (Scenarios B) drawdown in the alluvium to the east and northeast of the borefield where mine cumulative drawdown is experienced.

8.2 Mitigation measures

If extraction from the operating borefield indicates possible impacts to the groundwater resource an independent review of the impact will be undertaken. This will include an investigation of aquifer groundwater level and quality trends in conjunction with rainfall data and BCOPL/neighbouring landholder pumping activities. Where neighbouring landholders show concern that their water supply maybe adversely affected by BCOPL pumping activities then the review in addition will provide an assessment of the condition of the groundwater works and historic usage.

Where impacts are identified then the following mitigation measures will be developed.

- BCOPL is to prepare an action plan to reduce the identified impact in consultation and agreement with NOW (or relevant regulator). This may include changes to pumping regime of the BCOPL borefield and modification to the groundwater monitoring program.
- If required and in accordance with the project approval, BCOPL will 'provide a compensatory water supply to any landowner whose water supply is shown to be adversely and directly impacted by the mining operations'. Compensatory works may include financial provisions, alternative water supply provisions or other 'make good' provisions.

9. Conclusions and recommendations

9.1 Conclusions

The groundwater numerical model built, calibrated and verified for this study is considered appropriate to assess possible drawdown and flow impacts from groundwater abstraction. Modelling was undertaken in accordance with the principles outlined in the Australian Modelling Guidelines and has the characteristics of a Class 2 to Class 3 model. Uncertainty of the model outputs are linked to the limitations and assumptions relating to model inputs such as future rainfall patterns and groundwater extraction for agriculture and town water supply.

Of the seven bores within the borefield, three bores (Cooboobindi, Victoria Park and Daisymede) are intended to be used for production and the remaining four bores (Roma, Heathcliffe, Belleview 1 and Belleview 2) are for contingency. The usage of contingency bores in some model simulations was optimised to minimise interference effects between operating production bores. The Daisymede production bore is located approximately 1.2 km from the Cooboobindi bore. Model results suggest that interference drawdown from the Cooboobindi bore may limit achievable pumping rate of the Daisymede bore during extended dry periods. These drawdown results are for bores operating continuously 24 hours a day. Realistically bore pumping may be stopped at times due to filling of site storages at the mine or maintenance and this will allow time for water levels to recover.

During average weather conditions, demand from the mine will require approximately 5.7 ML/day from the borefield with the remaining water derived from surface water sources. Drawdown impact of greater than 2 m over Life of Mine occurs at two active landholder bores within 1 km of Cooboobindi or Daisymede production bores. The 1m drawdown extends generally up to 2 to 3km south and west of the production bores and over 3km to the north and east where the aquifer narrows in thickness and is bounded by Boggabri Volcanics.

During an extended dry period, mine operations are estimated to require approximately 9.4 ML/day from the borefield, assuming that no water will be available from surface water sources. Under this scenario, drawdown at landholder bores is more extensive with the predicted 2m drawdown margin extending over 2km from the production bores. In this instance modelling indicates that drawdown will exceed 2 m at six active (or presumed active) bores and wells during Life of Mine.

The minimal impact consideration threshold of 2m drawdown as provided in the NOW Aquifer Interference policy is not adequate when considering adverse effects to shallow bores and concrete lined wells with limited available drawdown. Modelling identifies five shallow wells or bores on neighbouring properties which may become dry despite predicted groundwater drawdown being less than 2m for average weather conditions or extended dry periods.

The model results indicate that operating the borefield will likely affect groundwater discharge to the Namoi River. The calculated loss of baseflow is relatively low compared to average flow in the Namoi River at less than 0.2% for average flow conditions and less than 0.9% for low Namoi flow conditions (10% percentile).

The water table of the alluvial plain is typically greater than 2m depth and therefore unlikely to support stands of groundwater dependant vegetation along ephemeral streams. The Water Sharing Plan for the Upper and Lower Namoi Groundwater Sources identified there are no high priority groundwater dependent ecosystems. A BOM desktop assessment shows some areas on the alluvium plain and along the Namoi River, which have low to moderate potential for vegetation reliant on subsurface groundwater. These areas comprise River Red Gum open forest, Pilliga Box – Poplar Box – White Cypress Pine grassy open woodland and

Plains Grassland communities. Grassland communities have been identified as obtaining water from perched systems and the River Red Gum communities obtain water source from their deep extensive taproot system from both groundwater and Namoi River associated source. Abstraction from the borefield is unlikely to affect the perched systems due to disconnect with underlying alluvial aquifer.

The watertable of the alluvial plain is typically greater than 2m depth and therefore unlikely to support stands of groundwater dependant vegetation along ephemeral streams. The Water Sharing Plan for the Upper and Lower Namoi Groundwater Sources identified there are no high priority groundwater dependent ecosystems. A BOM desktop assessment shows some areas on the alluvium plain and along the Namoi River, which have low to moderate potential for vegetation reliant on subsurface groundwater. These areas comprise River Red Gum open forest, Pilliga Box – Poplar Box – White Cypress Pine grassy open woodland and Plains Grassland communities. Grassland communities have been identified as obtaining water from perched systems and the River Red Gum communities obtain water source from their deep extensive taproot system from both groundwater and Namoi River associated source. Abstraction from the borefield is unlikely to affect the perched systems due to disconnect with underlying alluvial aquifer and the River Red Gum communities due to their deep extensive taproots and associated reliance on the Namoi River.

The Victoria Park, Belleview and Daisymede bores may experience minor drawdown (<1m) from mine dewatering over the longterm (as predicted from cumulative mine impacts modelling) which when compounded with borefield pumping interference is unlikely to affect the sustainability of pumping rates in these bores, with the possible exception of Daisymede bore.

9.2 Assessment of impact against the Aquifer Interference Policy

The alluvial aquifer is categorised as a highly productive alluvial groundwater source according to criteria in the AIP. The following section provides an assessment of potential impacts and risk consideration of aquifer interference activities.

Neighbouring user groundwater supply works

The modelling predictions indicate that bores and wells on neighbouring properties will experience groundwater drawdown exceeding the 2m decline threshold as a minimal impact consideration in the AIP. The number of landholder groundwater supply works impacted will increase during extended dry conditions when the borefield is pumping at higher rate up to 9.4 ML/d.

A number of shallow wells and bores will receive less than 2m drawdown. However, supplies will be adversely affected due to the limited depth of the water column, and in some instances these groundwater supplies are predicted to dry up.

Appropriate arrangements will need to be made to mitigate these impacts.

Groundwater dependant ecosystems

The water table of the alluvial plain is typically greater than 2m depth and therefore unlikely to support stands of groundwater dependant vegetation along ephemeral streams. Vegetation communities along streams are disturbed by nearby clearing and farming activities. A review of the GDE Atlas recently compiled by the Bureau of Meteorology (2015) indicates that within the study area, the only groundwater dependant ecosystems which are potentially reliant on groundwater are restricted to the channel of Namoi River and floodplain south of Heathcliffe bore. These areas comprise River Red Gum open forest, Pilliga Box – Poplar Box – White Cypress Pine grassy open woodland and Plains Grassland communities. These vegetation communities are not considered to be high priority GDEs as they are not entirely reliant upon subsurface groundwater, for their water requirements. Grassland communities have been identified as obtaining water from perched systems and the River Red Gum communities obtain water source from their deep extensive taproot system from both groundwater and Namoi River associated source.

The operation of the borefield is therefore considered to have a low risk to groundwater dependant ecosystems.

Surface water – groundwater interaction

Drawdown due to pumping is likely to lead to a reduction in net groundwater discharge to the Namoi River (baseflow) under both normal and extended dry conditions simulations, assuming the river is hydraulically well-connected to the aquifer. According to the NSW Aquifer Interference Policy, any induced net loss from a surface water source is considered to be an indirect take from that surface water source and needs to be accounted for by relevant water access licences. BCOPL has existing WALs for the Namoi River and where necessary will obtain further WALs to cover licensing shortfall for the quantity of take from the River.

Multi-aquifer interference

The alluvial aquifer comprises gravel-sand channel deposits with variability in thickness across the region, and overlies the Boggabri Volcanics, which is of low permeability and considered an aquitard. There is minimal risk of deterioration in alluvial aquifer water chemistry from basement leakage due to the low permeability of the rock.

High priority culturally significant site

No high priority culturally significant sites in the region will be impacted by drawdown from borefield operations.

Baseline groundwater conditions

The risk of impacts to neighbouring user water supplies is identified as high and the requirement for baseline information is high as a consideration under the AIP. A hydrocensus was conducted on neighbouring user groundwater supplies in March – May 2015 and information was collected of water level, water quality, usage and condition of groundwater works. Some hydrocensus information was not available due to landholder unavailability or inaccessibility of bore headworks during site inspection. A follow up survey is needed.to obtain groundwater information from landholder water supply works identified as potentially being impacted. This includes:

- groundwater works where information was not available during the initial hydrocensus.
- collection of additional groundwater level data to account for seasonal variations in water levels from natural changes or invoked due to regional landholder irrigation pumping regimes.

Baseline groundwater levels, flows and quality at production and contingency bore sites have been obtained during bore construction and test pumping.

Groundwater levels of NOW monitoring bores from 2004 onwards were used to calibrate the groundwater model and provide baseline conditions of natural seasonal variations and response to water user activity.

9.3 Recommendations

Recommendation for Aquifer Resource Management

- Revise the groundwater management plan for the Boggabri Coal Operations to include the alluvial borefield region in consultation with NSW Office of Water. This includes the development of a groundwater monitoring program for on-going assessment of the impact from the borefield operations on the alluvial aquifer resource, surface water bodies and regional users.

- At a minimum, groundwater monitoring should take place at existing BCOPL bores in the borefield region (refer to Table 9.1); select landholder bores and additional monitoring locations where required. Metering of water take from production bores will be necessary. Monitoring data from NOW monitoring bores in the region will also be used to inform the assessment.

Table 9-1 BCOPL bores recommended in the monitoring program

Bore ID	Easting (MGA94)	Northing (MGA94)	Comment
BCOPL production and contingency bores			
Cooboobindi PB	217917	6606240	
Victoria Park PB (VP02)	221961	6605011	
Daisymede PB (DM1)	217880	6607431	
Roma CB	218612	6605874	
Belleview 1 CB (BCBF8)	218884	6607055	
Belleview 2 CB (BCBF10)	219408	6607016	
Heathcliffe CB (HC01)	216209	6608260	
BCOPL monitoring bores			
Cooboobindi MB	217939	6606232	Located adjacent Cooboobinidi PB
Victoria Park MB (VP01)	216204	6608210	Located adjacent Victoria Park PB
Daisymede MB	217853	6607430	Located adjacent Daisymede PB
Roma MB	218632	6605872	
Belleview 3 MB (BCBF3)	218868	6606990	Monitor bore for Belleview 1 CB
Belleview 11 MB (BCBF11)	219403	6606954	Monitor bore for Belleview 2 CB
Heathcliffe MB (HC02)	221950	6605014	

Note: PB is Production Bore; CB = Contingency Bore

- The frequency of monitoring is nominally 3 monthly monitoring of groundwater levels and yearly sampling for water quality analysis, with the exception of more regular monitoring of physio-chemical parameters from operating pumping bores. To capture short term events of water level variations such as response to rainfall recharge or regional user pumping events it is recommended that automated water level loggers are installed in select bores.
- The data collected from the monitoring program will be used to validate modelling predictions of drawdown trends from pumping. If measured drawdown responses deviate significantly from modelled predicted outcomes then it is recommended that the model is recalibrated using transient water level data from borefield pumping operations to provide revised predictive drawdown outputs.
- The monitoring data will be used to assess if water supply from landholder bores has been adversely affected to support compensation claims.
- A trigger action response plan is recommended to provide trigger thresholds for water level and quality exceedences at monitoring points and the management procedures including investigation, where applicable.

- Trends in the groundwater level and water quality monitoring data for the alluvial aquifer should be assessed periodically and presented in the annual environmental management review.

Recommendations for pumping bores

- Groundwater levels within pumping bores are to be monitored during borefield operations and assessed against reported sustainable levels. This is particularly important to evaluate interference effects from pumping multiple bores in the region, and in particular, the Daisymede production bore and contingency bore Heathcliffe when operating. These bores are located near the boundary of the alluvial aquifer and are constrained by aquifer boundary and aquifer depth and thickness.

10. References

AGE 2010, Continuation of Boggabri Coal Mine groundwater assessment, prepared for Boggabri Coal Pty Limited, dated October 2010.

AGE, 2011. Maules Creek Coal Project. Groundwater Impact Assessment, prepared for Aston Resources Limited, dated June 2011.

Anderson, M.P. and Woessner, W.M., 1992. Applied groundwater modelling. Academic Press, Inc., San Diego, California, 381 pp.

Andrew Fulton Groundwater Exploration Services Pty Ltd (AFGES) 2013, Boggabri Coal Groundwater Supply Investigation, report prepared for boggabri Coal Pty Ltd, Dated March 2013.

Barnett, B., L. R. Townley, et al. 2012. Australian groundwater modelling guidelines. Waterlines Report Series, National Water Commission. 82: 191.

Barrett C., 2010 Upper Namoi Groundwater Sources Resource condition assessment report (December, 2010, NSW Office of Water, Sydney.

Barrett C, 2012. Upper Namoi Groundwater Source – Status Report 2011, NSW Office of Water, Sydney.

Bureau of Meteorology 2012, Groundwater dependent ecosystems atlas, 18/06/15, http://www.bom.gov.au/water/groundwater/gde/index.shtml

CSIRO, 2007. "Water availability in the Namoi – A Report to the Australian Government from the CSIRO Murray Darling Commission Sustainable Yields Project".

Davies, N. 1953. Investigations on the soil and water relations of the river red gum forests. Final Report Murray Management Survey. Forestry Commission of New South Wales, Resources Branch Report No. R.124.

Department of Land and Water Conservation 2002, The NSW State Groundwater Dependent Ecosystem Policy, Department of Land and Water Conservation, Sydney.

Department of Primary Industries – Office of Water 2012, NSW Aquifer Interference Policy, NSW Government policy for the licensing and assessment of aquifer interference

Doherty, J., 2003. Groundwater model calibration using pilot points and regularisation. Ground Water. 41 (2): 170-177.

Eamus, D, Froend, R, Loomes, R, Hose, G & Murray, B 2006, 'A functional methodology for determining the groundwater regime needed to maintain the health of groundwater-dependent vegetation', Australian Journal of Botany, vol. 24, pp. 97–114.

Geoscience Australia 2011, 1 second SRTM Derived Digital Elevation Models (DEM, DEM-S, DEM-H) Version 1.0.

Hatton, T. & Evans, R. 1998, Dependence of ecosystems on groundwater and its significance to Australia, Land and Water Resources Research and Development Corporation, Canberra.

Heritage Computing 2012a, A hydrogeological assessment in support of the Tarrawonga Coal Project Environmental Assessment, Report No.: HC2011/11, prepared for Tarrawonga Coal Pty Ltd, dated January 2012.

Heritage Computing 2012b, Cumulative groundwater management protocol for Boggabri coal mine, Tarrawonga coal mine and Maules Creek coal project, Report No HC2011/15, prepared for Boggabri Coal Pty Ltd, Tarrawonga Coal Pty Ltd, Aston Resources Ltd, dated September 2012.

McDonald, M.G., Harbaugh, A.W. 1988 A modular three-dimensional finite-difference ground-water flow model: Techniques of Water-Resources Investigations of the United States Geological Survey, Book 6, Chapter A1, 586 p.

NSW Department of Land and Water Conservation. 1998. Aquifer Risk Assessment Report. NSW Department of Land and Water Conservation, Sydney.

NSW Office of Water (NOW) 2012, NSW aquifer Interference policy. Department of Primary Industries, dated September 2012.

NSW Government, 2003, *Water Sharing Plan for the Upper and Lower Namoi Groundwater Sources 2003,* http://www.legislation.nsw.gov.au/viewtop/inforce/subordleg+1035+2002+FIRST+0+N/

Panday, S., C. D. Langevin, et al. 2013. MODFLOW–USG Version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation, U.S. Geological Survey.

Parsons Brinckerhoff 2010, Boggabri Coal Mine hydrogeological investigation, report prepared for Boggabri Coal Pty Ltd, report no. 2123229A PR_5388, dated November 2010.

Parsons Brinckerhoff 2010a, Continuation of Boggabri Coal Mine – Biodiversity impact Assessment, report no: - 2118933A PR_1331 Rev F dated October 2010

Parsons Brinckerhoff 2014, Surface Water management Plan prepared for Boggabri Coal Pty Ltd., report no 2172723B Rev5, dated February 2014.

Parsons Brinckerhoff 2015a, Site Water Balance prepared for Boggabri Coal Pty Ltd., report no. 2200552A Rev6, dated June 2015.

Parsons Brinckerhoff 2015b, Test pumping assessment of Roma and Cooboobindi production bores, prepared for Boggabri Coal Pty Ltd., report no. 2200550A-WAT-REP-02 RevB, dated 17 June 2015.

Parsons Brinckerhoff 2015c, Test pumping assessment of Victoria Park and Heathcliffe production bores, prepared for Boggabri Coal Pty Ltd., report no. 2200550A-REP RevA, dated 29 January 2015.

Parsons Brinckerhoff 2015d, Landholder bore hydrocensus at Boggabri Coal Operations., report no. 2200553A-WAT-REP RevA, Draft, dated 16 June 2015.

Pratt, W. 1998, Gunnedah Coalfield (North) Regional Geology 1:100,000, First edition, Geological Survey of New South Wales, Sydney.

Thiem, G., 1906. Hydrologische Methoden. Gebhardt, Leipzig, Germany, 56 pp.

Appendix A Model classification

Table 2-1: Model confidence level classification—characteristics and indicators

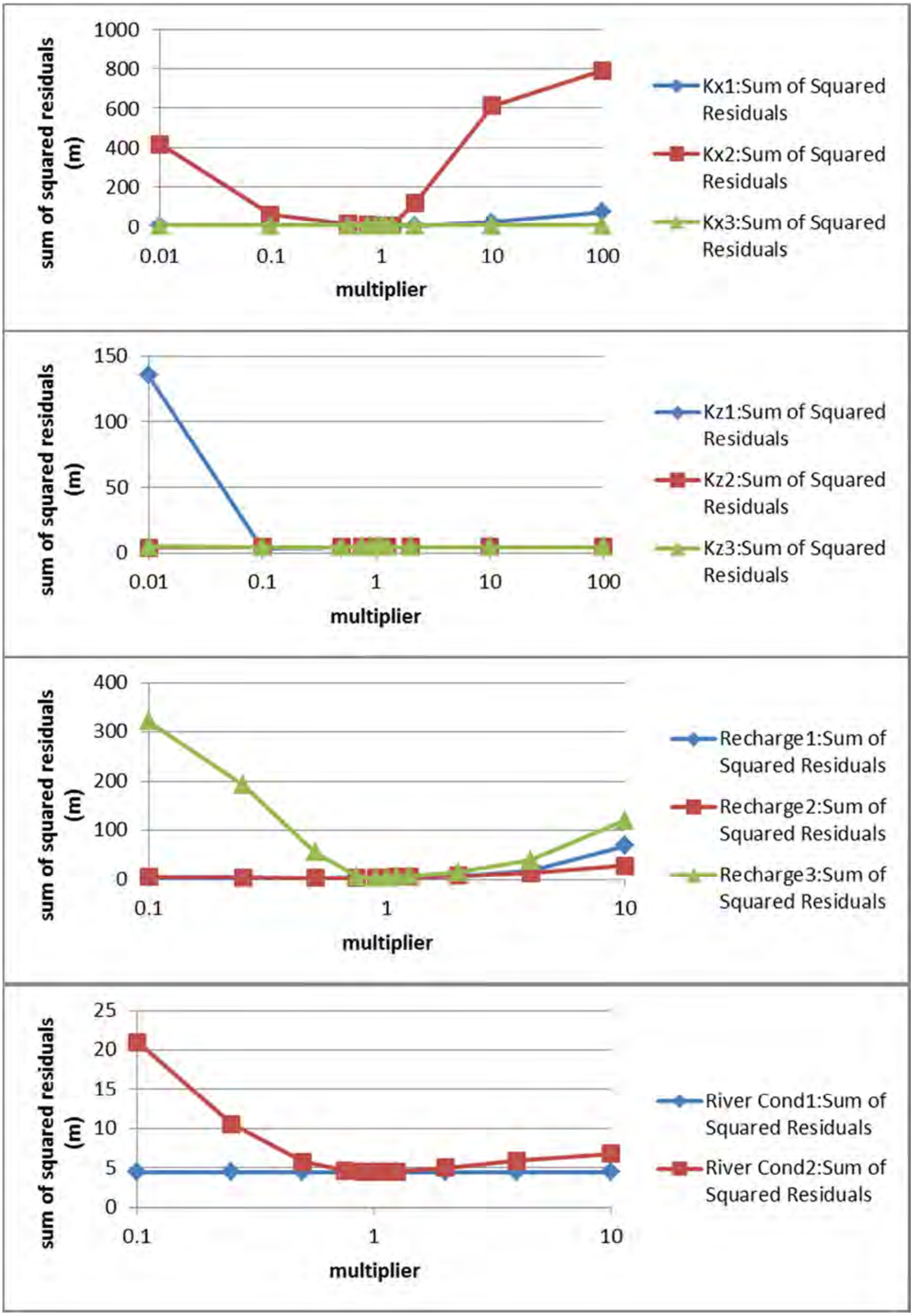
Confidence level classification	*Data*	*Calibration*	*Prediction*	*Key indicator*	*Examples of specific uses*
Class 3	• Spatial and temporal distribution of groundwater head observations adequately define groundwater behaviour, especially in areas of greatest interest and where outcomes are to be reported. • Spatial distribution of bore logs and associated stratigraphic interpretations clearly define aquifer geometry. • Reliable metered groundwater extraction and injection data is available. • Rainfall and evaporation data is available. • Aquifer-testing data to define key parameters. • Streamflow and stage measurements are available with reliable baseflow estimates at a number of points. • Reliable land-use and soil-mapping data available. • Reliable irrigation application data (where relevant) is available. • Good quality and adequate spatial coverage of digital elevation model to define ground surface elevation.	• Adequate validation* is demonstrated. • Scaled RMS error (refer Chapter 5) or other calibration statistics are acceptable. • Long-term trends are adequately replicated where these are important. • Seasonal fluctuations are adequately replicated where these are important. • Transient calibration is current, i.e. uses recent data. • Model is calibrated to heads and fluxes. • Observations of the key modelling outcomes dataset is used in calibration.	• Length of predictive model is not excessive compared to length of calibration period. • Temporal discretisation used in the predictive model is consistent with the transient calibration. • Level and type of stresses included in the predictive model are within the range of those used in the transient calibration. • Model validation* suggests calibration is appropriate for locations and/or times outside the calibration model. • Steady-state predictions used when the model is calibrated in steady-state only.	• Key calibration statistics are acceptable and meet agreed targets. • Model predictive time frame is less than 3 times the duration of transient calibration. • Stresses are not more than 2 times greater than those included in calibration. • Temporal discretisation in predictive model is the same as that used in calibration. • Mass balance closure error is less than 0.5% of total. • Model parameters consistent with conceptualisation. • Appropriate computational methods used with appropriate spatial discretisation to model the problem. • The model has been reviewed and deemed fit for purpose by an experienced, independent hydrogeologist with modelling experience.	• Suitable for predicting groundwater responses to arbitrary changes in applied stress or hydrological conditions anywhere within the model domain. • Provide information for sustainable yield assessments for high-value regional aquifer systems. • Evaluation and management of potentially high-risk impacts. • Can be used to design complex mine-dewatering schemes, salt-interception schemes or water-allocation plans. • Simulating the interaction between groundwater and surface water bodies to a level of reliability required for dynamic linkage to surface water models. • Assessment of complex, large-scale solute transport processes.
Class 2 *Cont'd overleaf*	• Groundwater head observations and bore logs are available but may not provide adequate coverage throughout the model domain.	• Validation* is either not undertaken or is not demonstrated for the full model domain. • Calibration statistics are generally reasonable but may suggest significant errors in parts of the	• Transient calibration over a short time frame compared to that of prediction. • Temporal discretisation used in the predictive model is different from that used in transient	• Key calibration statistics suggest poor calibration in parts of the model domain. • Model predictive time frame is between 3 and 10 times the duration of transient calibration. • Stresses are between 2 and 5 times greater than those	• Prediction of impacts of proposed developments in medium value aquifers. • Evaluation and management of medium risk impacts.

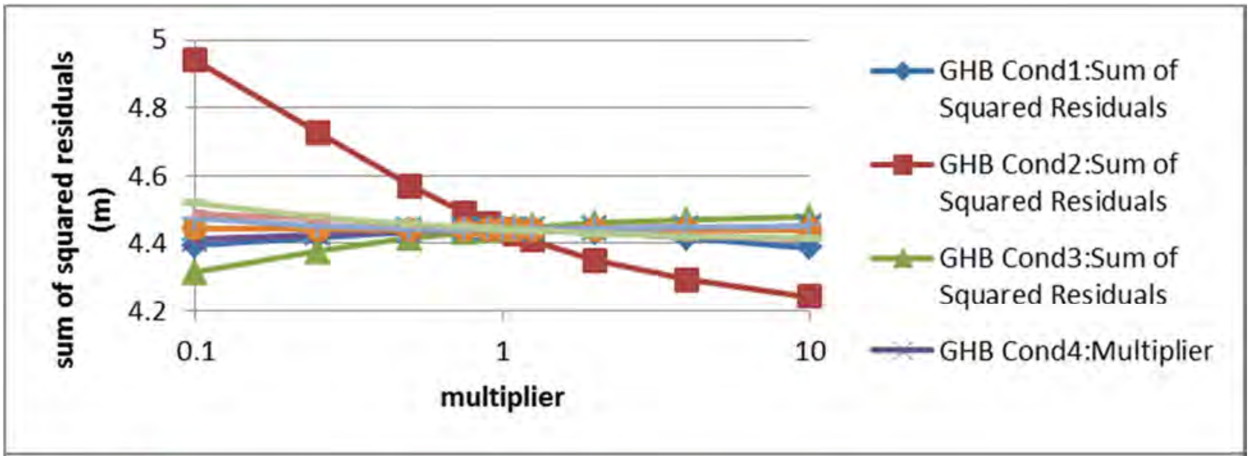
Confidence level classification	*Data*	*Calibration*	*Prediction*	*Key indicator*	*Examples of specific uses*
Class 2 *Cont'd*	• Metered groundwater-extraction data may be available but spatial and temporal coverage may not be extensive. • Streamflow data and baseflow estimates available at a few points. • Reliable irrigation-application data available in part of the area or for part of the model duration.	model domain(s). • Long-term trends not replicated in all parts of the model domain. • Transient calibration to historic data but not extending to the present day. • Seasonal fluctuations not adequately replicated in all parts of the model domain. • Observations of the key modelling outcome data set are not used in calibration.	calibration. • Level and type of stresses included in the predictive model are outside the range of those used in the transient calibration. • Validation* suggests relatively poor match to observations when calibration data is extended in time and/or space.	included in calibration. • Temporal discretisation in predictive model is not the same as that used in calibration. • Mass balance closure error is less than 1% of total. • Not all model parameters consistent with conceptualisation. • Spatial refinement too coarse in key parts of the model domain. • The model has been reviewed and deemed fit for purpose by an independent hydrogeologist.	• Providing estimates of dewatering requirements for mines and excavations and the associated impacts. • Designing groundwater management schemes such as managed aquifer recharge, salinity management schemes and infiltration basins. • Estimating distance of travel of contamination through particle-tracking methods. Defining water source protection zones.
Class 1	• Few or poorly distributed existing wells from which to obtain reliable groundwater and geological information. • Observations and measurements unavailable or sparsely distributed in areas of greatest interest. • No available records of metered groundwater extraction or injection. • Climate data only available from relatively remote locations. • Little or no useful data on land-use, soils or river flows and stage elevations.	• No calibration is possible. • Calibration illustrates unacceptable levels of error especially in key areas. • Calibration is based on an inadequate distribution of data. • Calibration only to datasets other than that required for prediction.	• Predictive model time frame far exceeds that of calibration. • Temporal discretisation is different to that of calibration. • Transient predictions are made when calibration is in steady state only. • Model validation* suggests unacceptable errors when calibration dataset is extended in time and/or space.	• Model is uncalibrated or key calibration statistics do not meet agreed targets. • Model predictive time frame is more than 10 times longer than transient calibration period. • Stresses in predictions are more than 5 times higher than those in calibration. • Stress period or calculation interval is different from that used in calibration. • Transient predictions made but calibration in steady state only. • Cumulative mass-balance closure error exceeds 1% or exceeds 5% at any given calculation time. • Model parameters outside the range expected by the conceptualisation with no further justification. • Unsuitable spatial or temporal discretisation. • The model has not been reviewed.	• Design observation bore array for pumping tests. • Predicting long-term impacts of proposed developments in low-value aquifers. • Estimating impacts of low-risk developments. • Understanding groundwater flow processes under various hypothetical conditions. • Provide first-pass estimates of extraction volumes and rates required for mine dewatering. • Developing coarse relationships between groundwater extraction locations and rates and associated impacts. • As a starting point on which to develop higher class models as more data is collected and used.

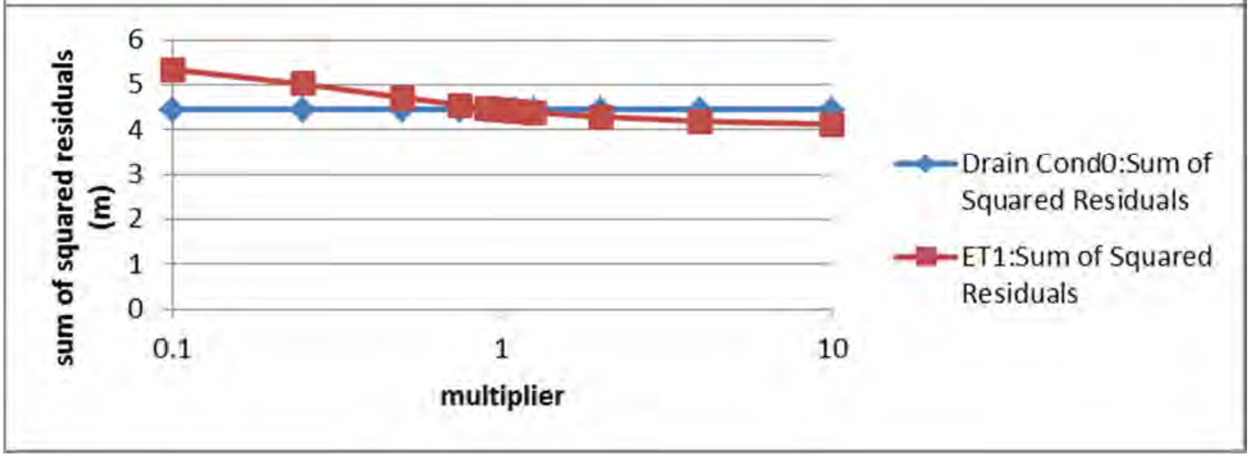
(*Refer Chapter 5 for discussion around validation as part of the calibration process.)

Appendix B

Calibration sensitivity

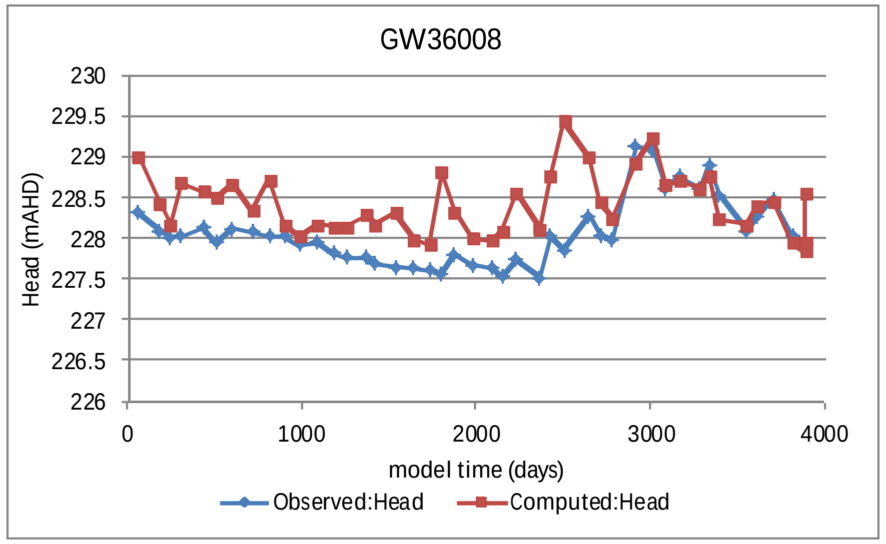

sum of squared residuals (m)
1000
800
600
400
200
0
0.01
0.1
1
10
100
multiplier
Kx1:Sum of Squared Residuals
Kx2:Sum of Squared Residuals
Kx3:Sum of Squared Residuals
sum of squared residuals (m)
150
100
50
0
0.01
0.1
1
10
100
multiplier
Kz1:Sum of Squared Residuals
Kz2:Sum of Squared Residuals
Kz3:Sum of Squared Residuals
sum of squared residuals (m)
400
300
200
100
0
0.1
1
10
multiplier
Recharge1:Sum of Squared Residuals
Recharge2:Sum of Squared Residuals
Recharge3:Sum of Squared Residuals
sum of squared residuals (m)
25
20
15
10
5
0
0.1
1
10
multiplier
River Cond1:Sum of Squared Residuals
River Cond2:Sum of Squared Residuals

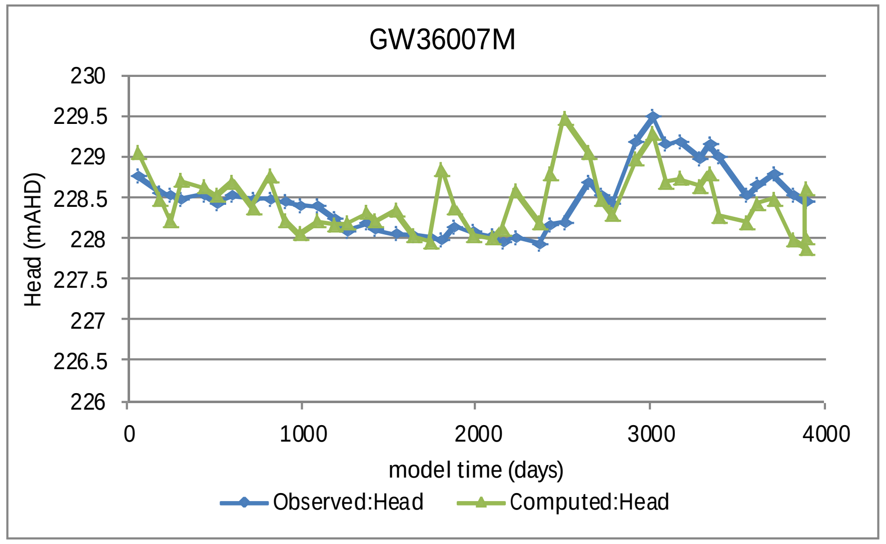

5
4.8
4.6
4.4
4.2
sum of squared residuals (m)
0.1
1
10
multiplier
GHB Cond1:Sum of Squared Residuals
GHB Cond2:Sum of Squared Residuals
GHB Cond3:Sum of Squared Residuals
GHB Cond4:Multiplier

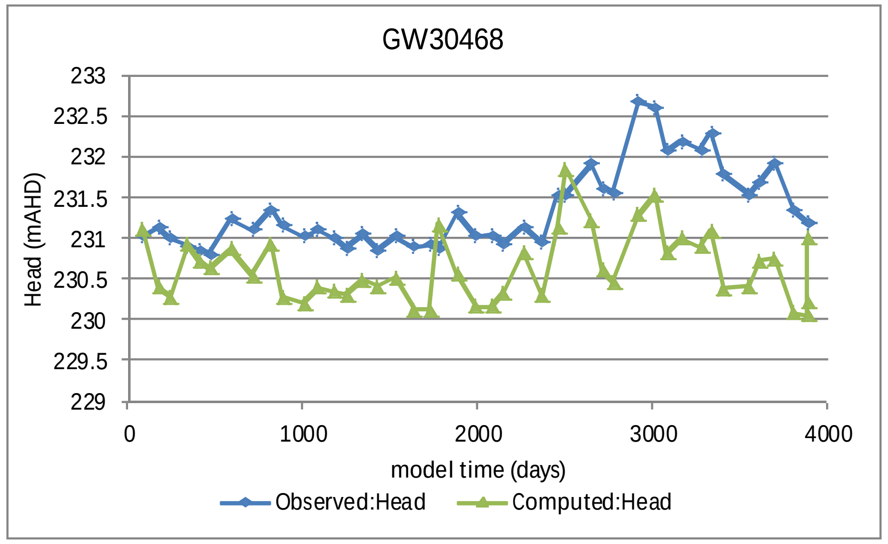

6
5
4
3
2
1
0
sum of squared residuals (m)
0.1
1
10
multiplier
Drain Cond0:Sum of Squared Residuals
ET1:Sum of Squared Residuals

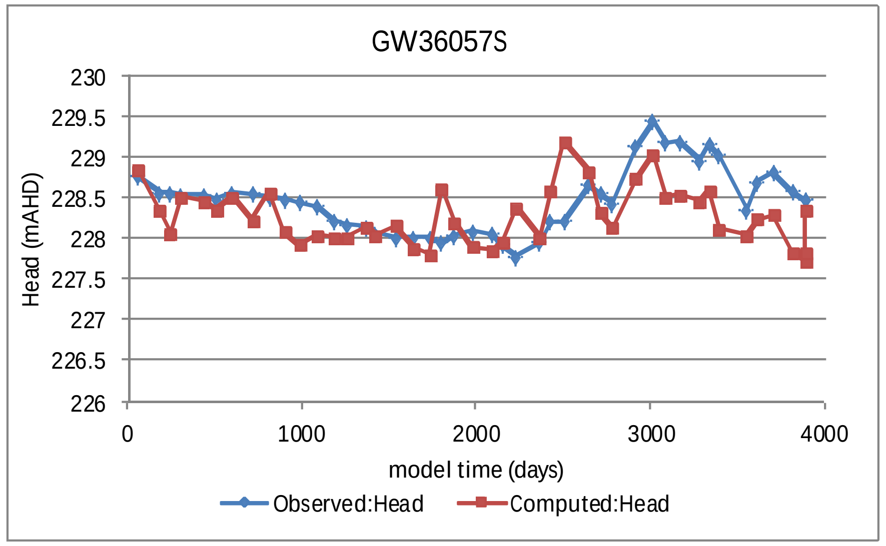
Appendix C

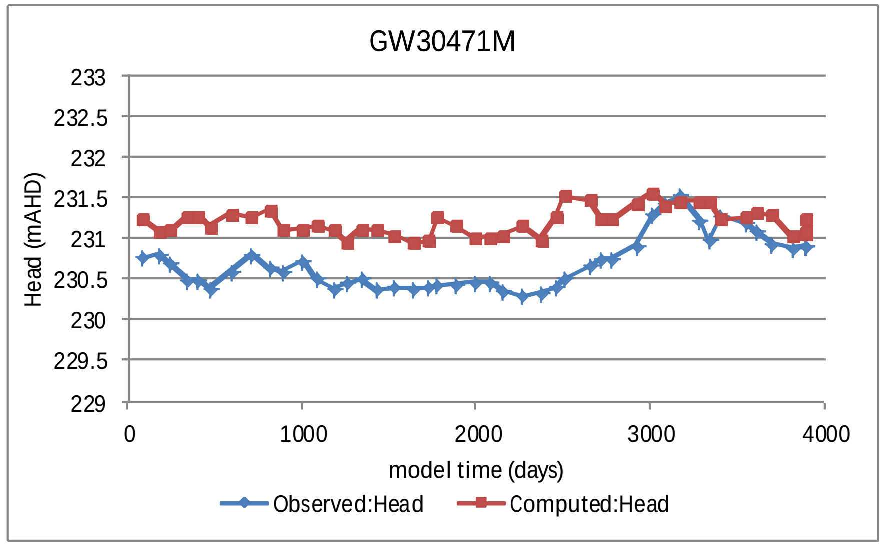
Hydrographs showing modelled and observed heads

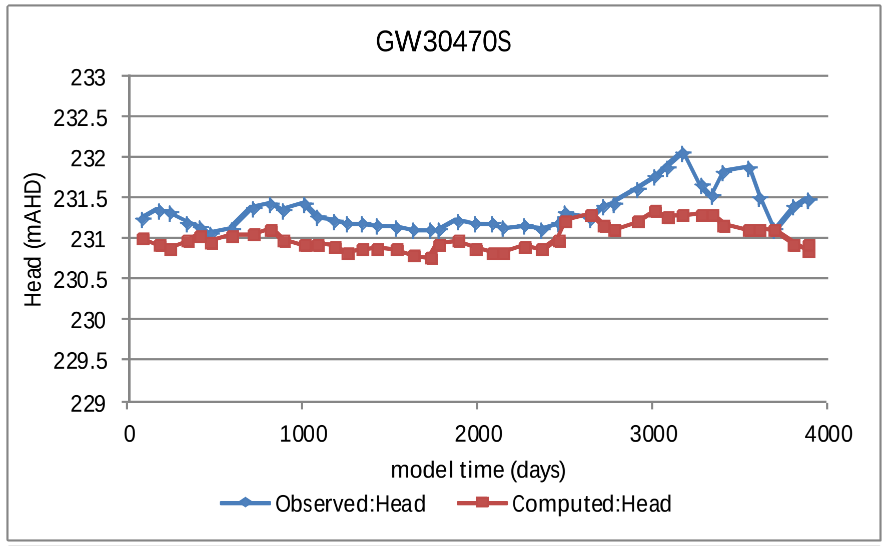

GW36008
Head (mAHD)
230
229.5
229
228.5
228
227.5
227
226.5
226
0
1000
2000
3000
4000
model time (days)
Observed:Head
Computed:Head

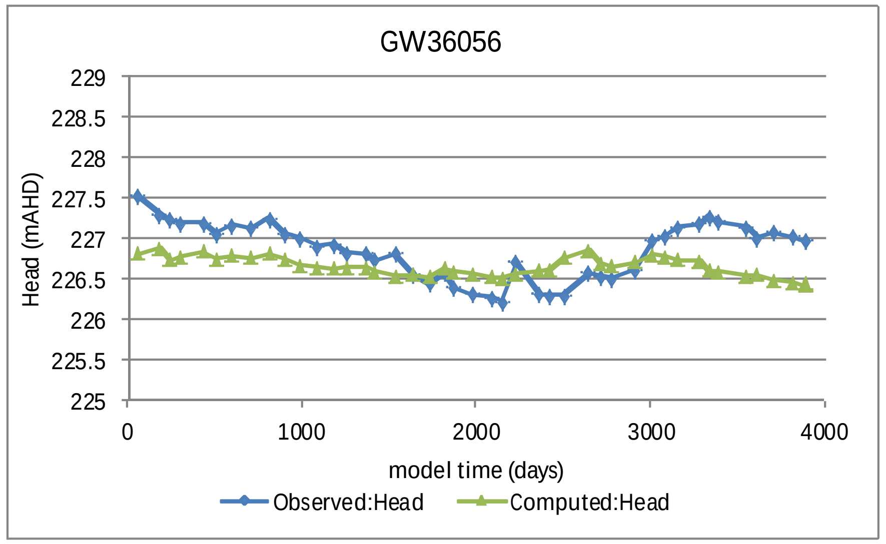

GW36007M
Head (mAHD)
230
229.5
229
228.5
228
227.5
227
226.5
226
0
1000
2000
3000
4000
model time (days)
Observed:Head
Computed:Head

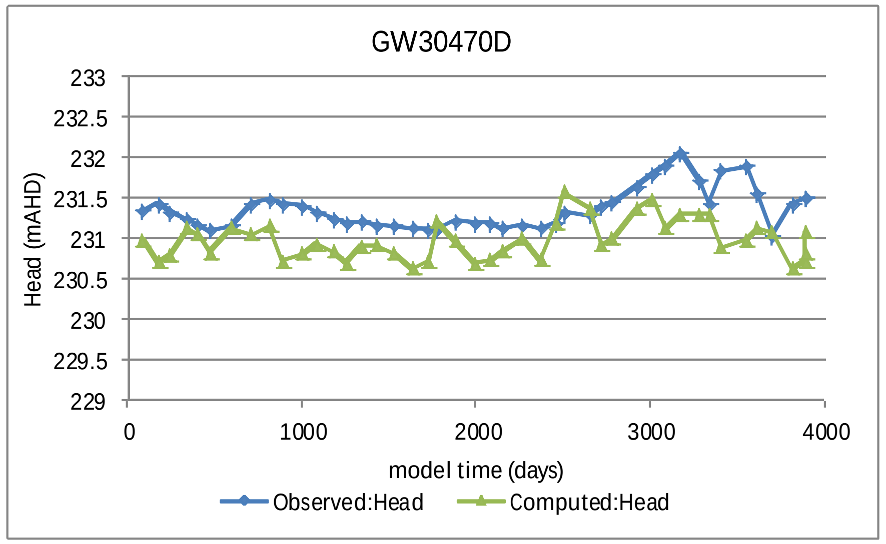

GW30468
Head (mAHD)
233
232.5
232
231.5
231
230.5
230
229.5
229
0
1000
2000
3000
4000
model time (days)
Observed:Head
Computed:Head

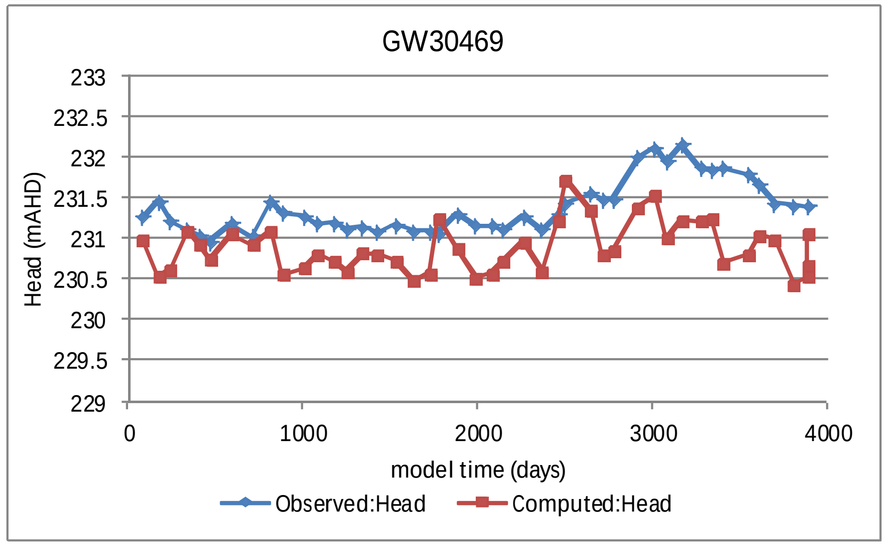

GW36057S
Head (mAHD)
230
229.5
229
228.5
228
227.5
227
226.5
226
0
1000
2000
3000
4000
model time (days)
Observed:Head
Computed:Head


GW30471M
Head (mAHD)
233
232.5
232
231.5
231
230.5
230
229.5
229
0
1000
2000
3000
4000
model time (days)
Observed:Head
Computed:Head


GW30470S
Head (mAHD)
233
232.5
232
231.5
231
230.5
230
229.5
229
0
1000
2000
3000
4000
model time (days)
Observed:Head
Computed:Head

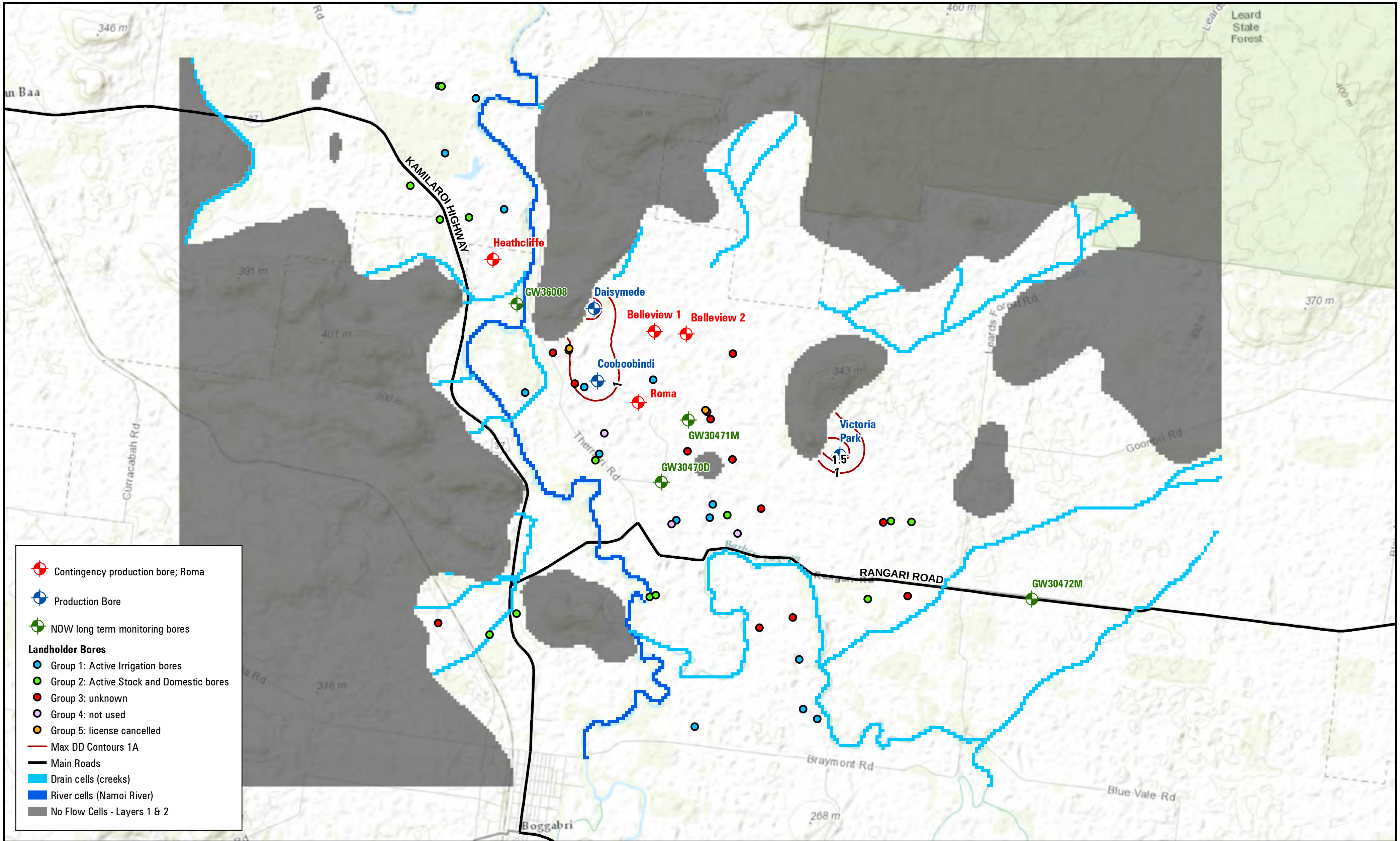

GW36056
Head (mAHD)
229
228.5
228
227.5
227
226.5
226
225.5
225
0
1000
2000
3000
4000
model time (days)
Observed:Head
Computed:Head


GW30470D
Head (mAHD)
233
232.5
232
231.5
231
230.5
230
229.5
229
0
1000
2000
3000
4000
model time (days)
Observed:Head
Computed:Head


GW30469
Head (mAHD)
233
232.5
232
231.5
231
230.5
230
229.5
229
0
1000
2000
3000
4000
model time (days)
Observed:Head
Computed:Head

Appendix D

Drawdown Plots



Map: 2200555A_GIS_016_A1_APP-D1a	Author: M Goganovski
Date: 26/08/2015	Approved by: - S Focke

Data source: -

0 750 1,500 m

1:84,000

Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A4

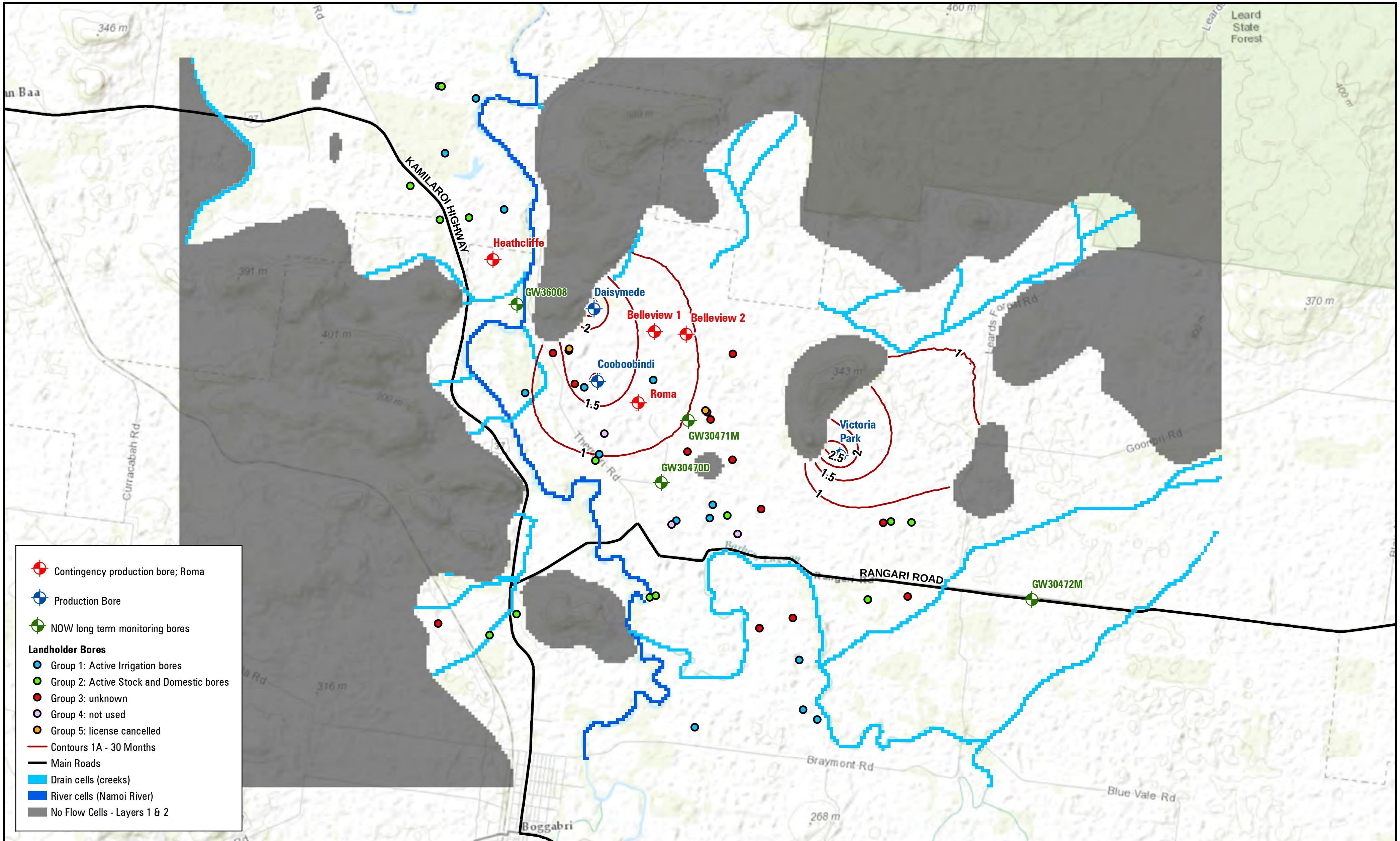
WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine

Appendix D1a

Modelled drawdown contours after 4 month – Scenario 1A

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.



Map: 2200555A_GIS_017_A1_APP-D1b	Author: M Goganovski
Date: 26/08/2015	Approved by: - S Focke

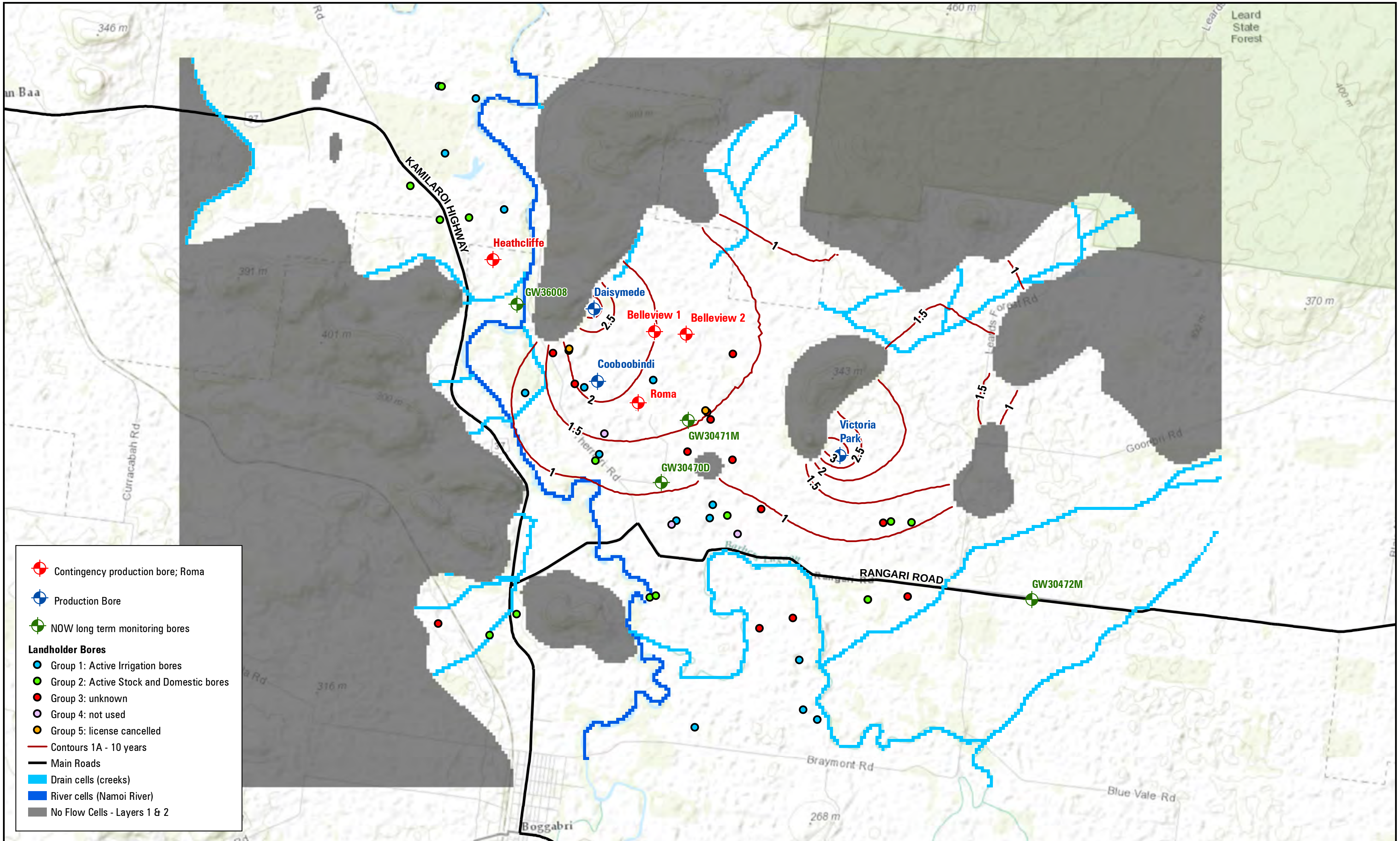
Data source: -

0 750 1,500 m
1:84,000
Coordinate system: GDA 1994 MGA Zone 56
Scale ratio correct when printed at A4

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine
Appendix D1b
Modelled drawdown contours after 30 months – Scenario 1A



Map: 2200555A_GIS_018_A1_APP-D1c | Author: M Goganovski

Date: 26/08/2015 | Approved by: - S Focke

Data source: -

0 750 1,500 m

1:84,000

Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A4

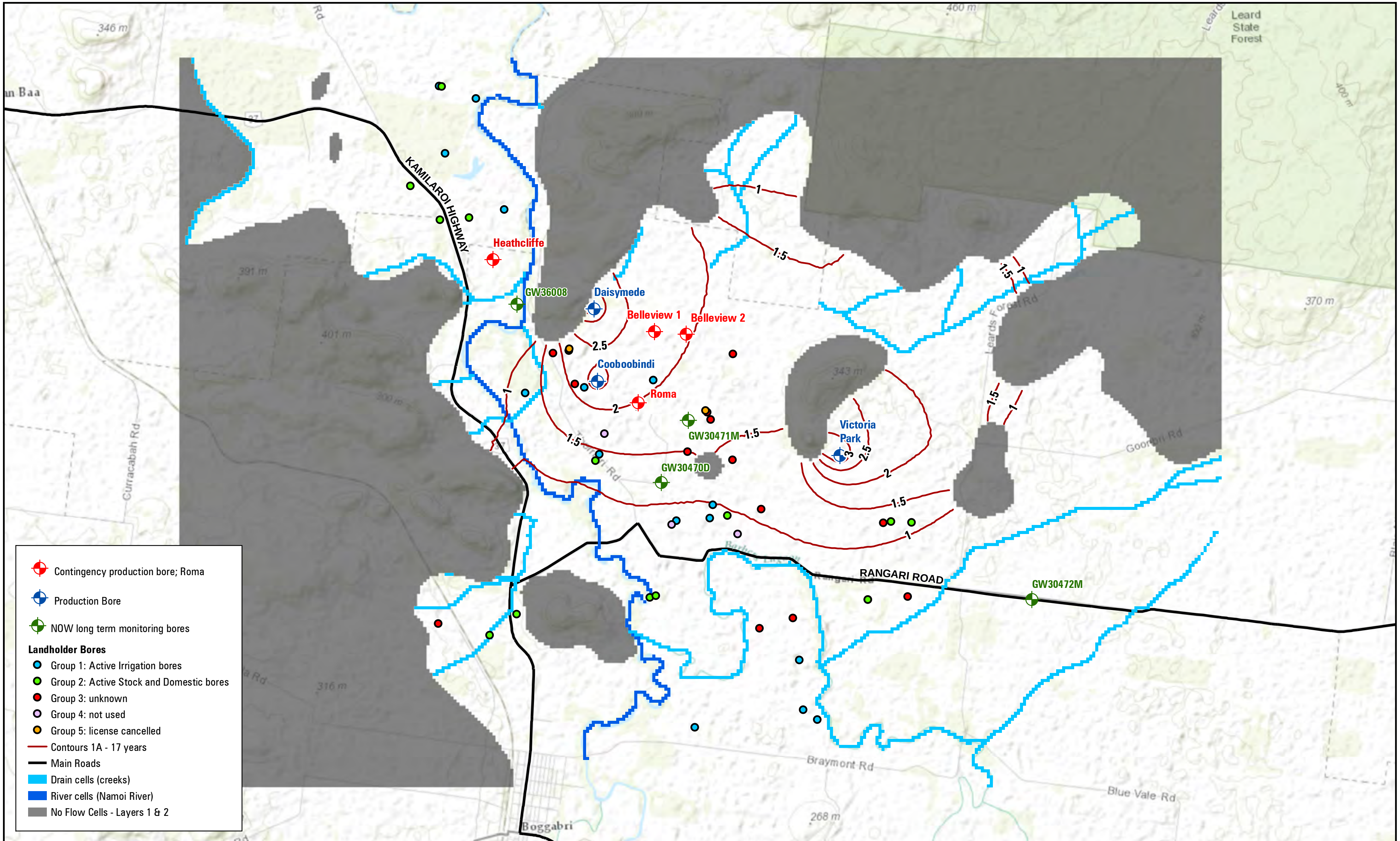
© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine

Appendix D1c

Modelled drawdown contours after 10 years – Scenario 1A



Map: 2200555A_GIS_019_A1_APP-D1d	Author: M Goganovski
Date: 26/08/2015	Approved by: - S Focke

Data source: -

0 750 1,500 m

1:84,000

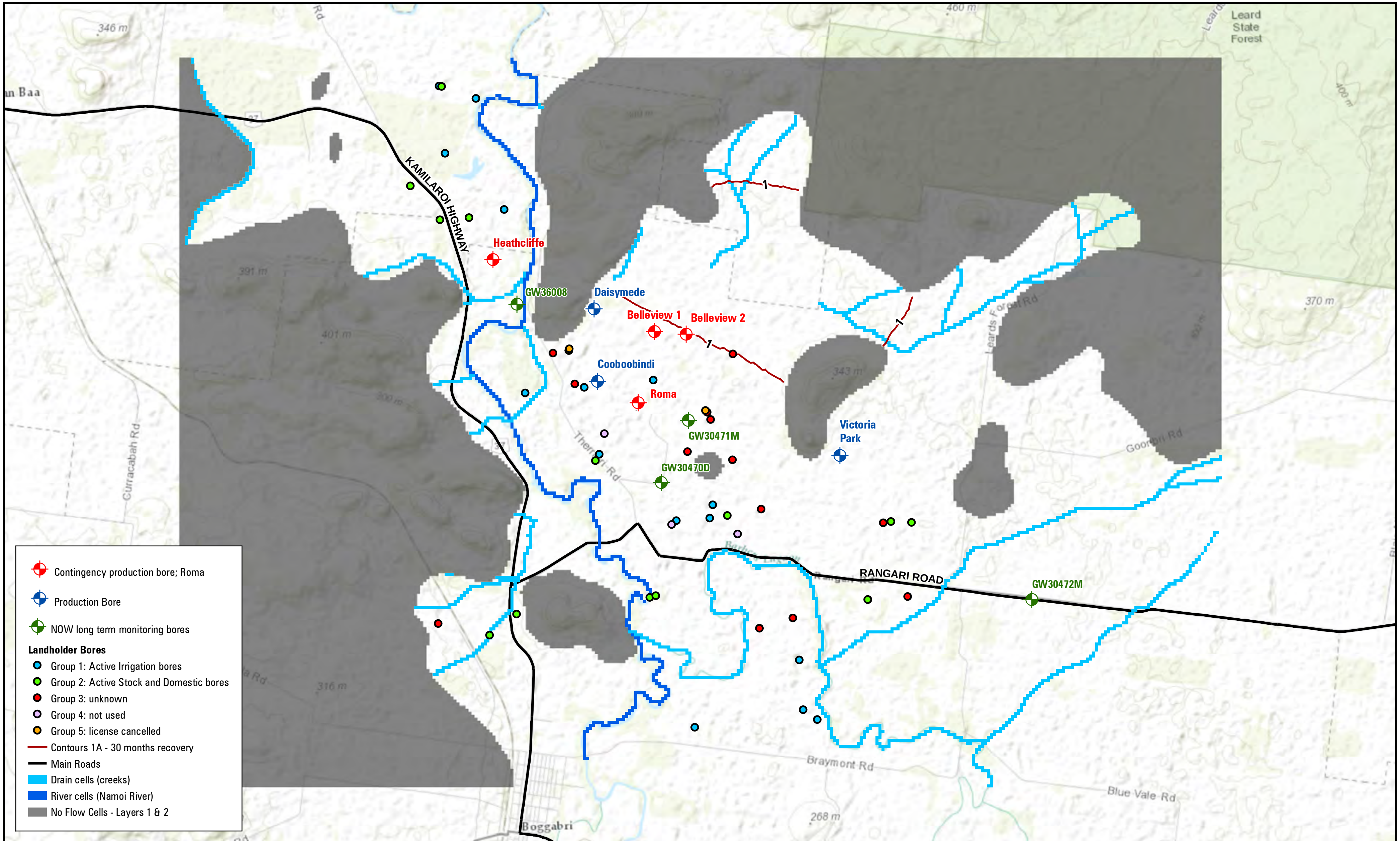
Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A4

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine
Appendix D1d
Modelled drawdown contours after 17 years – Scenario 1A



Map: 2200555A_GIS_020_A1_APP-D1e	Author: M Goganovski
Date: 26/08/2015	Approved by: - S Focke

Data source: -

0 750 1,500 m

1:84,000

Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A4

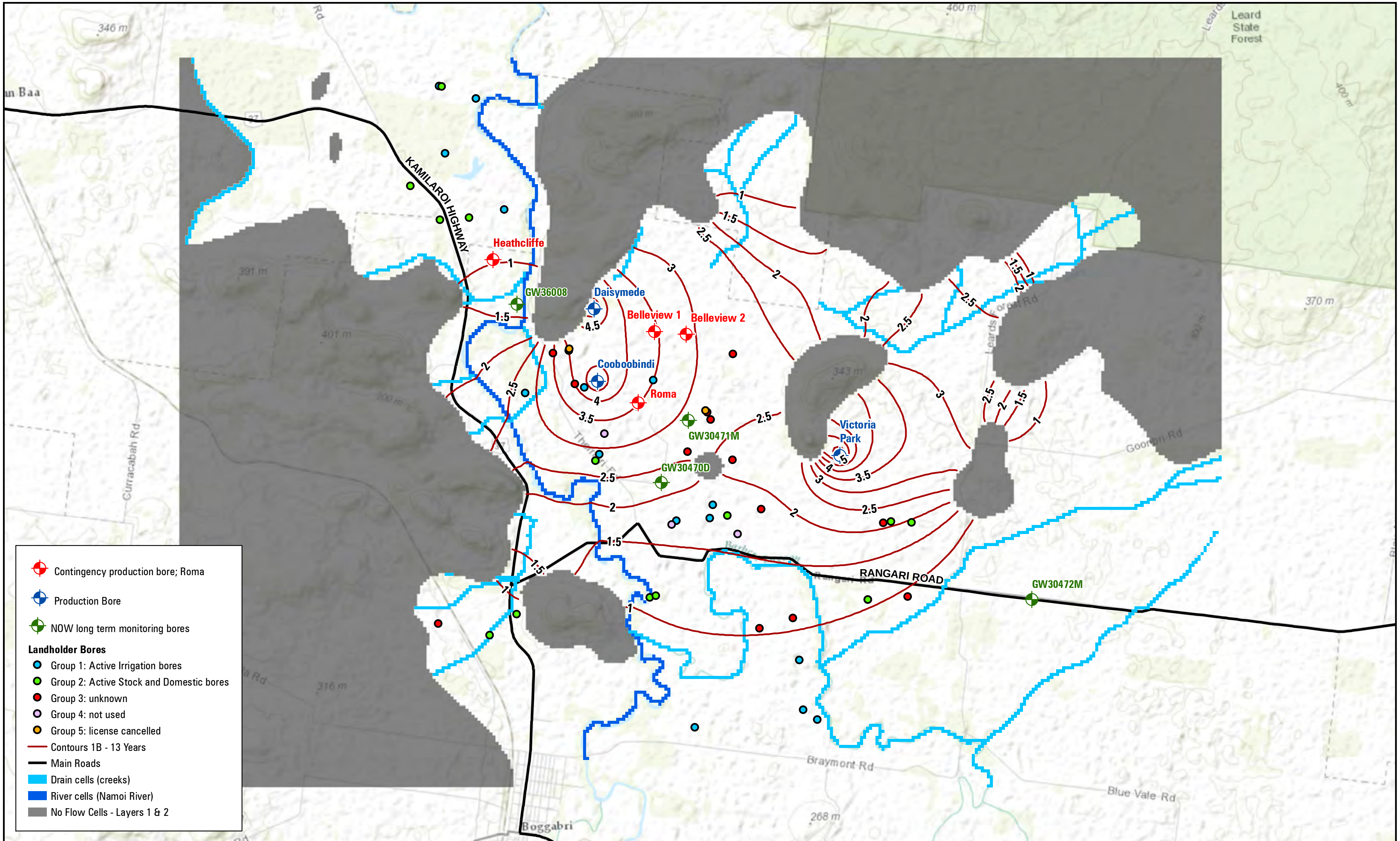
© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine

Appendix D1e

Modelled drawdown contours after 2.5 years recovery – Scenario 1A



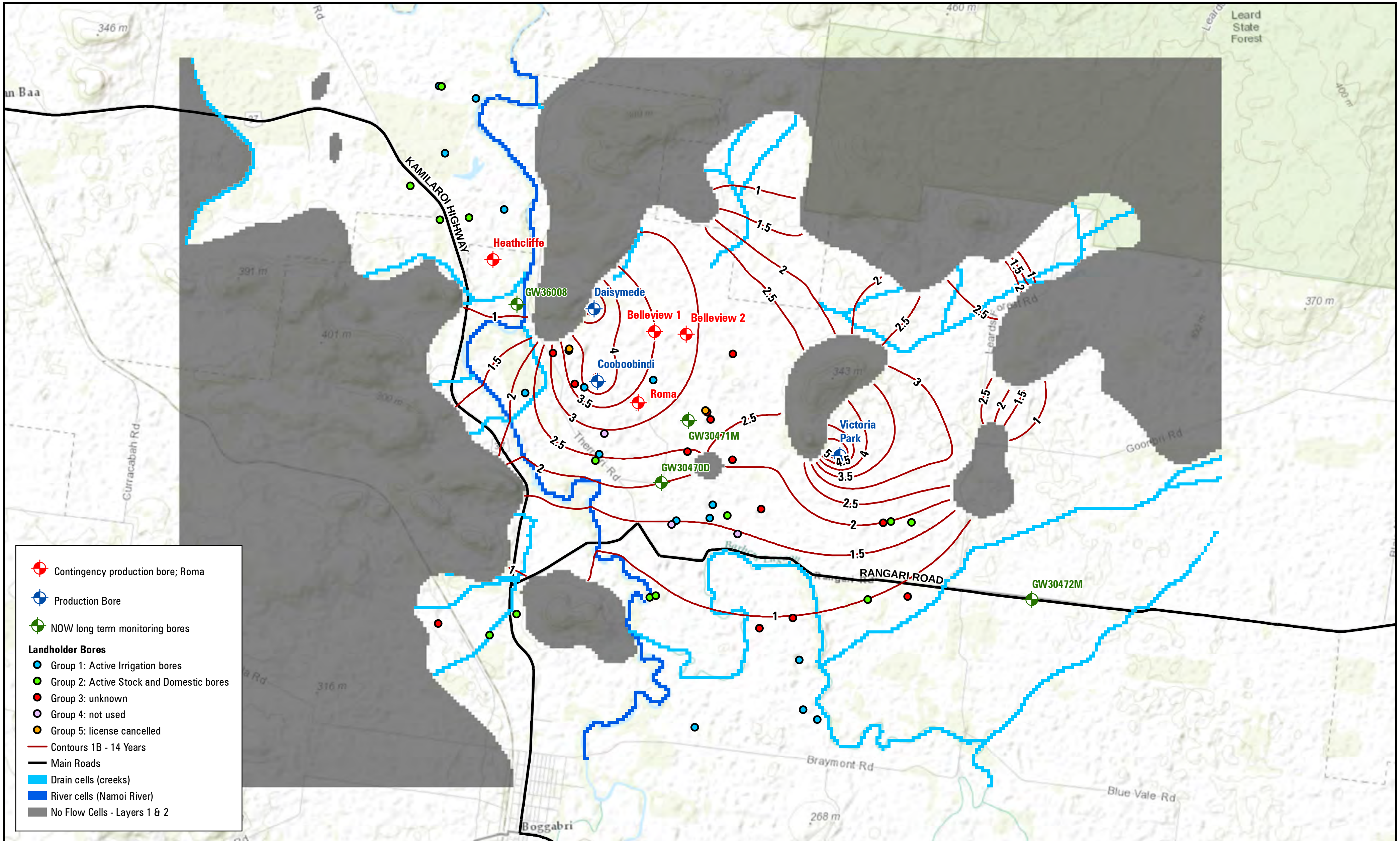
Map: 2200555A_GIS_021_A1_APP-D2a	Author: M Goganovski
Date: 26/08/2015	Approved by: - S Focke

Data source: -

0 750 1,500 m
1:84,000
Coordinate system: GDA 1994 MGA Zone 56
Scale ratio correct when printed at A4

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine
Appendix D2a
Modelled drawdown contours after 13 years – Scenario 1B

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.



Map: 2200555A_GIS_022_A1_APP-D2b	Author: M Goganovski		0 750 1,500 m 1:84,000
Date: 26/08/2015	Approved by: - S Focke		
Data source: -			Coordinate system: GDA 1994 MGA Zone 56 Scale ratio correct when printed at A4

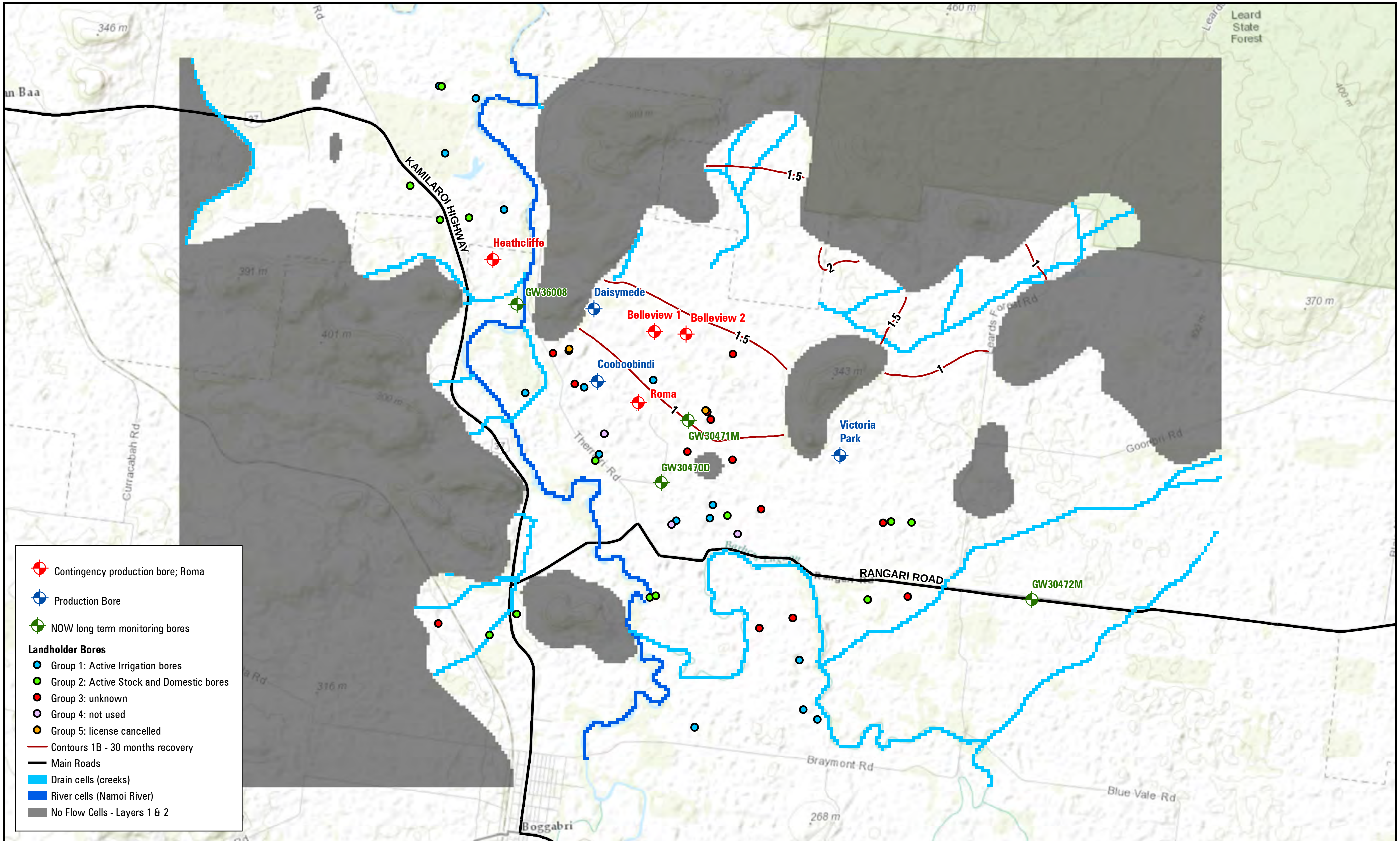
© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine

Appendix D2b

Modelled drawdown contours after 14 years – Scenario 1B



Map: 2200555A_GIS_023_A1_APP-D2c | Author: M Goganovski

Date: 26/08/2015 | Approved by: - S Focke

Data source: -

0 750 1,500 m

1:84,000

Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A4

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine

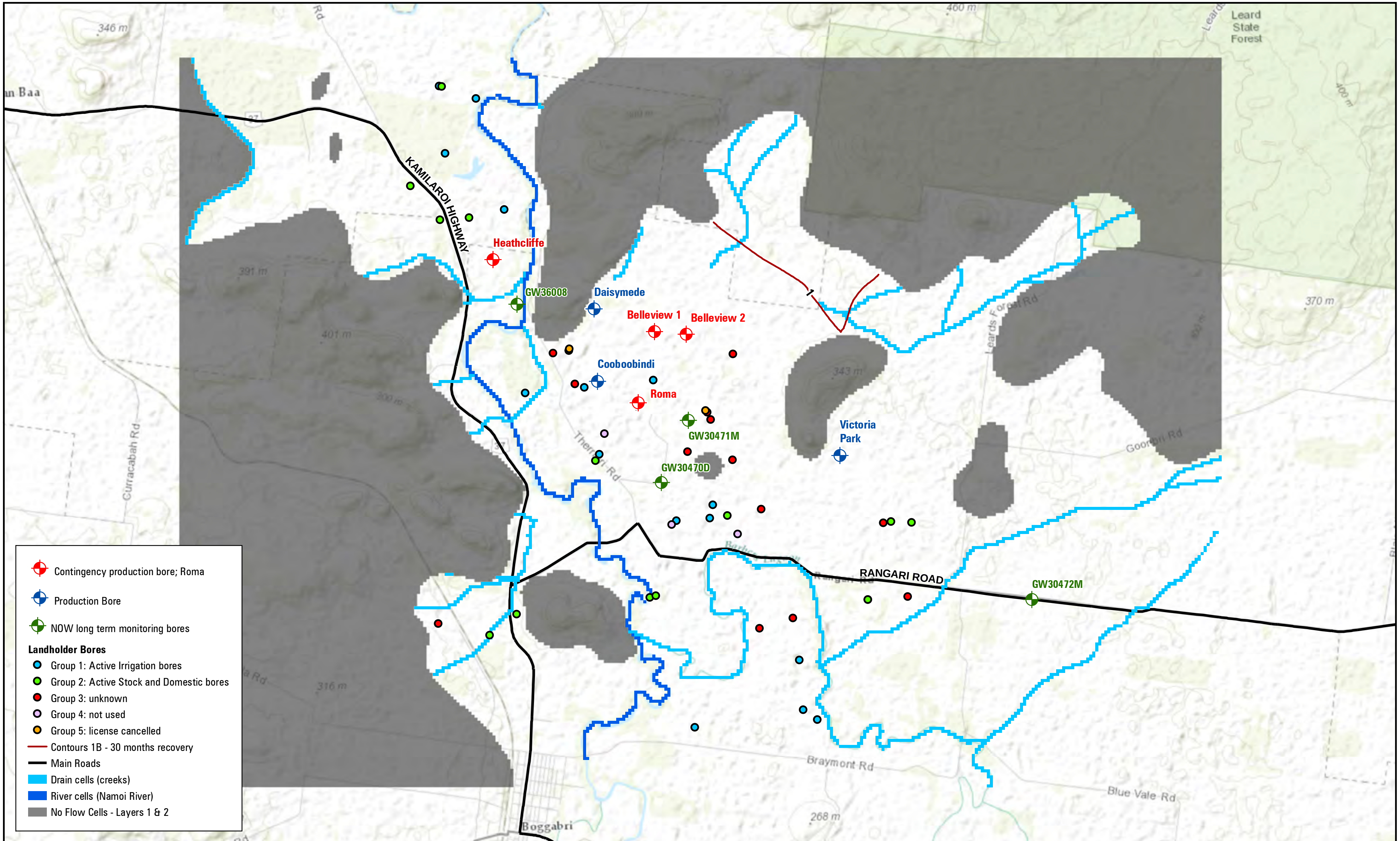
Appendix D2c

Modelled drawdown contours after 30 months – Scenario 1B

\\Apbnefil03\proj\I\Idemitsu_Aus_Resources\2200555A_DRWDN_IMPCT_BOREFIELD_BOGGABR\10_GIS\Projects\Maps\2200555A_GIS_023_A1_APP-D2c.mxd

Idemitsu Australia Resources

www.pbworld.com



Map: 2200555A_GIS_024_A1_APP-D2d | Author: M Goganovski

Date: 26/08/2015 | Approved by: - S Focke

Data source: -

0 750 1,500 m

1:84,000

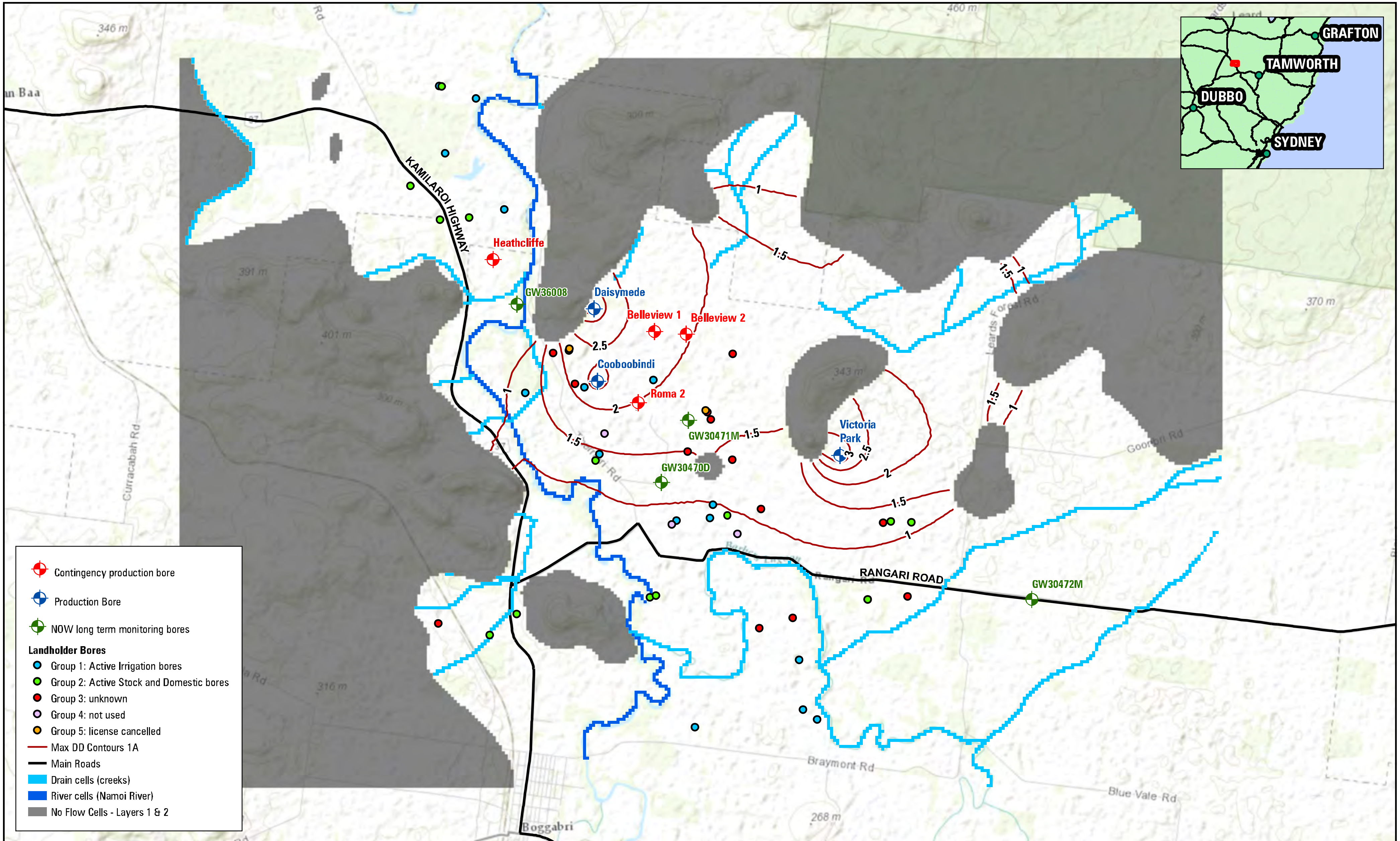
Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A4

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine
Appendix D2d
Modelled drawdown contours after 10 years – Scenario 1B



Map: 2200555A_GIS_006_A1	Author: M Goganovski
Date: 14/07/2015	Approved by: - S.Focke

Data source: -

0 750 1,500 m

1:84,000

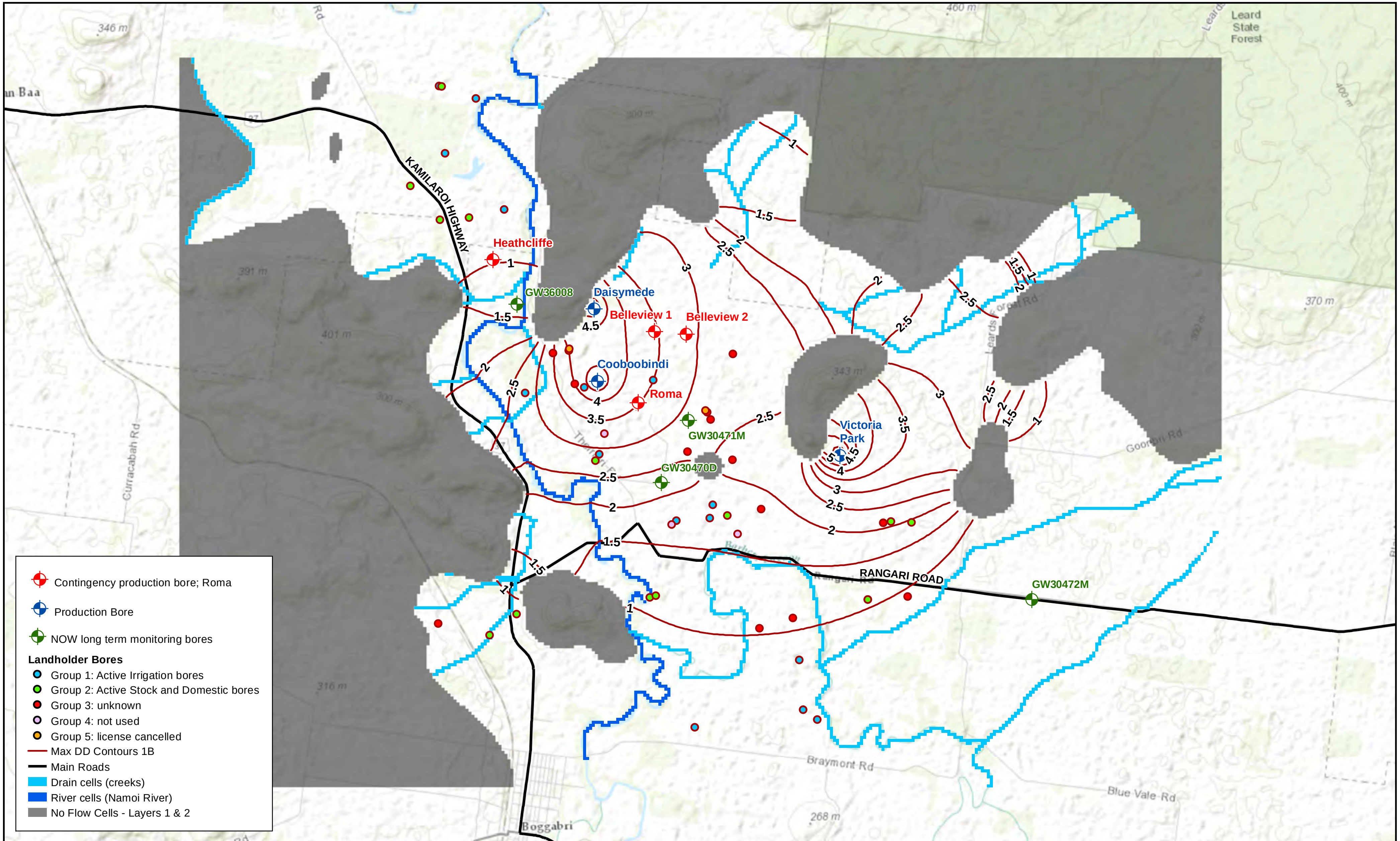
Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A4

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine
Appendix D
Maximum LOM drawdown contours - Scenario 1A



Map: 2200555A_GIS_007_A1	Author: M Goganovski
Date: 28/08/2015	Approved by: - S Focke

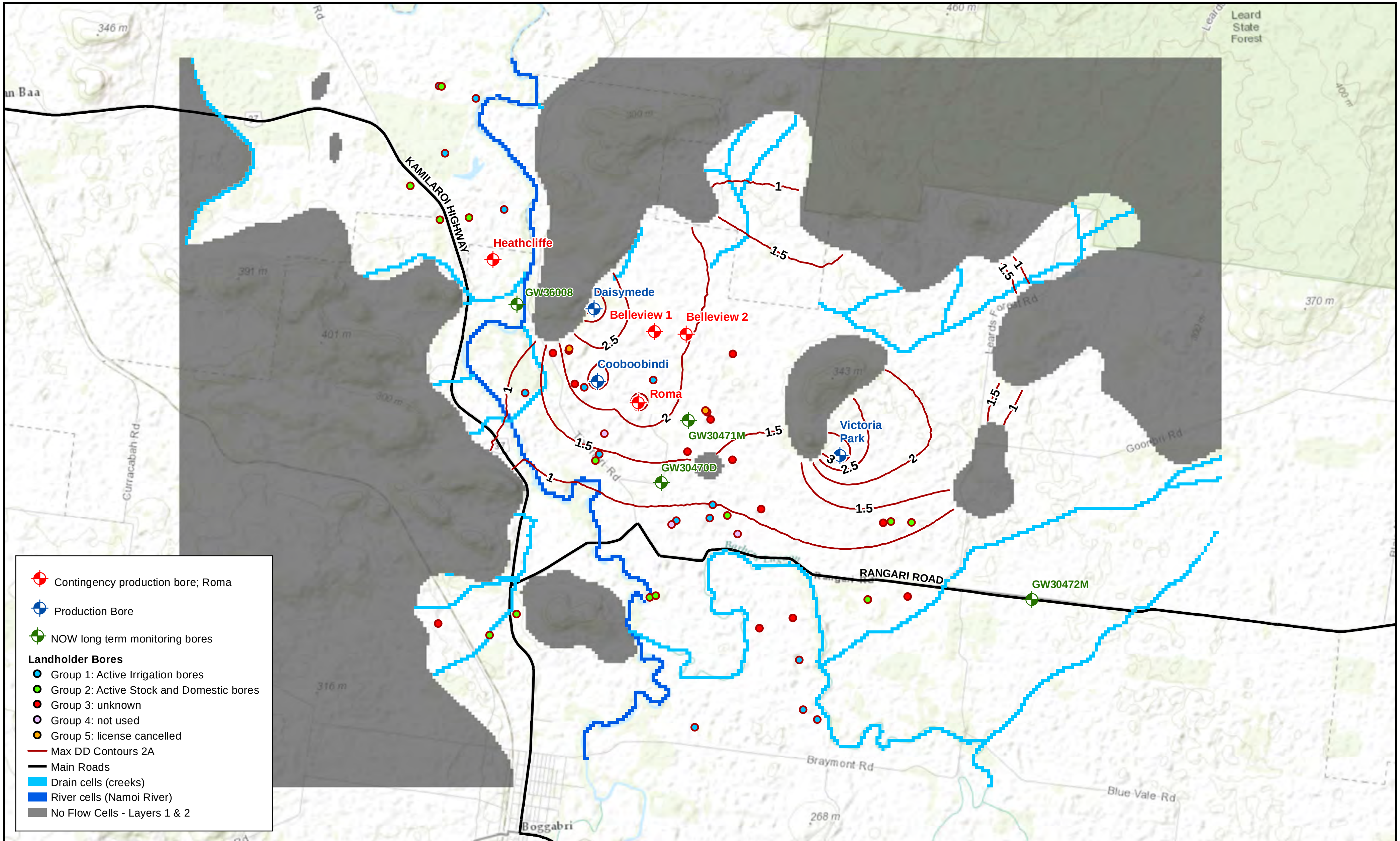
Data source: -

0 750 1,500 m
1:84,000
Coordinate system: GDA 1994 MGA Zone 56
Scale ratio correct when printed at A4

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine
Appendix D2
Maximum LOM drawdown contours - Scenario 1B



Map: 2200555A_GIS_008_A2_APP-D3	Author: M Goganovski	
Date: 28/08/2015	Approved by: - S Focke	

Data source: -

0 750 1,500 m

1:84,000

Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A4

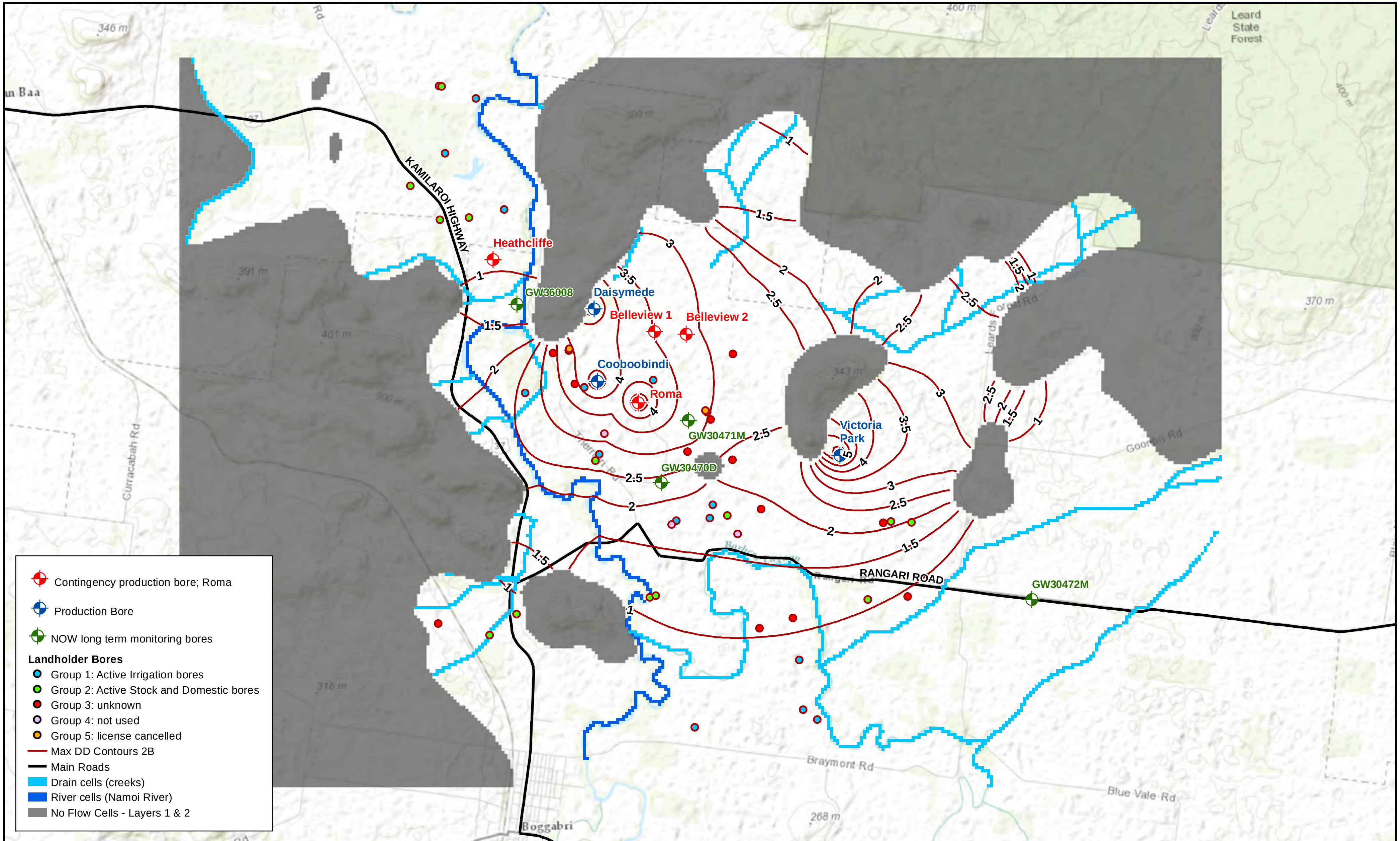
Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine

Appendix D3

Maximum LOM drawdown contours - Scenario 2A

WSP | PARSONS BRINCKERHOFF

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.



Map: 2200555A_GIS_009_A1_APP-D4	Author: M Goganovski
Date: 28/08/2015	Approved by: - S Focke

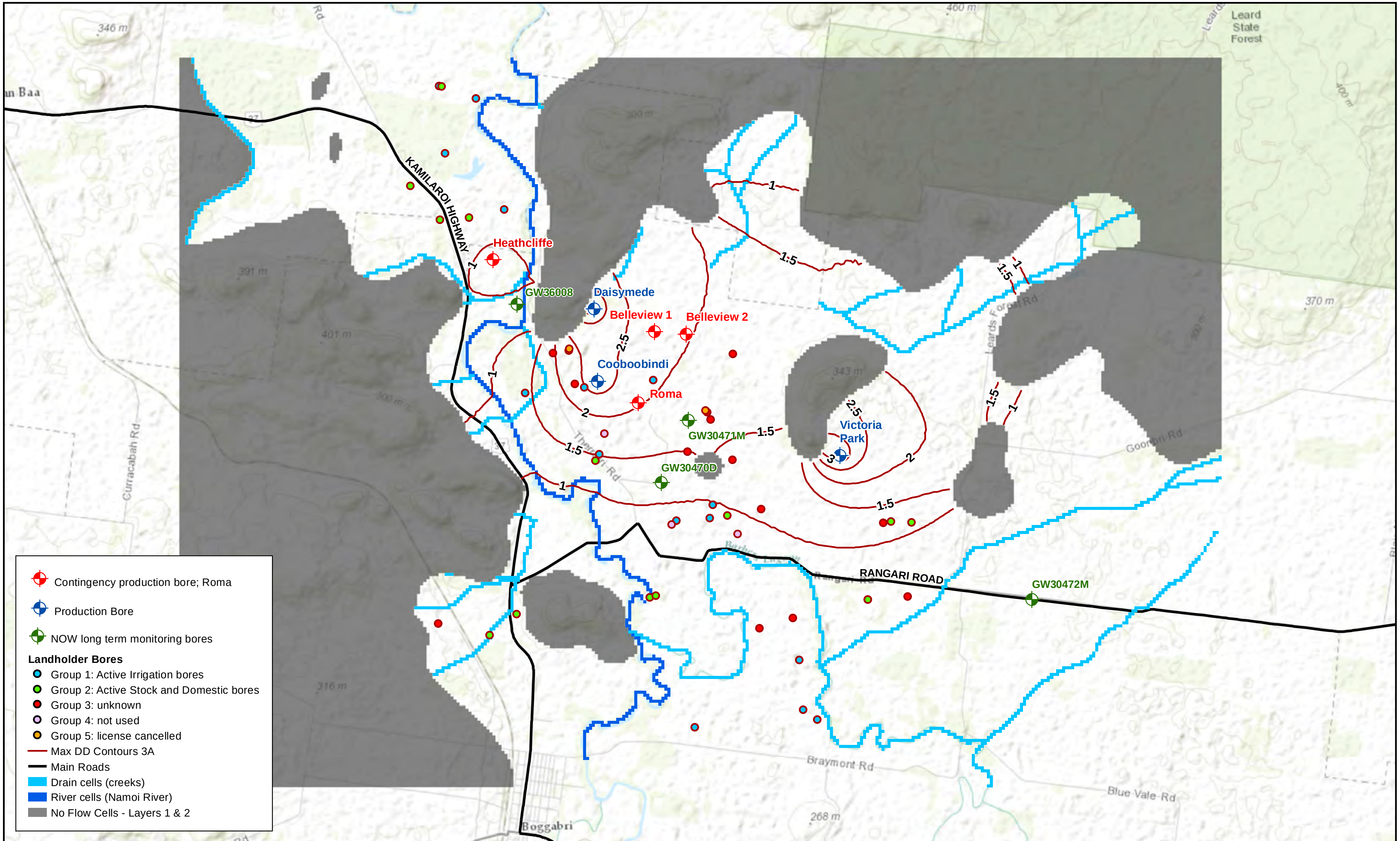
Data source: -

0 750 1,500 m
1:84,000
Coordinate system: GDA 1994 MGA Zone 56
Scale ratio correct when printed at A4

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine
Appendix D4
Maximum LOM drawdown contours - Scenario 2B

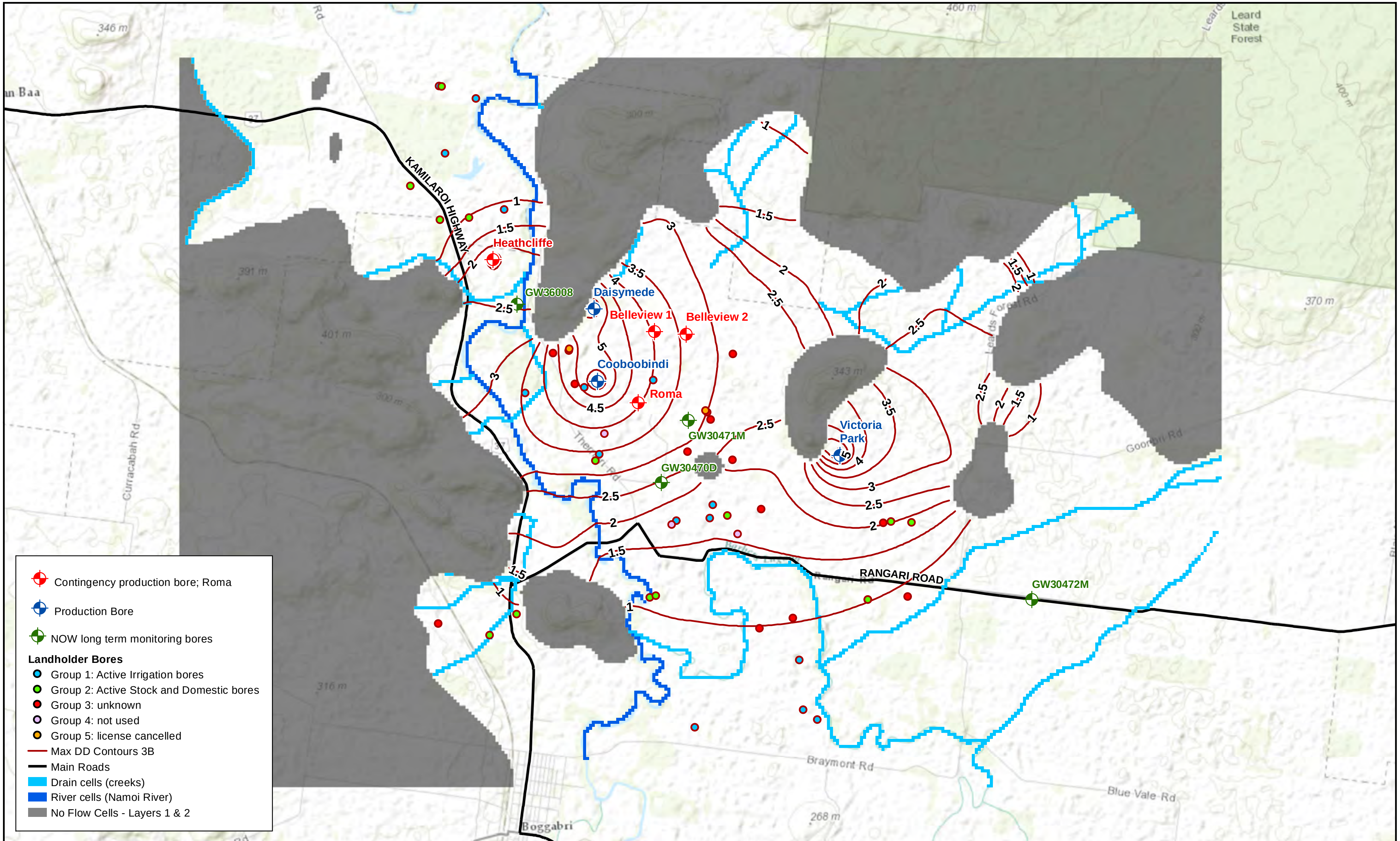


Map: 2200555A_GIS_010_A1_APP-D5	Author: M Goganovski		0 750 1,500 m 1:84,000
Date: 28/08/2015	Approved by: - S Focke		
Data source: -			Coordinate system: GDA 1994 MGA Zone 56 Scale ratio correct when printed at A4

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine
Appendix D5
Maximum LOM drawdown contours - Scenario 3A



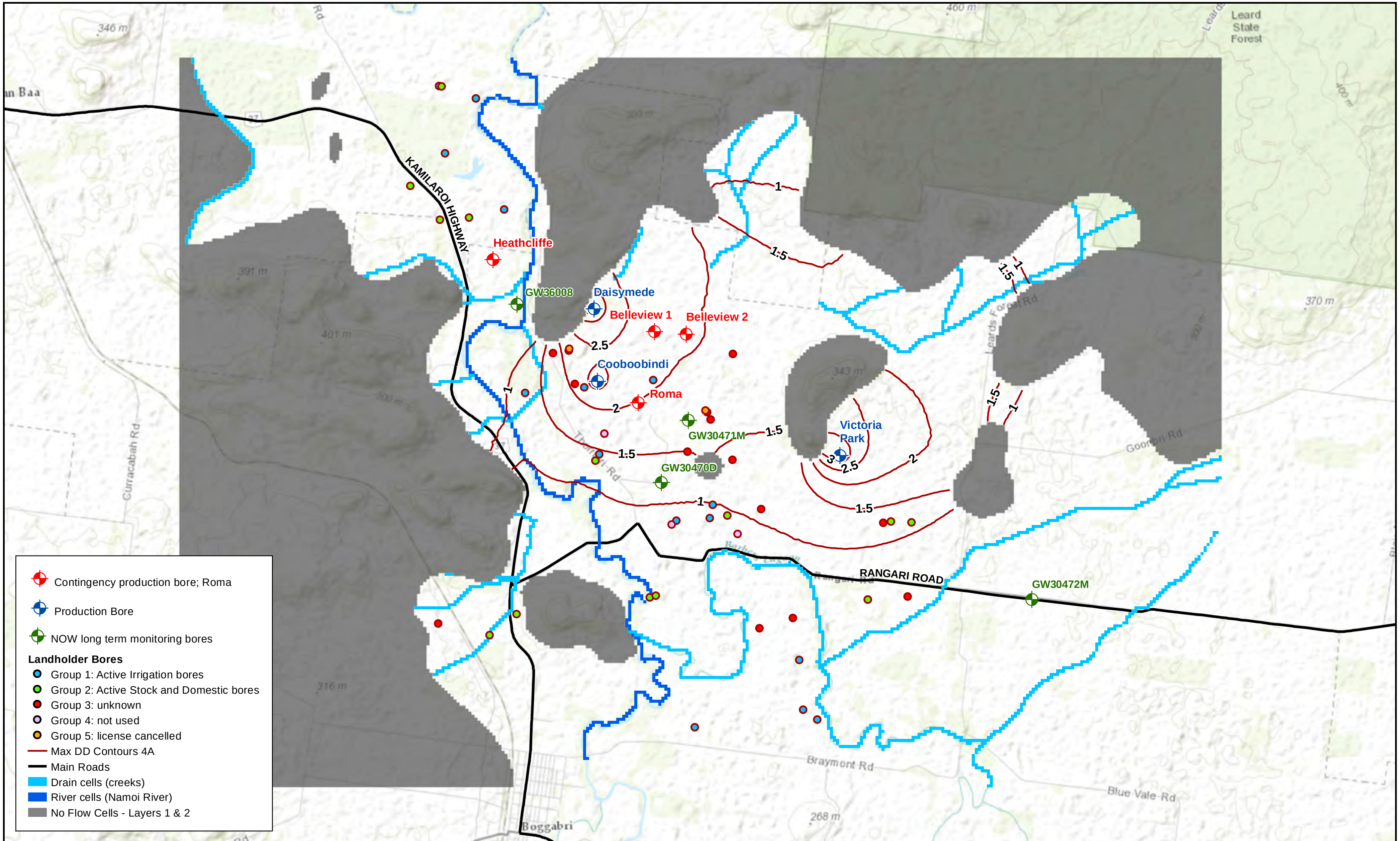
Map: 2200555A_GIS_011_A1_APP-D6	Author: M Goganovski		0 750 1,500 m 1:84,000
Date: 28/08/2015	Approved by: - S Focke		Coordinate system: GDA 1994 MGA Zone 56 Scale ratio correct when printed at A4

Data source: -

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine
Appendix D6
Maximum LOM drawdown contours - Scenario 3B



Map: 2200555A_GIS_012_A1_APP-D7	Author: M Goganovski
Date: 28/08/2015	Approved by: - S Focke

Data source: -

0 750 1,500 m

1:84,000

Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A4

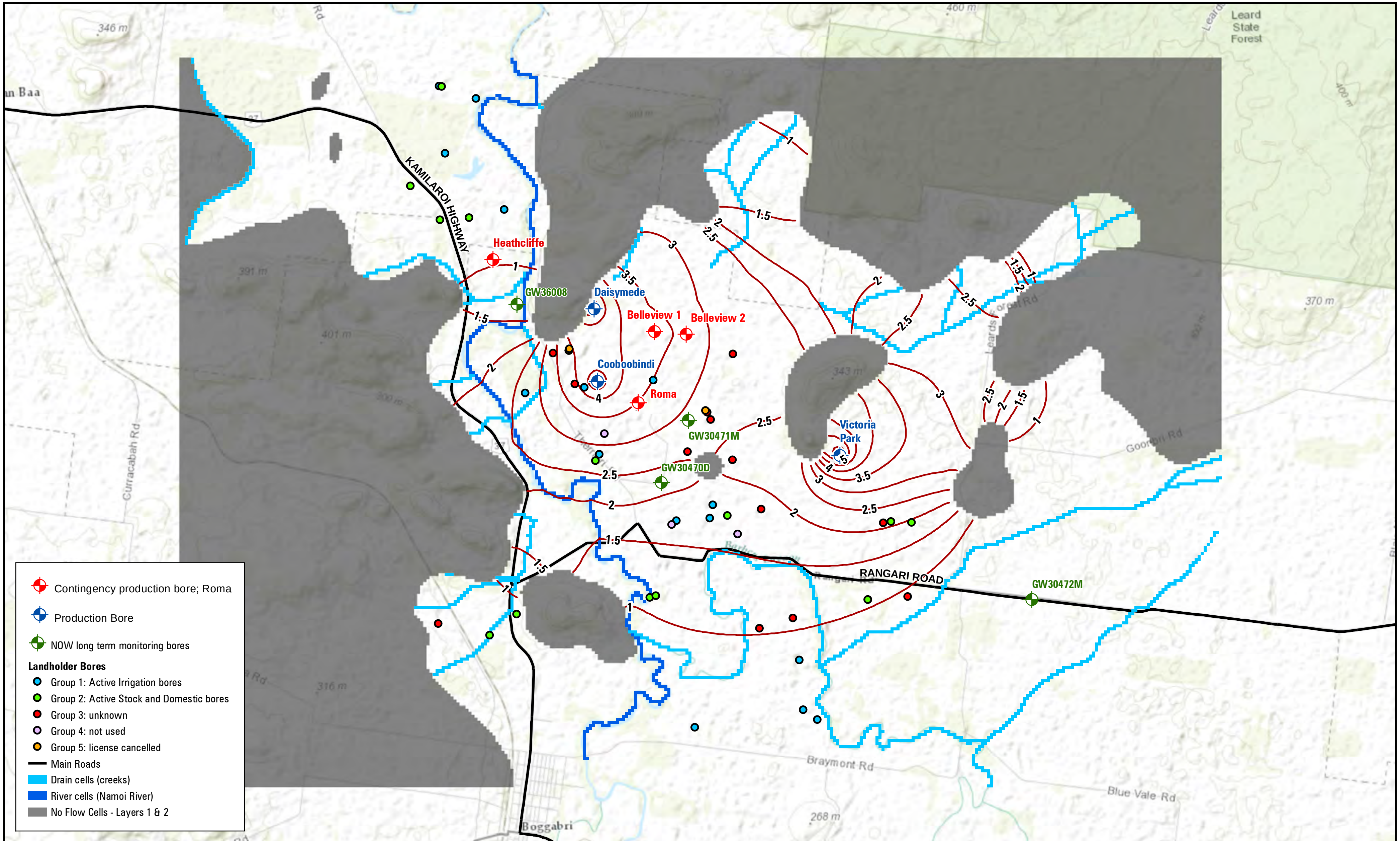
WSP | PARSONS BRINCKERHOFF

Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine

Appendix D7

Maximum LOM drawdown contours - Scenario 4A

© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.



Map: 2200555A_GIS_013_A1_APP-D8	Author: M Goganovski		0 750 1,500 m 1:84,000
Date: 26/08/2015	Approved by: - S Focke		Coordinate system: GDA 1994 MGA Zone 56 Scale ratio correct when printed at A4
Data source: -			

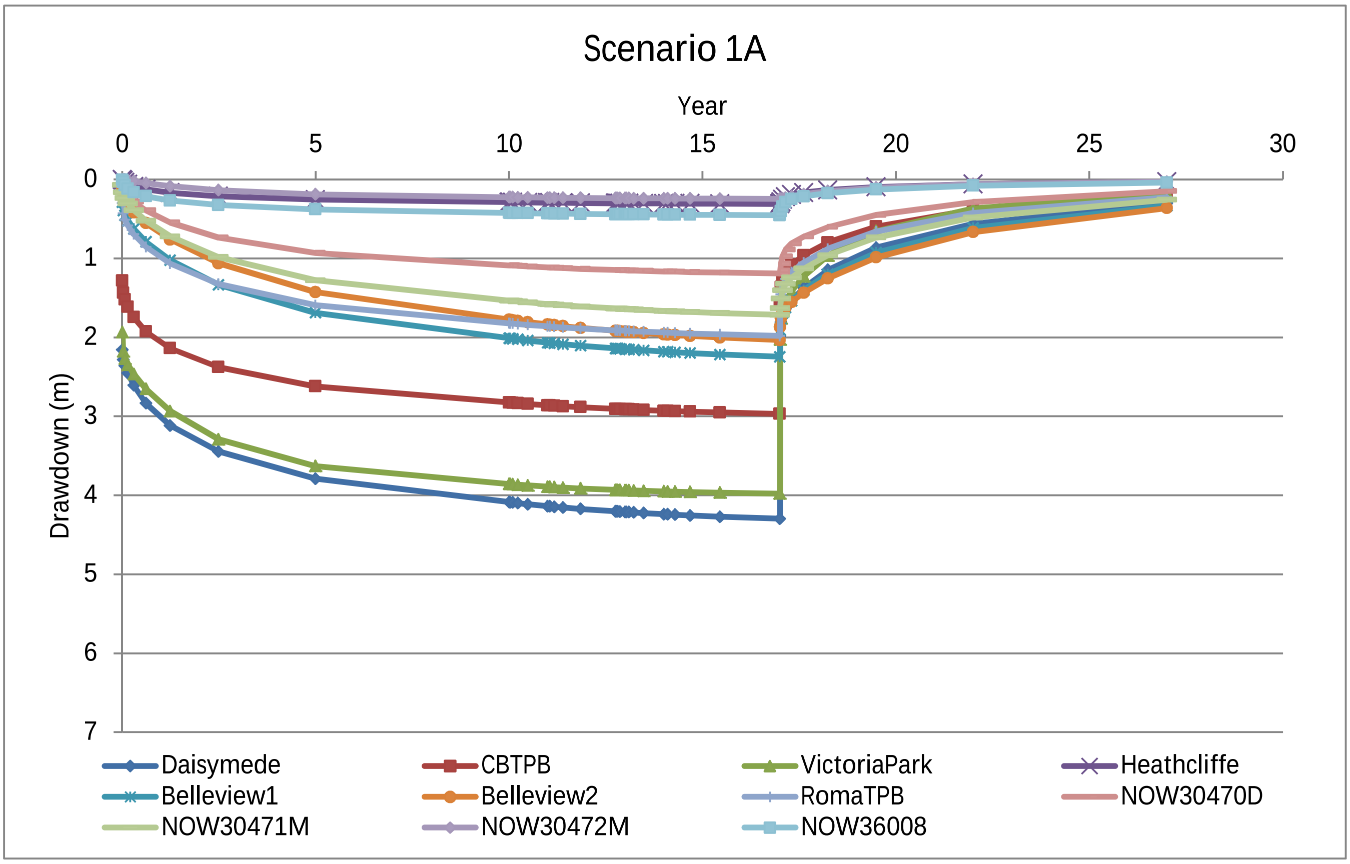
© Parsons Brinckerhoff Australia Pty Ltd ("PB") Copyright in the drawings, information and data recorded ("the information") is the property of PB. This document and the information are solely for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or part for any purpose other than that which it was supplied by PB. PB makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or the information. NCSI Certified Quality System to ISO 9001. © APPROVED FOR AND ON BEHALF OF Parsons Brinckerhoff Australia Pty Ltd.

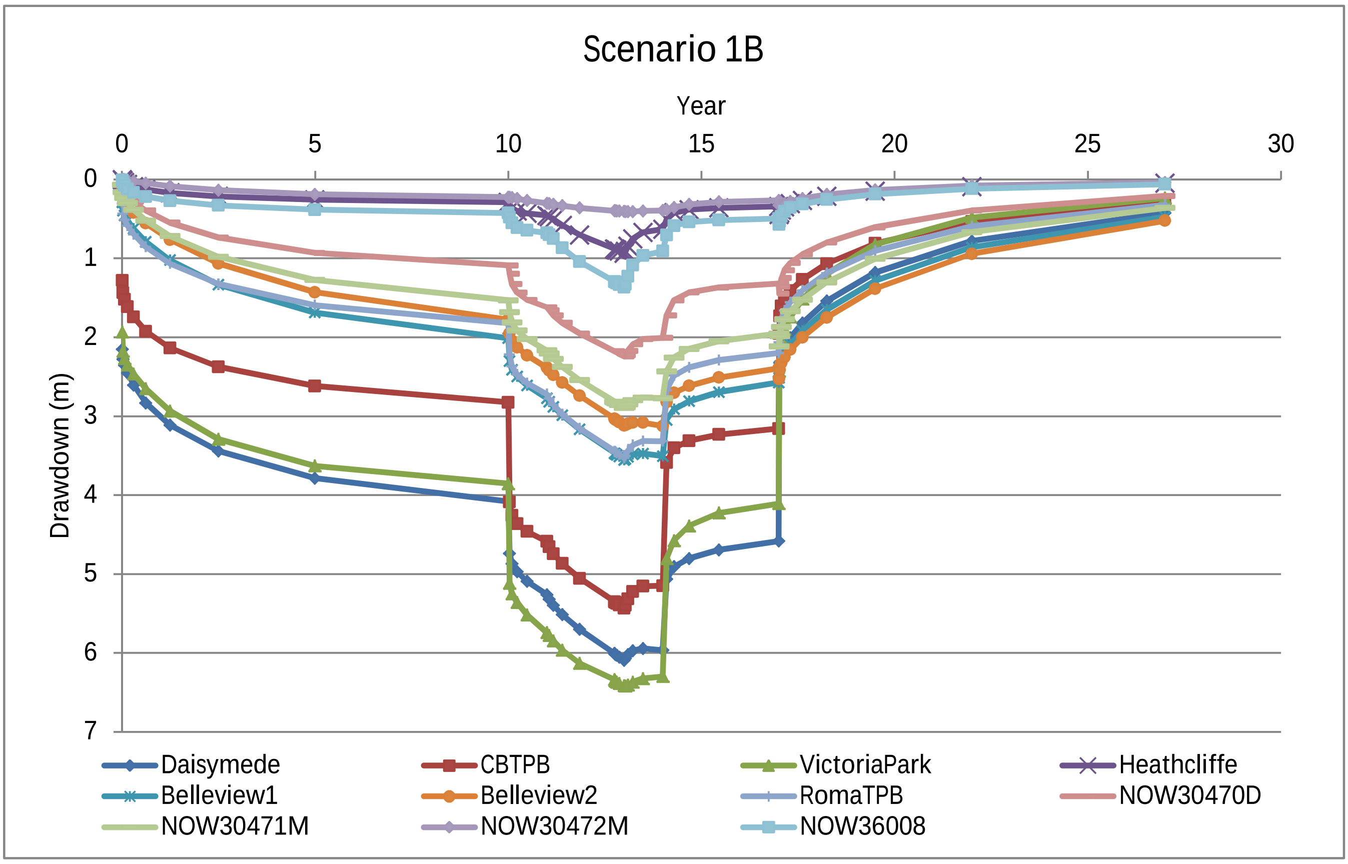
WSP | PARSONS BRINCKERHOFF

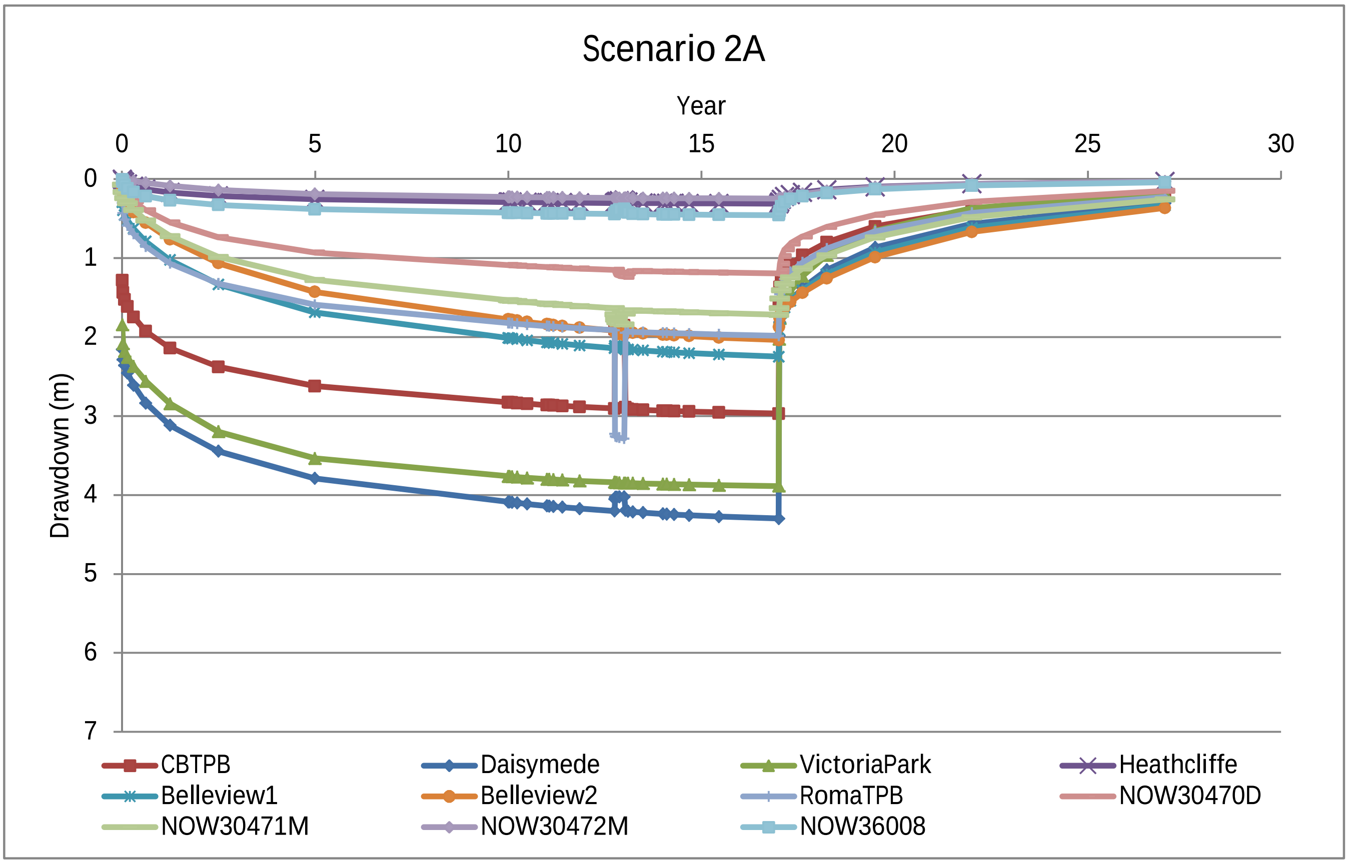
Drawdown Impact Assessment of Proposed Borefield Operations, Boggabri Coal Mine
Appendix D8
Maximum LOM drawdown contours - Scenario 4B

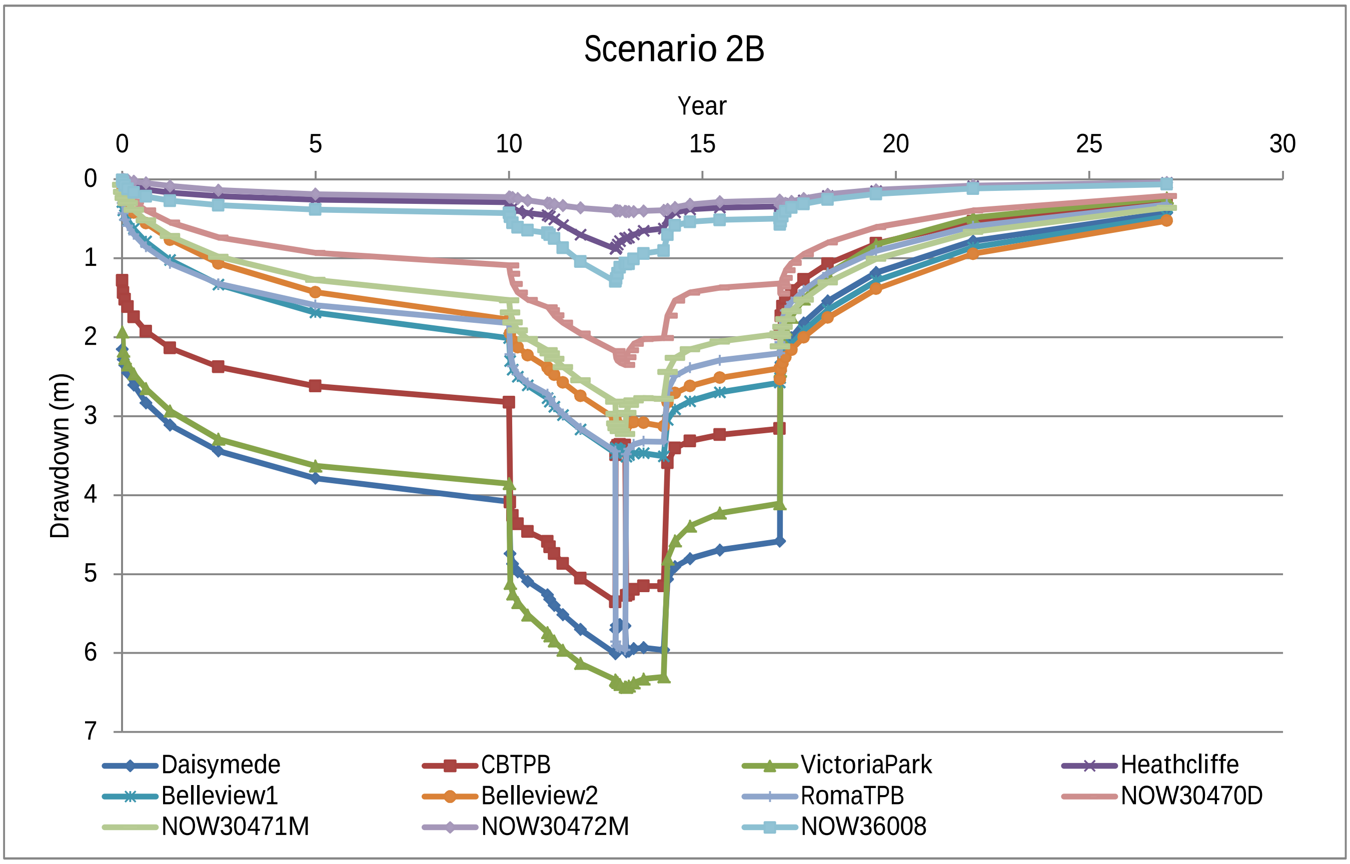
Appendix E

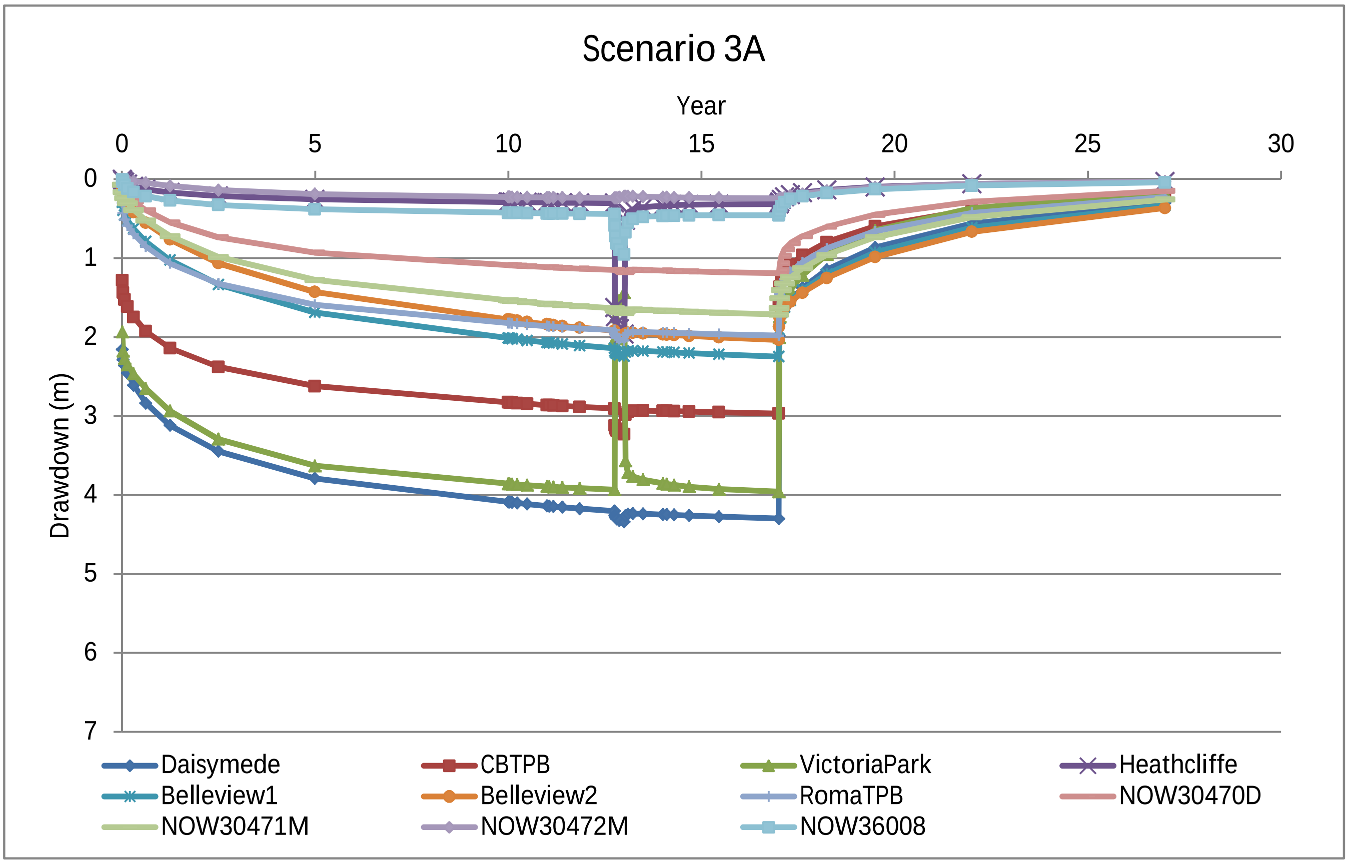
Drawdown hydrographs

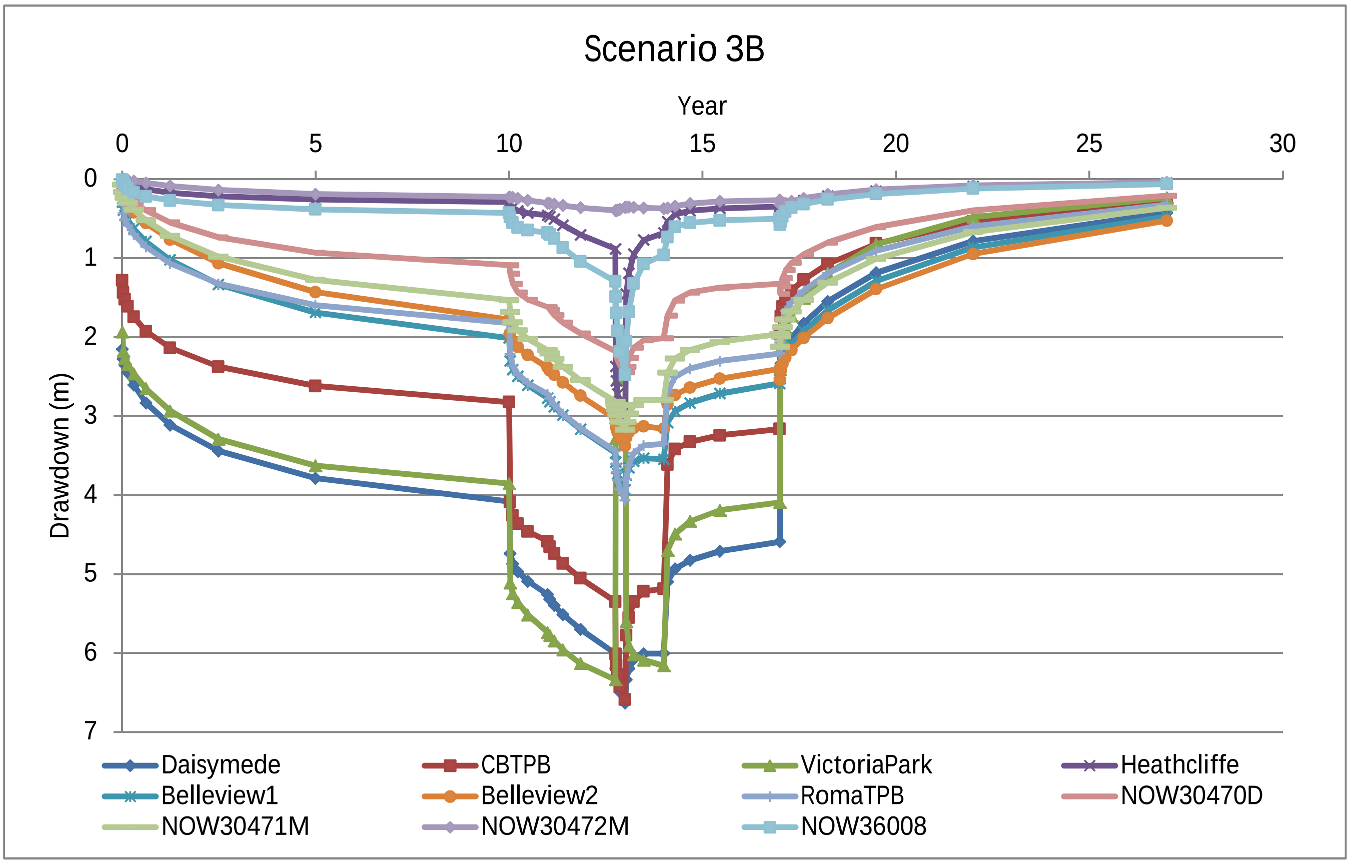

Scenario 1A
Year
0
5
10
15
20
25
30
0
1
2
3
4
5
6
7
Drawdown (m)
Daisymede
CBTPB
VictoriaPark
Heathcliffe
Belleview1
Belleview2
RomaTPB
NOW30470D
NOW30471M
NOW30472M
NOW36008

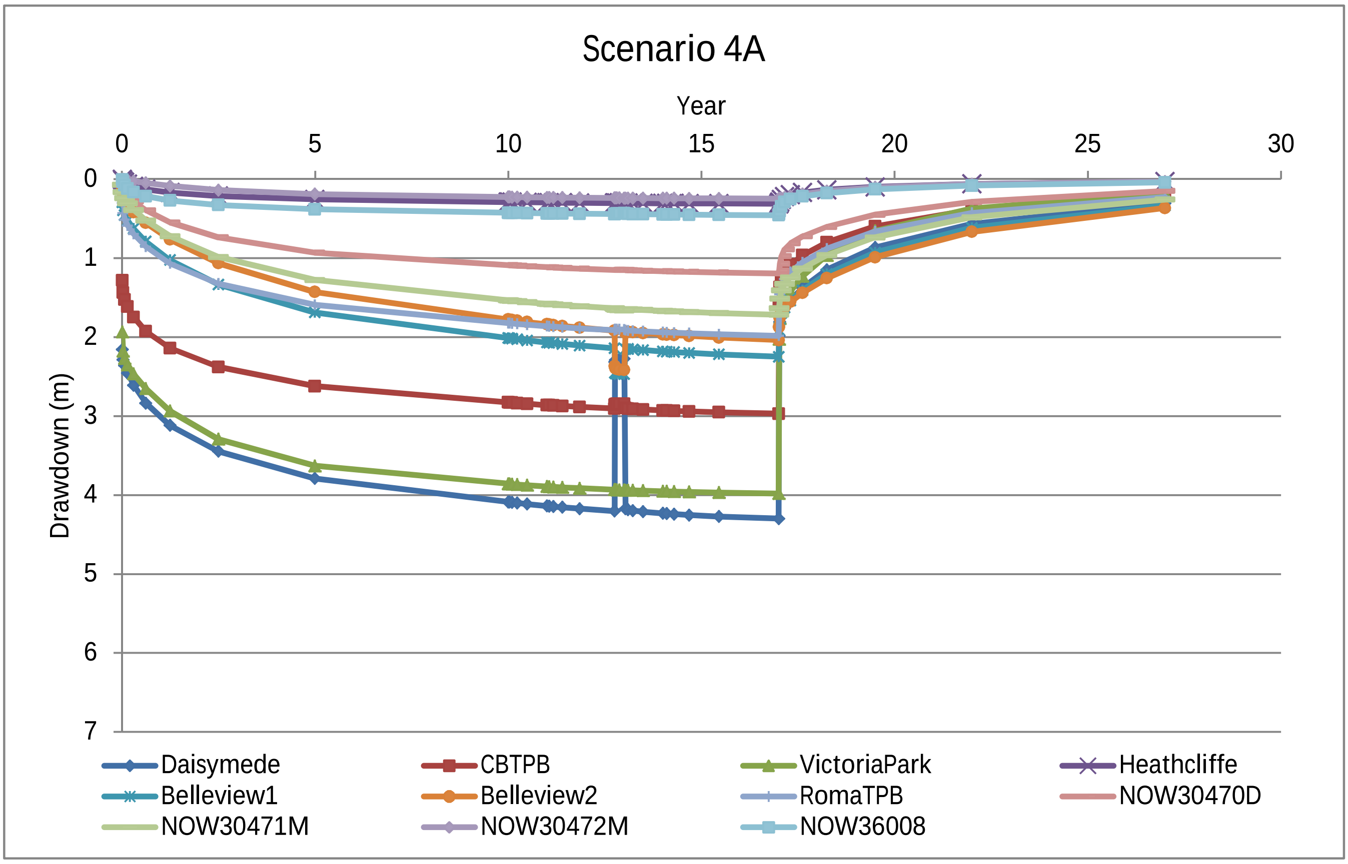

Scenario 1B
Year
0
5
10
15
20
25
30
0
1
2
3
4
5
6
7
Drawdown (m)
Daisymede
CBTPB
VictoriaPark
Heathcliffe
Belleview1
Belleview2
RomaTPB
NOW30470D
NOW30471M
NOW30472M
NOW36008

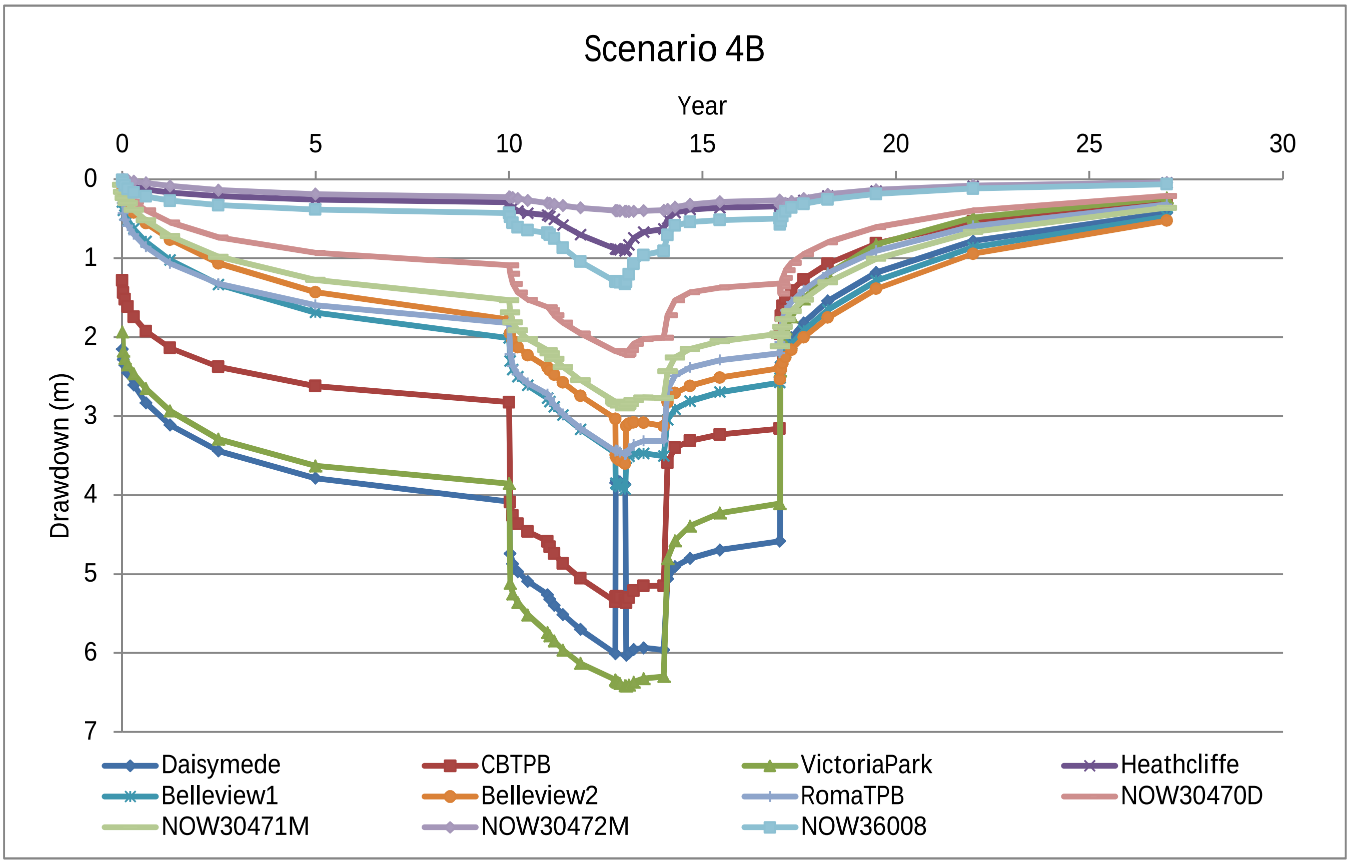

Scenario 2A
Year
0
5
10
15
20
25
30
Drawdown (m)
0
1
2
3
4
5
6
7
CBTPB
Daisymede
VictoriaPark
Heathcliffe
Belleview1
Belleview2
RomaTPB
NOW30470D
NOW30471M
NOW30472M
NOW36008

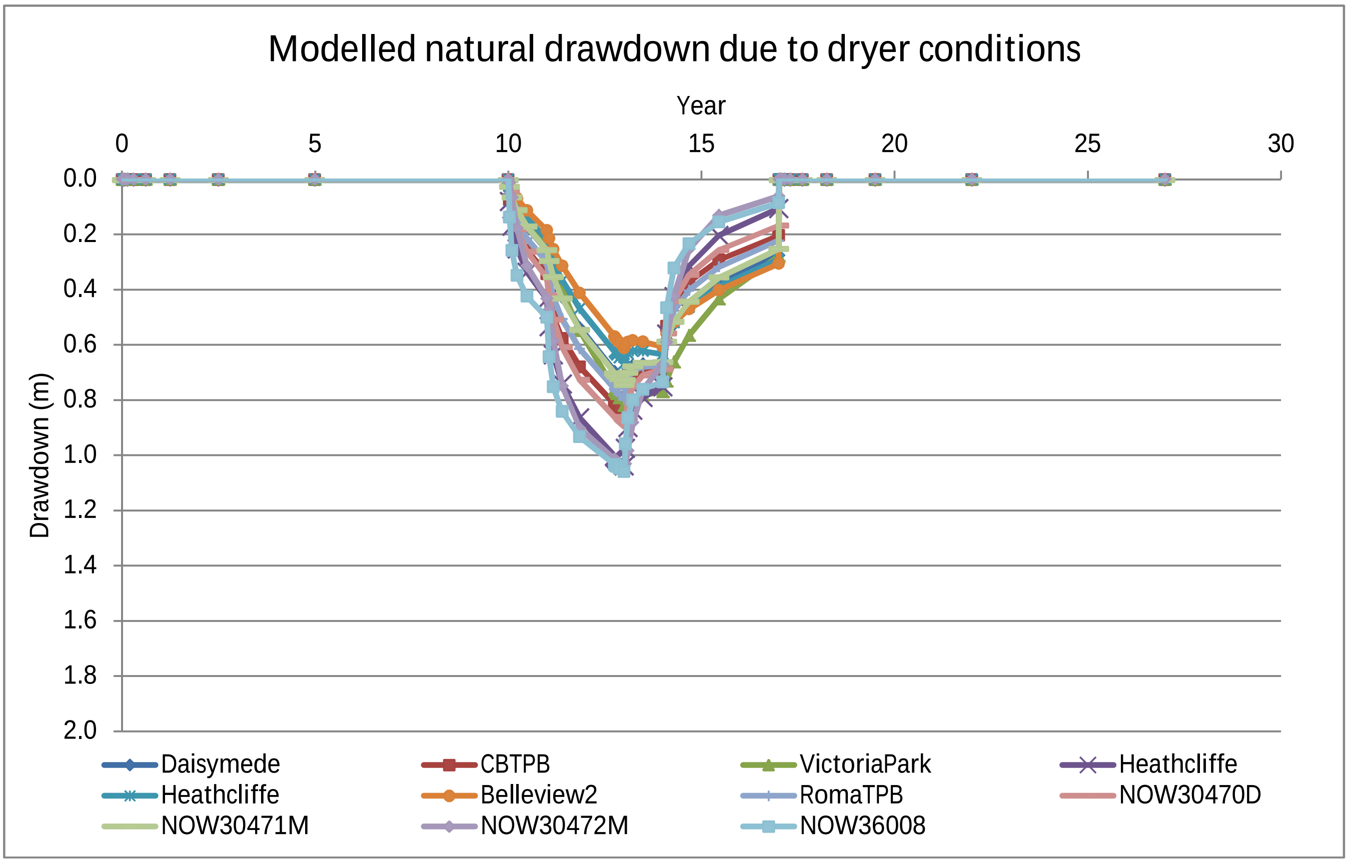

Scenario 2B
Year
0
5
10
15
20
25
30
Drawdown (m)
0
1
2
3
4
5
6
7
Daisymede
CBTPB
VictoriaPark
Heathcliffe
Belleview1
Belleview2
RomaTPB
NOW30470D
NOW30471M
NOW30472M
NOW36008


Scenario 3A
Year
0
5
10
15
20
25
30
Drawdown (m)
0
1
2
3
4
5
6
7
Daisymede
CBTPB
VictoriaPark
Heathcliffe
Belleview1
Belleview2
RomaTPB
NOW30470D
NOW30471M
NOW30472M
NOW36008


Scenario 3B
Year
0
5
10
15
20
25
30
Drawdown (m)
0
1
2
3
4
5
6
7
Daisymede
CBTPB
VictoriaPark
Heathcliffe
Belleview1
Belleview2
RomaTPB
NOW30470D
NOW30471M
NOW30472M
NOW36008


Scenario 4A
Year
0
5
10
15
20
25
30
Drawdown (m)
0
1
2
3
4
5
6
7
Daisymede
CBTPB
VictoriaPark
Heathcliffe
Belleview1
Belleview2
RomaTPB
NOW30470D
NOW30471M
NOW30472M
NOW36008


Scenario 4B
Year
0
5
10
15
20
25
30
Drawdown (m)
0
1
2
3
4
5
6
7
Daisymede
CBTPB
VictoriaPark
Heathcliffe
Belleview1
Belleview2
RomaTPB
NOW30470D
NOW30471M
NOW30472M
NOW36008



Modelled natural drawdown due to dryer conditions
Year
0
5
10
15
20
25
30
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Drawdown (m)
Daisymede
CBTPB
VictoriaPark
Heathcliffe
Heathcliffe
Belleview2
RomaTPB
NOW30470D
NOW30471M
NOW30472M
NOW36008

Appendix F

Landholder bore drawdown information

Appendix F Table 1 Summary of modelled maximum drawdown for landholder bores

Reg Bore Number	Modelled maximum drawdown (m)								Comment
	1A	1B	2A	2B	3A	3B	4A	4B	
GW005441	1.25	2.11	1.25	2.13	1.23	2.02	1.25	2.11	registered use unknown
GW010797	0.62	1.07	0.62	1.08	0.61	1.02	0.62	1.07	decommissioned ?
GW022957	1.25	2.78	1.25	2.67	1.41	3.57	1.25	2.71	not operational, unlicensed
GW025856	0.18	0.52	0.18	0.45	0.53	1.12	0.18	0.51	
GW026063	0.23	0.41	0.23	0.41	0.23	0.38	0.23	0.41	
GW031926	1.67	2.73	1.72	2.96	1.67	2.91	1.67	2.75	license inactive, abandoned ?
GW031927	1.71	2.79	1.77	3.03	1.71	2.99	1.71	2.81	abandoned ?
GW031928	1.82	2.75	1.82	2.81	1.82	2.86	1.82	2.77	not used, salty water
GW032080	0.55	1.11	0.55	1.13	0.54	1.09	0.55	1.10	abandoned
GW032116	0.54	0.92	0.54	0.93	0.53	0.87	0.54	0.92	
GW032136	1.94	3.47	2.77	5.02	2.00	3.99	1.94	3.43	Not used, adjacent Roma BCOPL bore, dry for B-scenarios
GW032232	0.88	1.68	0.89	1.72	0.88	1.71	0.88	1.67	abandoned well
GW032233	0.97	1.74	0.97	1.79	0.96	1.65	0.97	1.73	unlicensed, dry for A- and B-scenarios
GW032234	0.91	1.63	0.91	1.67	0.90	1.55	0.91	1.63	
GW032235	1.07	1.86	1.07	1.91	1.06	1.77	1.07	1.86	well with opportunistic usage when not dry, dry for A- and B-scenarios
GW032246	0.61	1.08	0.61	1.10	0.60	1.03	0.61	1.08	registered use unknown
GW032247	0.57	1.04	0.57	1.06	0.57	0.98	0.57	1.04	
GW032249	1.32	2.21	1.32	2.31	1.31	2.16	1.32	2.22	
GW032251	1.50	2.63	1.60	2.88	1.49	2.88	1.50	2.63	inactive; initially , dry for A- and B-scenarios
GW032252	1.45	2.89	1.45	2.78	1.51	3.43	1.45	2.84	abandoned, dry, silted to 8m depth
GW032254	1.36	2.78	1.36	2.67	1.42	3.30	1.36	2.73	dry for B-scenarios
GW032265	0.26	0.60	0.26	0.58	0.26	0.65	0.26	0.60	license inactive
GW032290	2.12	4.00	2.12	3.89	2.28	4.86	2.12	3.90	decommissioned
GW032291	1.78	3.47	1.78	3.36	1.95	4.30	1.78	3.36	abandoned, dry for B-scenarios
GW035052	2.20	4.03	2.20	3.91	2.35	4.84	2.20	3.91	licence cancelled
GW043433	0.16	0.47	0.16	0.40	0.49	1.03	0.16	0.46	possibly license inactive
GW043448	0.10	0.28	0.10	0.25	0.23	0.53	0.10	0.27	possibly dry, dry for A- and B-scenarios
GW053270	0.99	1.79	0.99	1.85	0.98	1.74	0.99	1.79	license cancelled; currently inactive
GW053271	1.72	2.81	1.79	3.05	1.72	3.02	1.72	2.83	
GW053309	2.20	4.03	2.20	3.91	2.35	4.84	2.20	3.91	Last used in 2008
GW053593	0.04	0.12	0.04	0.11	0.09	0.21	0.04	0.11	license cancelled
GW054713	0.31	0.73	0.31	0.70	0.31	0.81	0.31	0.72	
GW055081	0.25	0.59	0.25	0.57	0.25	0.63	0.25	0.58	registered use unknown
GW057944	2.29	4.27	2.29	4.15	2.46	5.16	2.29	4.17	Irrigation entitlement sold to BCOPL and BCOPL Cooboobindi PB adjacent
GW071936	0.13	0.38	0.13	0.33	0.37	0.81	0.13	0.38	
GW072013	0.62	1.07	0.62	1.08	0.61	1.02	0.62	1.07	
GW103405	0.90	1.70	0.91	1.75	0.90	1.73	0.90	1.69	
GW900014	1.68	3.24	1.68	3.13	1.76	3.85	1.68	3.19	Not currently used
GW900024	0.45	0.80	0.45	0.81	0.44	0.76	0.45	0.80	
GW900106	0.03	0.08	0.03	0.07	0.06	0.14	0.03	0.08	
GW900743	0.27	0.49	0.27	0.49	0.27	0.46	0.27	0.49	
GW901414	2.05	3.49	2.21	3.85	2.08	3.94	2.06	3.48	
GW901835	0.21	0.40	0.21	0.41	0.21	0.38	0.21	0.40	bore currently not used
GW901836	0.08	0.24	0.08	0.21	0.19	0.45	0.08	0.24	
GW965386	0.93	1.71	0.94	1.76	0.93	1.65	0.93	1.70	
GW967252	0.52	1.07	0.52	1.09	0.52	1.06	0.52	1.07	

Reg Bore Number	Modelled maximum drawdown (m)								Comment
	1A	1B	2A	2B	3A	3B	4A	4B	
GW967663	1.25	2.10	1.25	2.11	1.23	2.01	1.25	2.10	Registration use unknown
GW968402	2.22	4.04	2.22	3.92	2.37	4.85	2.22	3.92	Entitlement sold to BCOPL
GW970167	0.03	0.08	0.03	0.07	0.06	0.14	0.03	0.08	
GW970797	1.14	1.92	1.14	1.93	1.13	1.84	1.14	1.92	

Note: red numbers = greater than 2m drawdown

Histograms showing bore depth distribution and percentage of water column reduction

Approximately half the registered bores are drilled to less than 15 m below ground with a mean depth of 25.12 m. Given that the initial mean water column height across all bores is 15.41 m, the relative reduction of available water column (in %) is relatively large compared to the modelled drawdown (m). The depth of some of the licensed bores (concrete lined wells) are drilled to just below the water table. Given a degree of model uncertainty and limits to calibration, one of the bores was modelled as dry (negative water column height for GW43448).

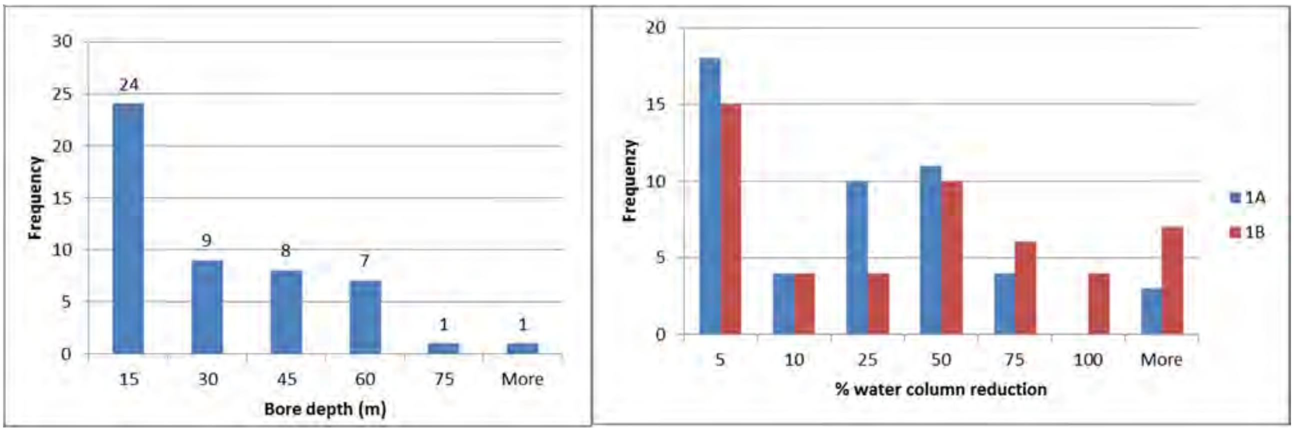


Figure 1 **Bore depth and percentage reduction of the water column for scenarios 1A and 1B**

Appendix F Table 1: Modelled reduction of water column in registered bores for scenarios 1A and 1B

Reg Number	Bore Depth (m)	License status	Registered use	Initial depth to water* (m)	Initial water column height (m)	Modelled minimum water column (1A)	Modelled minimum water column (1B)	% reduction 1A	% reduction 1B
GW005441	12.2	unlicensed ?	not known	9.51	2.69	1.45	0.58	46.30	78.49
GW010797	14.6	active	stock	12.68	1.92	1.30	0.84	32.34	55.96
GW022957	12.5	active	irrigation	6.81	5.69	4.44	2.91	21.98	48.88
GW025856	18.3	active	irrigation	7.61	10.69	10.51	10.17	1.65	4.88
GW026063	40.5	active	irrigation	**11.00**	29.50	29.27	29.09	0.77	1.38
GW031926	12.2	active	unknown	8.67	3.53	1.87	0.80	47.20	77.30
GW031927	12.2	active	unknown	7.44	4.76	3.05	1.98	35.89	58.52
GW031928	22.9	active	unknown	7.23	15.67	13.85	12.92	11.62	17.57
GW032080	10.4	active	domestic	7.93	2.47	1.93	1.36	22.10	44.87
GW032116	13.7	active	unknown	**11.98**	1.72	1.18	0.80	31.31	53.60
GW032136	12.2	active	unknown	8.83	3.37	1.43	-0.09	57.63	102.81
GW032232 *	13.4	inactive	not used	8.67	4.73	3.85	3.05	18.66	35.46
GW032233 *	11.44	active	domestic	**10.66**	0.78	-0.19	-0.96	124.09	222.77
GW032234 *	13.1	inactive	not used	8.55	4.55	3.64	2.91	19.98	35.94
GW032235 *	8.93	active	opportunity if not dry – stock?	**8.60**	0.33	-0.74	-1.53	322.73	563.71
GW032246	12.2	active	unknown	10.34	1.86	1.26	0.78	32.63	58.19
GW032247	12.2	active	unknown	**9.30**	2.90	2.33	1.86	19.79	35.83
GW032249 *	12.5	active	not known	**9.56**	2.94	1.62	0.73	44.85	75.20

Reg Number	Bore Depth (m)	License status	Registered use	Initial depth to water* (m)	Initial water column height (m)	Modelled minimum water column (1A)	Modelled minimum water column (1B)	% reduction 1A	% reduction 1B
GW032251	12.2	active	not known	**12.20**	0.00	-1.50	-2.63	150.00	263.00
GW032252	11.6	inactive	irrigation	9.54	2.06	0.61	-0.83	70.27	140.48
GW032254	11.6	active	domestic	**9.23**	2.37	1.01	-0.41	57.40	117.15
GW032265	18.2	active	general use	**15.38**	2.82	2.56	2.22	9.23	21.29
GW032290	14.6	decommissioned	previous irrigation	7.77	6.83	4.72	2.83	30.98	58.60
GW032291 *	11	not used	not known	7.81	3.19	1.41	-0.28	55.74	108.84
GW035052	13.4	cancelled	irrigation	6.53	6.87	4.68	2.85	31.98	58.60
GW043433	10.4	active	stock	9.85	0.55	0.38	0.08	29.80	85.58
GW043448	9.9	active	stock	10.57	-0.67	-0.77	-0.95	-14.34	-41.03
GW053270	16.4	active ?	irrigation	**9.41**	6.99	6.00	5.20	14.13	25.65
GW053271	19	cancelled	domestic	**8.83**	10.17	8.45	7.36	16.91	27.60
GW053309	17.7	lapsed	stock, domestic	**6.80**	10.90	8.70	6.87	20.16	36.95
GW053593	31.3	active	irrigation	11.24	20.06	20.02	19.95	0.20	0.58
GW054713	30.5	active	stock. domestic	16.80	13.70	13.39	12.97	2.29	5.33
GW055081	23.8	active	stock, domestic	**7.72**	16.08	15.83	15.49	1.57	3.65
GW057944	45	entitlement sold to BCOPL	previously irrigation	7.96	37.04	34.75	32.77	6.17	11.54
GW071936	18	active	stock, domestic	10.97	7.03	6.89	6.64	1.86	5.47
GW072013	12.2	active	stock	**10.00**	2.20	1.58	1.13	28.18	48.76

Reg Number	Bore Depth (m)	License status	Registered use	Initial depth to water* (m)	Initial water column height (m)	Modelled minimum water column (1A)	Modelled minimum water column (1B)	% reduction 1A	% reduction 1B
GW103405	50	active	irrigation	8.88	41.12	40.22	39.42	2.19	4.15
GW900014	46.5	active	not used	7.97	38.53	36.85	35.29	4.36	8.42
GW900024	53.3	active	irrigation	**11.00**	42.30	41.85	41.50	1.06	1.89
GW900106	53.3	active	stock, domestic, irrigation	11.12	42.18	42.15	42.10	0.06	0.19
GW900743	53	active	irrigation	**11.00**	42.00	41.73	41.51	0.65	1.16
GW901414	32.3	active	irrigation	**9.97**	22.33	20.28	18.84	9.20	15.63
GW901835	42.1	active	irrigation	**11.00**	31.10	30.89	30.70	0.67	1.30
GW901836	67	active	irrigation	9.45	57.55	57.47	57.31	0.14	0.41
GW965386	45.5	active	irrigation	9.05	36.45	35.52	34.74	2.56	4.69
GW967252	32	active	stock/domestic	**9.24**	22.76	22.24	21.69	2.30	4.72
GW967663	34	active	stock	9.71	24.29	23.05	22.19	5.13	8.64
GW968402	21	entitlement sold to BCOPL	stock, domestic	**7.85**	13.15	10.93	9.11	16.86	30.75
GW970167	79.5	active	irrigation	**11.50**	68.00	67.97	67.92	0.04	0.11
GW970797	54	active	domestic/stock	**13.41**	40.59	39.45	38.67	2.81	4.73

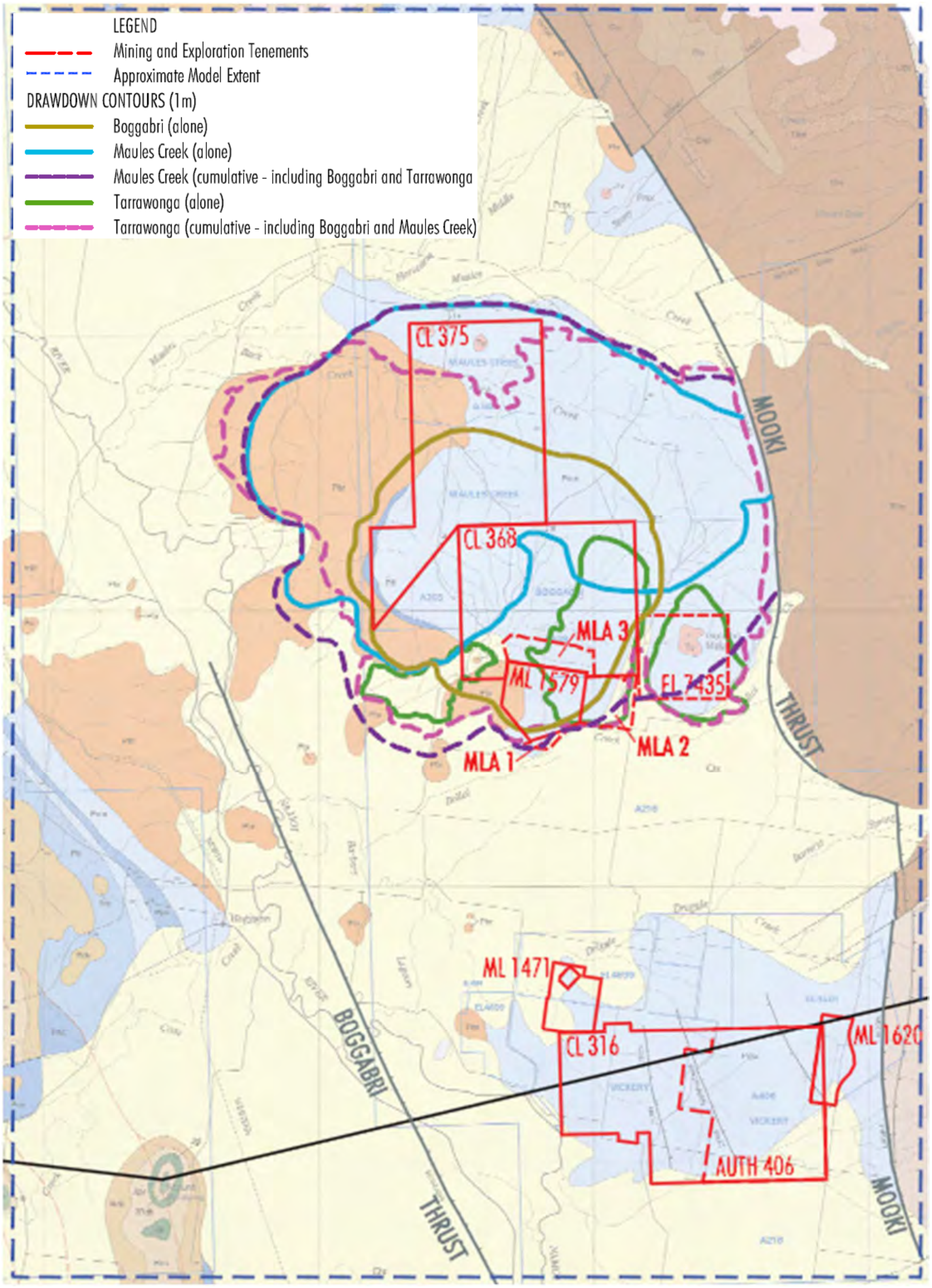
= **Bold** refers to measured values obtained from 2015 hydrocensus or records obtained in the last 5 years. Normalised text is modelled water levels

* = concrete lined well

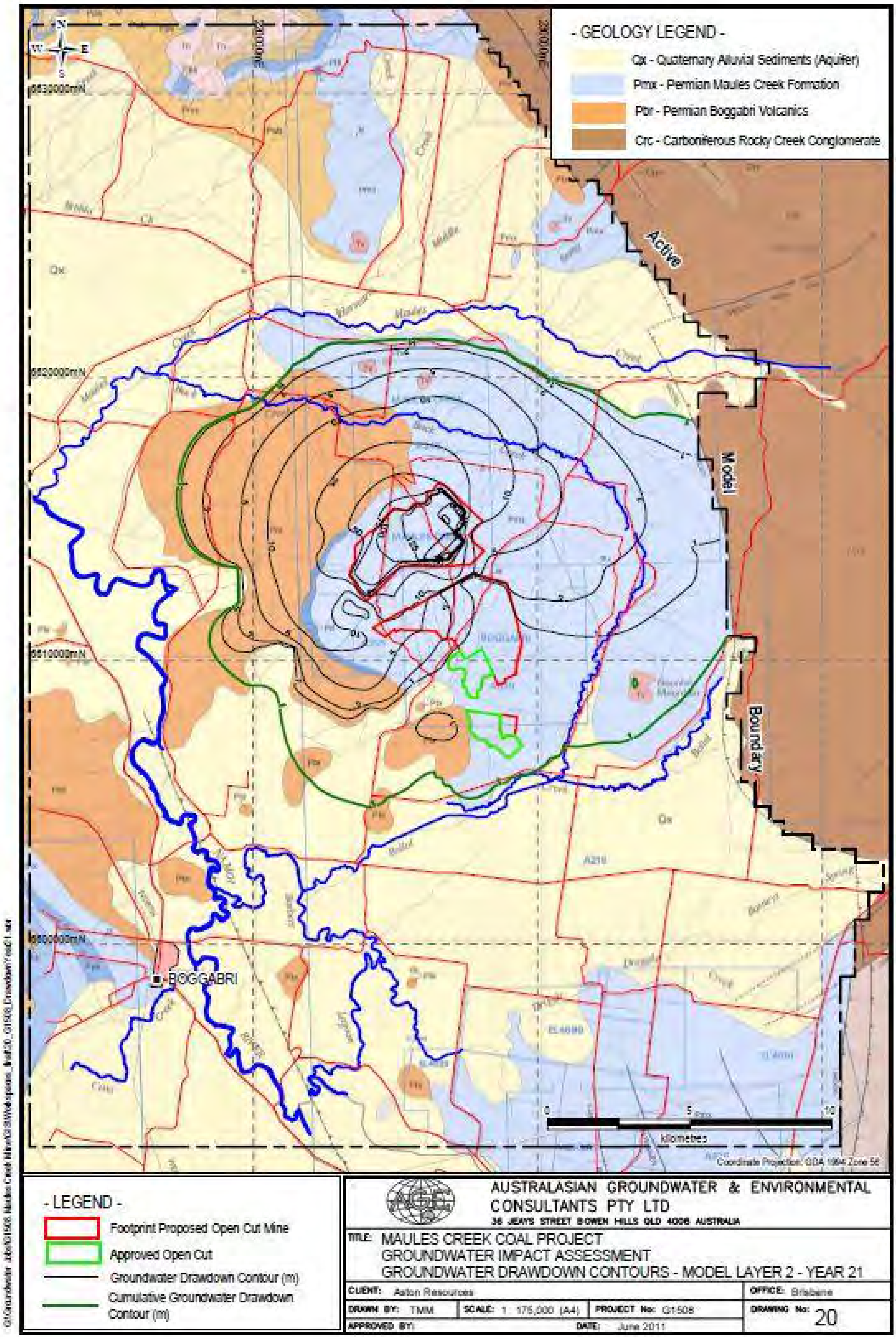
Note that four bores (scenario 1A) or eight bores (scenario 1B) may temporarily fall dry during the 17 year pumping period (indicated with a negative minimum water column for the scenarios). All those bores are associated with an initial water column of less than 3.4 m

Appendix G

Plan of cumulative drawdown of three coal mines



Predicted 1m Watertable Drawdown Extents by Various Models (Heritage Computing, 2012b, Figure 6)



Predicted cumulative drawdown by AGE (2011) after 21 years. Conducted for Maules Creek Project groundwater impact assessment