Appendix H

Groundwater Impact Assessment

Australasian Groundwater & Environmental Consultants

Report on

Groundwater Impact Assessment Boggabri Coal Mine MOD8 to SSD 09_0182

Prepared for
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Executive summary

The Boggabri Coal Mine (BCM) is located approximately 15 kilometres (km) northeast of the township of Boggabri in northwestern NSW. The proposed modification (MOD 8) involves increasing the depth of mining within the currently approved mine disturbance boundary from the currently approved Merriown Coal Seam to the deeper Templemore Coal Seam. MOD 8 will require an increase of six years to the mine life, with coal extraction until the end of 2039. A Groundwater Impact Assessment (GIA) was undertaken to assess the impact of the MOD 8 on the groundwater regime. The GIA comprised two parts, firstly a description of the existing hydrogeological environment, and secondly an assessment of MOD 8 on that environment. The scope of the GIA was designed to address state/federal assessment requirements under the NSW Aquifer Interference Policy (AIP) and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The most productive groundwater system in the area is the Gunnedah Formation which is present within the lower parts of the Quaternary alluvium. Less productive groundwater systems occur within the shallow alluvium (Narrabri Formation) and parts of the Permian coal measures. Basement volcanics form a relatively impermeable unit and are found underlying both the alluvium and the coal measures. The productivity of these groundwater systems is reflected in the local Water Sharing Plans (WSPs), which specifies that the 'highly productive' Upper Namoi Alluvium and the 'less productive' Gunnedah-Oxley Basin Porous Rock is present in the region.

The impact of MOD 8 on the groundwater regime was assessed using a 3D numerical groundwater flow model that was developed to represent the cumulative impacts of the Boggabri, Tarrawonga, and Maules Creek Complex (BTM Complex). This model has been incrementally refined and updated over more than a ten year period, with the most recent significant update completed in December 2020. The current version of the model provides a sophisticated and robust assessment tool that is based on an ever improving understanding of the groundwater regime in the region. The currently approved mining at BCM and the proposed mining for MOD 8 was represented in the numerical model. The potential impacts after mining ceases were also assessed over a period of 1,000 years by continuing the simulations under long-term average climatic drivers.

The model simulations indicated that cumulative impacts of MOD 8 would largely meet the AIP's Level 1 minimal impact considerations, while incremental impacts relative to approved mining would meet all of the AIP's Level 1 minimal impact considerations. Water table or water pressure declines of more than 2 m are not predicted at any water supply work within alluvial water sources, while predicted exceedances within the Gunnedah-Oxley Basin Porous Rock Water Source for cumulative mining are unlikely to require any make good provisions. The predicted decline in water table and water pressure is predominately due to approved mining, with the incremental impact of MOD 8 being negligible. The nature of impacts associated with MOD 8 indicates that the beneficial use of surrounding groundwater systems will not be affected, and that no long-term salinity increases in any connected surface water bodies will occur. The modelling indicated that water table drawdown from cumulative impacts at the end of mining could impact several high priority Groundwater Dependent Ecosystems (GDEs) and exceed the Level 1 minimal impact consideration provided in the AIP, as listed under the relevant WSPs. Previous investigations have indicated that some of these GDEs are unlikely to represent vegetation that is solely reliant upon groundwater. Potential impacts to these GDEs have been considered as part of original approval investigations for the BTM Complex mines and the negligible incremental impacts of MOD 8 do not alter the findings of those assessments.

MOD 8 is not predicted to generate an impact that is considered significant according to guidelines supporting the *EPBC Act.* This is because predicted changes associated with MOD 8 are not of sufficient scale or intensity as to significantly reduce the quantity or quality of the water resource for third party users or the environment.

There is no need for MOD 8 remedial action given that specific impacts to groundwater assets are predicted to be minimal relative to approved mining, and additional groundwater take can be accommodated by existing licences. An in-field assessment of the potentially impacted private registered bore (GW002523) is recommended. It is also recommended that the existing monitoring network is supplemented with additional new monitoring bores installed in the Quaternary alluvium to the southwest of BCM, as well as a number of deep multi-level monitoring sites, both within the approved mine disturbance boundary and further to the east of the approved BCM mining area.

Groundwater Impact Assessment
Boggabri Coal Mine Modification 8 to SSD 09_0182

1 Introduction

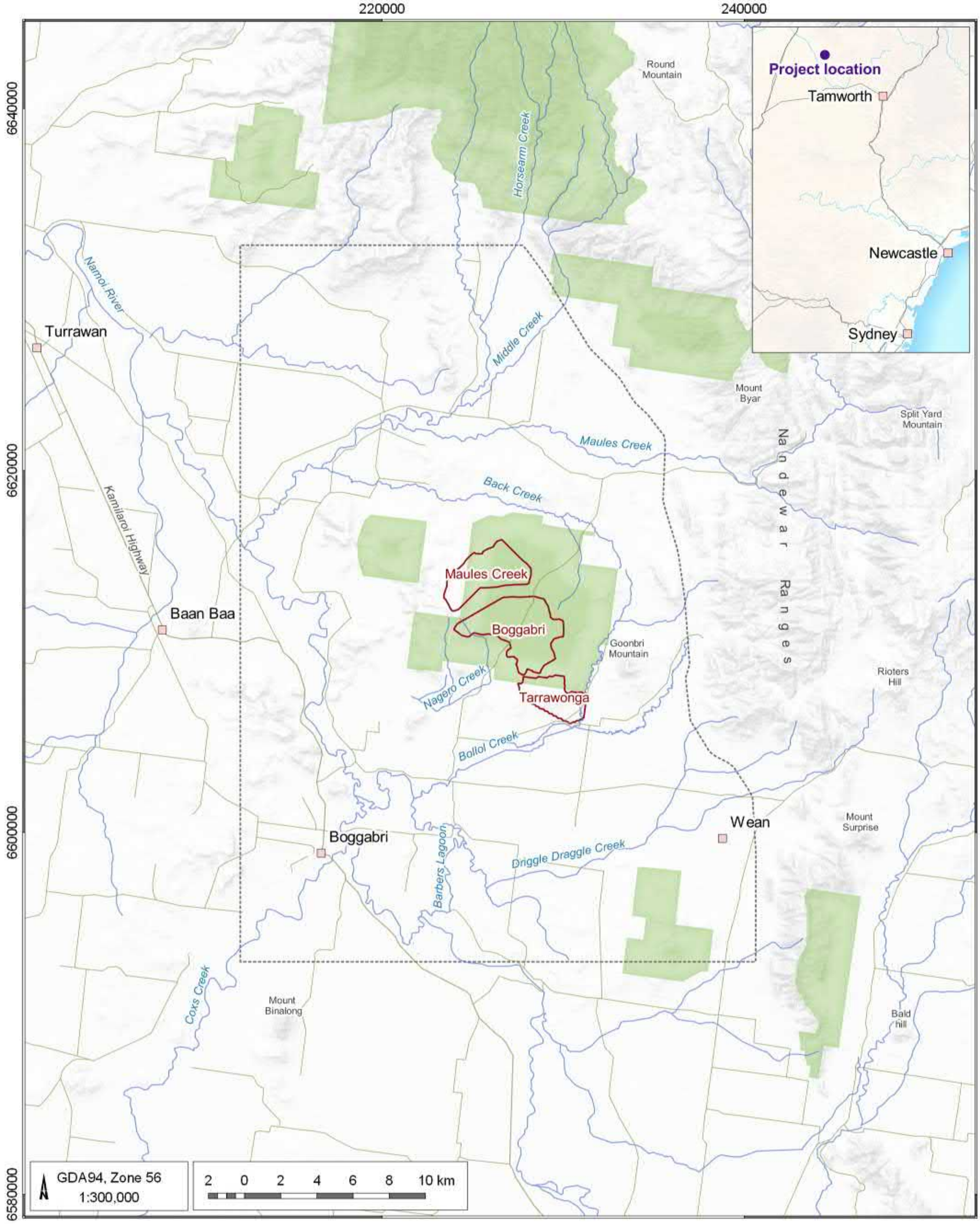
The Boggabri Coal Mine (BCM) is located in the Gunnedah Basin, approximately 15 kilometres (km) northeast of the township of Boggabri in northwestern NSW (Figure 1.1). BCM is operated on behalf of Idemitsu Australia Resources (IAR) via its subsidiary company Boggabri Coal Pty Ltd (BCOPL) (80%) and its joint venture parties (Chugoku Electric Power Australia Resources Pty Ltd (10%) and NS Boggabri Pty Ltd (10%)). BCOPL currently holds State Significant Development (SSD) Approval 09_0182 to conduct open cut mining operations down to the Merriown Coal Seam, at a rate of up to 8.6 Million tonnes per annum (Mtpa) of Run of Mine (ROM) coal until the end of 2033.

BCOPL proposes to modify SSD 09_0182 (MOD 8) to include the following:

- Increasing the approved maximum depth of mining down to the Templemore Coal Seam to recover an additional 61.6 Million tonnes (Mt) of Run of Mine (ROM) coal within the currently approved Mine Disturbance Boundary. It is expected that the additional ROM coal will be suitable for producing a lower ash, higher energy thermal, semi-soft coking and pulverised coal injection (PCI) quality products for sale to the export market. This will result in the extension of the mine life by six years.
- Construction of a specifically designed fauna movement crossing over the existing haul road between the overburden emplacement area (OEA) and the western side of the regional biodiversity corridor. The establishment of the fauna movement crossing is proposed to improve the movement of fauna from the Leard State Forest through the Southern Rehabilitation Area (SRA).

Increases in the depth of mining will occur on a staged basis, with extraction below the Merriown Coal Seam planned to first occur in 2022.

This Groundwater Impact Assessment (GIA) has been prepared by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) as part of the Modification Report for MOD 8. The Modification Report is to be prepared by Hansen Bailey on behalf of BCOPL.



LEGEND

- Populated place
- Road
- Drainage
- Extent of mining
- Investigation area
- State Forest/National Park/Nature Reserve/Recreation Area

Boggabri MOD8 (G1850W)

Project location

AGE

DATE 14/07/2021

FIGURE No: **1.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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1.1 Objectives and scope of work

The objectives of this GIA are to assess the impact of MOD 8 on the groundwater regime and to address the requirements of NSW/Federal government legislation and policies. The GIA comprises two parts, a review of the existing hydrogeological environment, and an assessment of mining impacts on that environment.

Works included:

- summarising existing background data and previous hydrogeological investigations (Sections 3 to 6);
- updating the existing cumulative groundwater model for the Boggabri, Tarrawonga, Maules Creek (BTM) mining complex (BTM Complex), which was recently developed and updated to address comments from the NSW Government (Section 7 and Appendix A);
- assessing cumulative and BCM specific impacts as a result of MOD 8 (Section 8);
- assessing potential groundwater dependent ecosystem (GDE) impacts as a result of changes to the regional groundwater system (Section 8);
- assessing the potential third party impacts (i.e. private bores) as a result of changes to the regional groundwater system (Section 8);
- assessing against the Aquifer Interference Policy (AIP) and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Sections 8 to 8.2.4); and
- provision of recommendations for the management of groundwater impacts including recommendations for monitoring (Section 10).

2 Regulatory framework

The GIA was undertaken in accordance with the scope requested by Hansen Bailey on behalf of BCOPL, dated 13 May 2020, and with reference to the Secretary's Environmental Assessment Requirements (SEARs), which was issued by the NSW Department of Planning Industry and Environment (DPIE) on 8 June 2021. In addition, MOD 8 needs to consider the requirements of the following legislation, policy, and guidelines for groundwater:

- NSW Government:
  - *Water Act 1912*;
  - *Water Management Act 2000* and the associated Water Sharing Plans (WSP);
  - AIP (2012);
  - Groundwater Quality Protection Policy (1998);
  - Groundwater Dependent Ecosystems Policy (2002); and
  - Groundwater Quantity Management Policy (Policy Advisory Note No. 8).
- Commonwealth Government:
  - EPBC Act and related Independent Expert Scientific Committee (IESC) information guidelines for coal seam gas (CSG) and large coal mining development proposals, as well as Department of Agriculture Water and the Environment (DAWE) guidelines.

Sections below summarise the intent of the above legislation, policy, and guidelines, with details on how they apply to MOD 8 provided.

2.1 Water Act 1912

The *Water Act 1912* regulates water sources including rivers, lakes, and groundwater aquifers across the state. The trade of water licences and allocations are also managed. The *Water Management Act 2000* is progressively replacing the *Water Act 1912* in NSW and applies where a WSP is in place.

2.2 Water Management Act 2000

The NSW *Water Management Act 2000* provides for the 'protection, conservation and ecologically sustainable development of the water sources of the State'. The *Water Management Act 2000* provides arrangements for controlling land-based activities that affect the quality and quantity of the state's water resources.

The *Water Management Act 2000* includes the concept of 'no more than minimal harm' for both the granting of water access licences (WALs) and the granting of approvals. Aquifer interference approvals are not to be granted unless the Minister is satisfied that adequate arrangements are in force such that no more than minimal harm will be done to any water source, or its dependent ecosystems, as a consequence of it being interfered with in the course of the activities to which the approval relates. The requirement for an aquifer interference approval under the *Water Management Act 2000* has not yet been triggered/commenced and therefore an aquifer interference approval is not required.

The AIP establishes and objectively defines minimal impact considerations under the *Water Management Act 2000* as they relate to water-dependent assets and as the basis for providing advice to the assessment and/or determining authority.

2.3 Aquifer Interference Policy

The *Water Management Act 2000* defines an aquifer interference activity as involving any of the following:

- penetration of an aquifer;
- interference with water in an aquifer;
- obstruction of the flow of water in an aquifer;
- taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations; and
- disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.

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

The AIP states that:

> '*all water taken by aquifer interference activities, regardless of quality, needs to be accounted for within the extraction limits defined by the water sharing plans. A water licence is required under the Water Management Act 2000 (unless an exemption applies, or water is being taken under a basic landholder right) where any act by a person carrying out an aquifer interference activity causes:*
>
> - *the removal of water from a water source; or*
> - *the movement of water from one part of an aquifer to another part of an aquifer; or*
> - *the movement of water from one water source to another water source, such as:*
>   - *from an aquifer to an adjacent aquifer; or*
>   - *from an aquifer to a river/lake; or*
>   - *from a river/lake to an aquifer.'*

Proponents of aquifer interference activities are required to provide predictions of the volume of water to be taken from a water source as a result of the proposed activity. These predictions need to occur prior to approval. After approval and during operations, these volumes need to be measured and reported in an annual review or environmental management reports. The WAL must hold a sufficient share component and water allocation to account for the take of water from the relevant water source when the take occurs.

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

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

- '*water level, quality or pressure drawdown impacts on nearby water users who are exercising their right to take water under a basic landholder right;*
- *water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources;*
- *water level, quality or pressure drawdown impacts on groundwater dependent ecosystems;*
- *increased saline or contaminated water inflows to aquifers and highly connected river systems;*
- *to cause or enhance hydraulic connection between aquifers; and*
- *for river bank instability, or high wall instability or failure to occur.'*

In particular, the AIP describes minimal impact considerations for aquifer interference activities based upon whether the water source is highly productive or less productive and whether the water source is alluvial or porous/fractured rock in nature. The AIP minimal impact considerations are used to evaluate impacts on groundwater sources, connected water sources and their dependent ecosystems, culturally significant sites, and water users.

A 'highly productive' groundwater source is defined by the AIP as a groundwater source which has been declared in regulations and datasets, based on the following criteria:

- has a total dissolved solids (TDS) concentration less than 1,500 milligrams per litre (mg/L); and
- contains water supply works that can yield water at a rate greater than 5 litres per second (L/s).

Groundwater sources are further grouped by geology into alluvial, coastal sands, porous rock, and fractured rock. 'Less productive' groundwater sources are all other aquifers that do not satisfy the 'highly productive' criteria for yield and water quality.

The NSW Department of Planning, Industry and Environment – Water (DPIE-Water) has mapped areas of groundwater productivity across NSW, which shows that within the investigation area, the only 'highly productive' groundwater sources are associated with the alluvial plains (Figure 2.1).

The minimal impact considerations are a series of threshold levels defining minimal impact on groundwater sources, connected surface water sources, groundwater dependent ecosystems, culturally significant sites, and water users. The thresholds specify water table and groundwater pressure drawdown as well as groundwater and surface water quality changes. Sections 8 and 8.2.4 present the project impacts and compares these with AIP thresholds, where relevant.

2.4 Water Sharing Plans

Within the study area, groundwater is managed under two WSPs, namely the:

- Water Sharing Plan for the Upper and Lower Namoi Groundwater Sources Order 2020; and
- Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources Order 2020.

The WSP for the *Upper and Lower Namoi Groundwater Sources* includes all water contained in unconsolidated alluvial sediment aquifers, which are associated with the Namoi River and its tributaries. Alluvial aquifers are divided into a number of management zones, with Upper Zone 11, Upper Zone 5, Upper Zone 4 and Upper Zone 2 present in the investigation area (Figure 2.1).

Outside of the alluvial areas, groundwater is managed under the Gunnedah-Oxley Basin sub-division of the WSP for the *NSW Murray Darling Basin Porous Rock Groundwater Sources*. This sub-division includes all rocks that are Permian, Triassic, Jurassic, Cretaceous and Tertiary in age, as well as any alluvial sediments within outcropped areas.

Under 2020 updates to the WSPs, high potential terrestrial GDEs, as defined in the GDE Atlas of Australia (BoM, 2019), are now considered high priority GDEs under the *Water Management Act 2000*. As such, the minimal impact considerations of the AIP need to be considered.

Each groundwater management zone has a specific number of WALs, which pertain to a total annual entitlement (not including basic access rights). A comparison between the total entitlements for each management zone and the entitlements held by BCM are provided below in Table 2.1.

Table 2.1 Water access licence entitlements

Groundwater Source	Total number of WALs	Total entitlement (units shares) [a/b]	BCM entitlement (unit shares) [a/b]
Upper Zone 11	29	2,223	20
Upper Zone 5	76	15,992	0
Upper Zone 4	167	21,032	1,028
Upper Zone 2	30	7,141	0
Gunnedah-Oxley Basin	144	23,109	842

Notes: Data taken from the WaterNSW Water Register for the 2019/2020 financial year accessed: *https://waterregister.waternsw.com.au/water-register-frame;*

(a) ML – megalitres; and

(b) Unless the Minister otherwise determines, at the commencement of each water year an available water determinations of 1 ML per unit share for all listed Groundwater Sources. Maximum carryover of remaining water allocation account is equal to 1 ML per unit share for the Gunnedah-Oxley Basin Groundwater Source, and 2 ML per unit share for all listed alluvial Groundwater Sources.

The flow in the Namoi River is regulated by releases from Keepit Dam. The Namoi River is classified as the Upper Namoi Regulated Water Source and is managed under the WSP for the Upper Namoi and Lower Namoi Regulated River Water Sources 2016. All other surface water in the investigation area is managed under the WSP for the Namoi and Peel Unregulated Rivers Water Sources 2012.

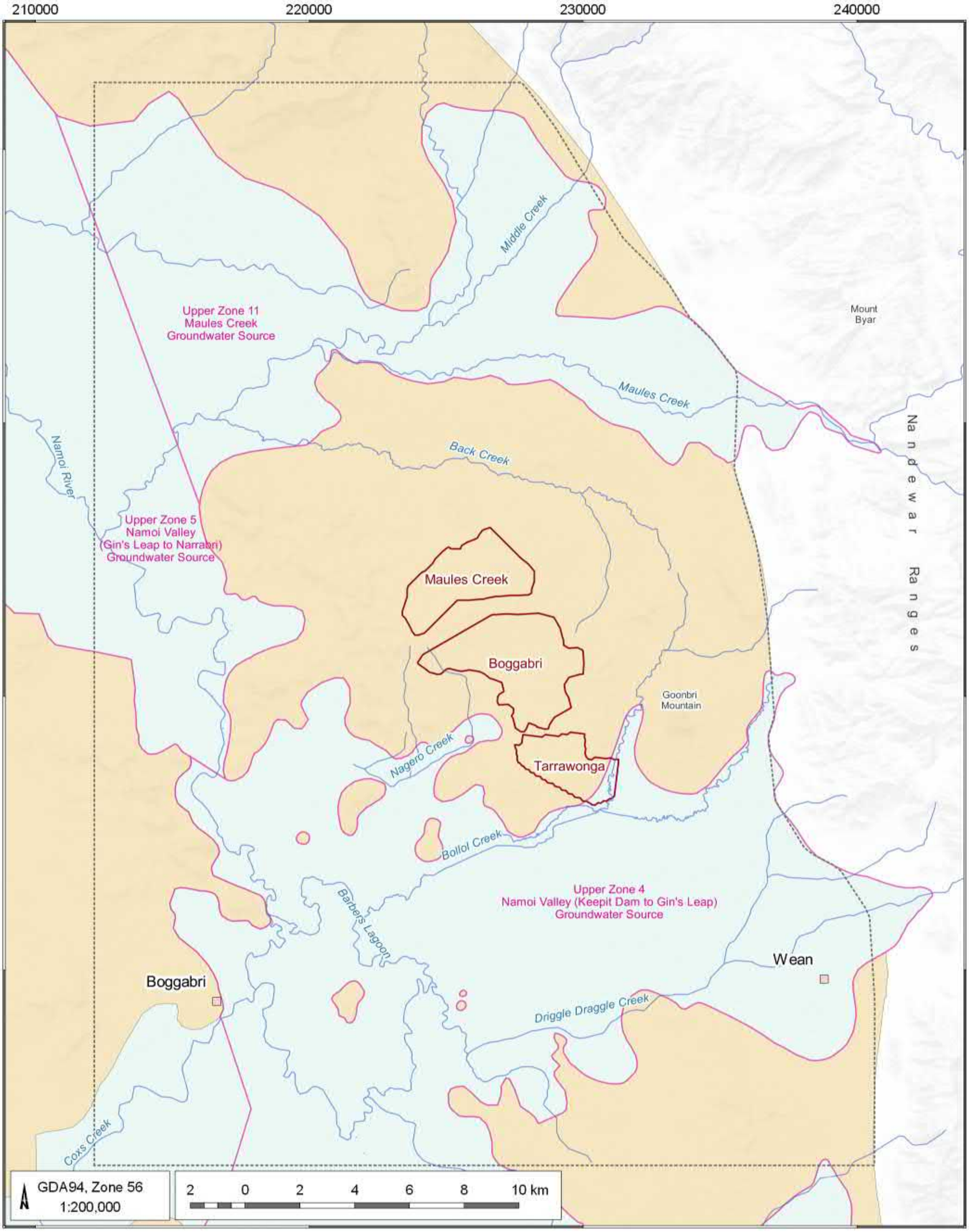
2.5 Existing approval conditions

As discussed in Section 1, BCOPL currently holds SSD Approval 09_0182, which details groundwater specific approval requirements that include the implementation of a Groundwater Management Plan (condition 38(c)) and a Leard Forest Mining Precinct Water Management Strategy (condition 38(d)). These conditions state that BCOPL are required to:

> *'co-ordinate modelling programs [with surrounding mines] for validation, re-calibration and re-running of the groundwater and surface water models using approved mine operation plans* (condition 38(d)); and
>
> *[implement] a program to validate the groundwater model for the project, including an independent review of the model every 3 years, and comparison of monitoring results with modelled predictions (condition 38(c)).'*

Existing operations are also approved under the EPBC Act as per the Boggabri Coal Mine Extension approval (EPBC 2009/5256).

This GIA assesses the impact of MOD 8 using recent updates to the BTM Complex's cumulative 3D numerical groundwater flow model (AGE, 2020). This cumulative model has seen continuous refinements and updates over more than a ten year period and the current iteration has been subject to multiple phases of review by the Natural Resources Access Regulator (NRAR) and the water division of DPIE.



LEGEND

- Populated place
- Drainage
- Extent of mining
- Groundwater source
- Investigation area

Aquifer productivity

- High - Alluvial
- Less - Porous rock

Boggabri MOD8 (G1850W)

Groundwater Sources and aquifer productivity

AGE

DATE 14/07/2021

FIGURE No: **2.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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2.6 Commonwealth Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act is Commonwealth legislation administered by the DAWE and is designed to protect national environmental assets, known as matters of national environmental significance (MNES). Under the 2013 amendment to the EPBC Act (the water trigger), significant impacts on water resources associated with coal mining and/or coal seam gas (CSG) developments were included as MNES.

To guide compliance with the EPBC Act, the DAWE have issued a number of guidelines, which include the:

- significant impact guidelines 1.1: Matter of National Environmental Significance;
- significant impact guidelines 1.2: Actions on, or impacting upon, Commonwealth land, and actions by Commonwealth agencies; and
- significant impact guidelines 1.3: Coal seam gas and large coal mining developments - impacts on water resources.

The bilateral agreement under the EPBC Act with the NSW Government notes that NSW should seek and consider expert advice from the IESC in relation to coal seam gas or large coal mining developments that are likely to have a significant impact on water resources. The Information Guidelines developed by the IESC outline the information considered necessary to enable the IESC to provide robust scientific advice to government regulators on the water-related impacts of CSG and large coal mining development proposals. The Information Guidelines have been considered during the preparation of this GIA, as well as associated explanatory notes, which include:

- Information guidelines for proponents preparing coal seam gas and large coal mining development proposals (Commonwealth of Australia, 2018);
- Uncertainty analysis – Guidance for groundwater modelling within a risk management framework (Middlemis and Peeters, 2018); and
- Assessing Groundwater Dependent Ecosystems (Doody et al, 2019).

A referral under the EPBC Act was submitted to the DAWE prior to the completion of this GIA. Within this referral, a conceptualisation of the perceived impacts that are associated with MOD 8 was presented, which was based on previous modelling and observations to date. A meeting with DAWE and the Office of Water Science (OWS) was held on 24 May 2021 to discuss the impact assessment works done to date, which included numerical model predictions. Feedback from this meeting has been considered as part of this report. DAWE determined that MOD 8 would constitute a controlled action on 28 May 2021, deeming that MOD 8 is likely to have a significant impact on:

> *'A water resource, in relation to coal seam gas development and large coal mining development'*

DPIE subsequently issued the SEARs for MOD 8 on 8 June 2021, which included a number of assessment requirements pertaining to key issues. Relevant assessment requirements have been addressed as part of this GIA, and the manner in which this has been done is tabulated in Appendix B.

3 Environmental setting

3.1 Climate

The climate of the investigation area is characterised by hot summers, with thunderstorms and comparatively mild dry winters. Climate data was sourced from the Scientific Dataset for Land Owners (SILO), for the coordinates 30.60°S, 150.15 E. The SILO dataset is used to obtain location specific climate data, which is calculated from surrounding weather stations and interpolated through splining and kriging techniques. Climate data for the 2006 to 2020 period was analysed within this section, where the start date coincides with initial mining approvals for the BCM.

The mean annual rainfall recorded over 2006 to 2020 was 618 millimetres (mm)/year, most of which falls in the warmer months of the year (November to March). Potential evaporation rates (pan evaporation) exceed rainfall throughout the year, with the highest moisture deficits occurring in summer (Table 3.1 and Figure 3.1).

Table 3.1 Summary of climate averages (January 2006 to July 2020)

Month	Mean monthly rainfall (mm)	Mean monthly pan evaporation (mm)
January	72	255
February	76	207
March	58	179
April	31	128
May	35	84
June	49	55
July	34	62
August	40	93
September	41	134
October	43	187
November	75	220
December	64	241
Annual	**618**	**1,846**

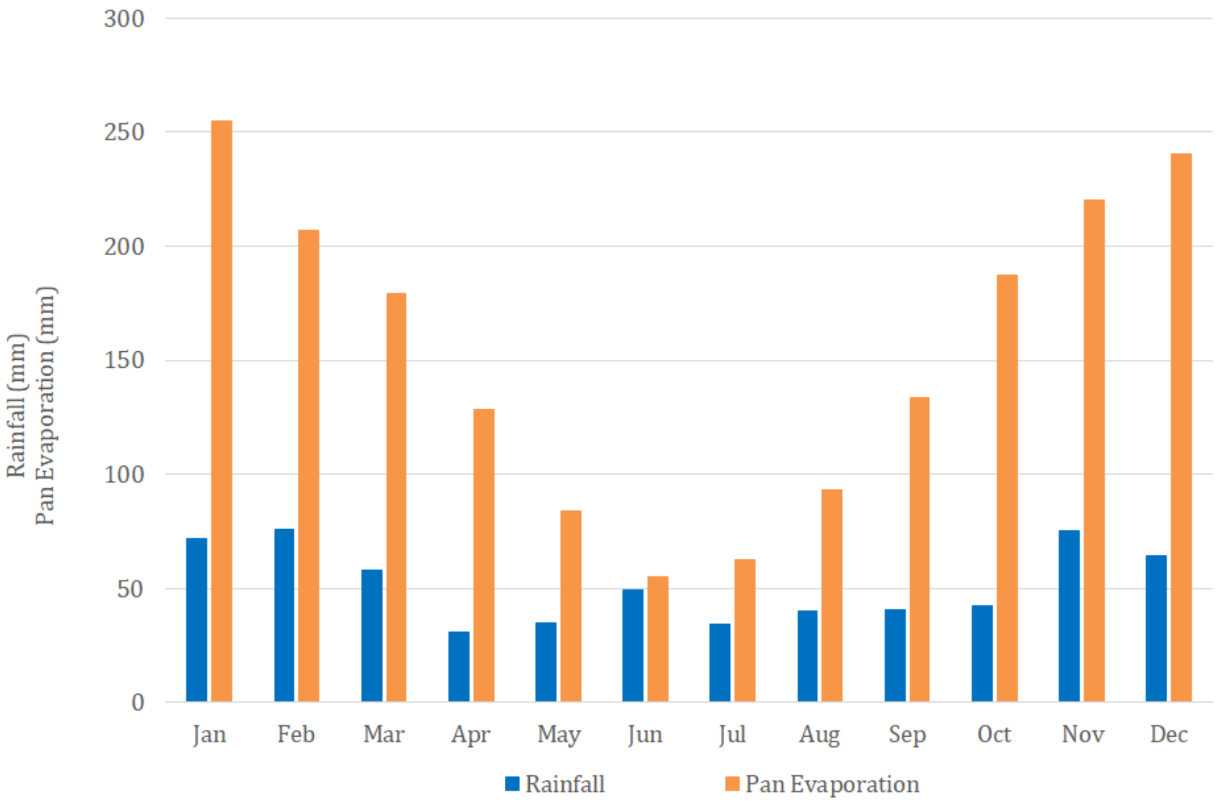


Figure 3.1 Average monthly rainfall and pan evaporation (January 2006 to July 2020)

In order to place recent rainfall years into a historical context, the cumulative rainfall departure (CRD) (also referred to as the residual rainfall mass) was calculated. The CRD is calculated by subtracting the long-term average monthly rainfall from the actual monthly rainfall, providing a monthly departure from average conditions. A rising slope in the CRD plot indicates periods of above average rainfall, while a falling slope indicates below average rainfall. A standard technique for assessing groundwater level trends is to compare the water level hydrographs with the CRD. The CRD can be used to assess if changes in groundwater levels are correlated with climatic conditions or other factors such as resource extraction, mining, irrigation etc.

Variations in CRD for the 2006 to 2020 period are shown in Figure 3.2, with longer term variations (post 1950) also provided for context. Notable trends, which occurred after the onset of mining, include a running eight year period of below average rainfall, occurring between 2012 and 2020. Since February 2020, higher than average levels of rainfall have created a rising trend in the CRD. Long term variations demonstrate the cyclic nature of drought, with the drought from 2017 to 2020 being a significant event with a rainfall deficit of some 800 mm.

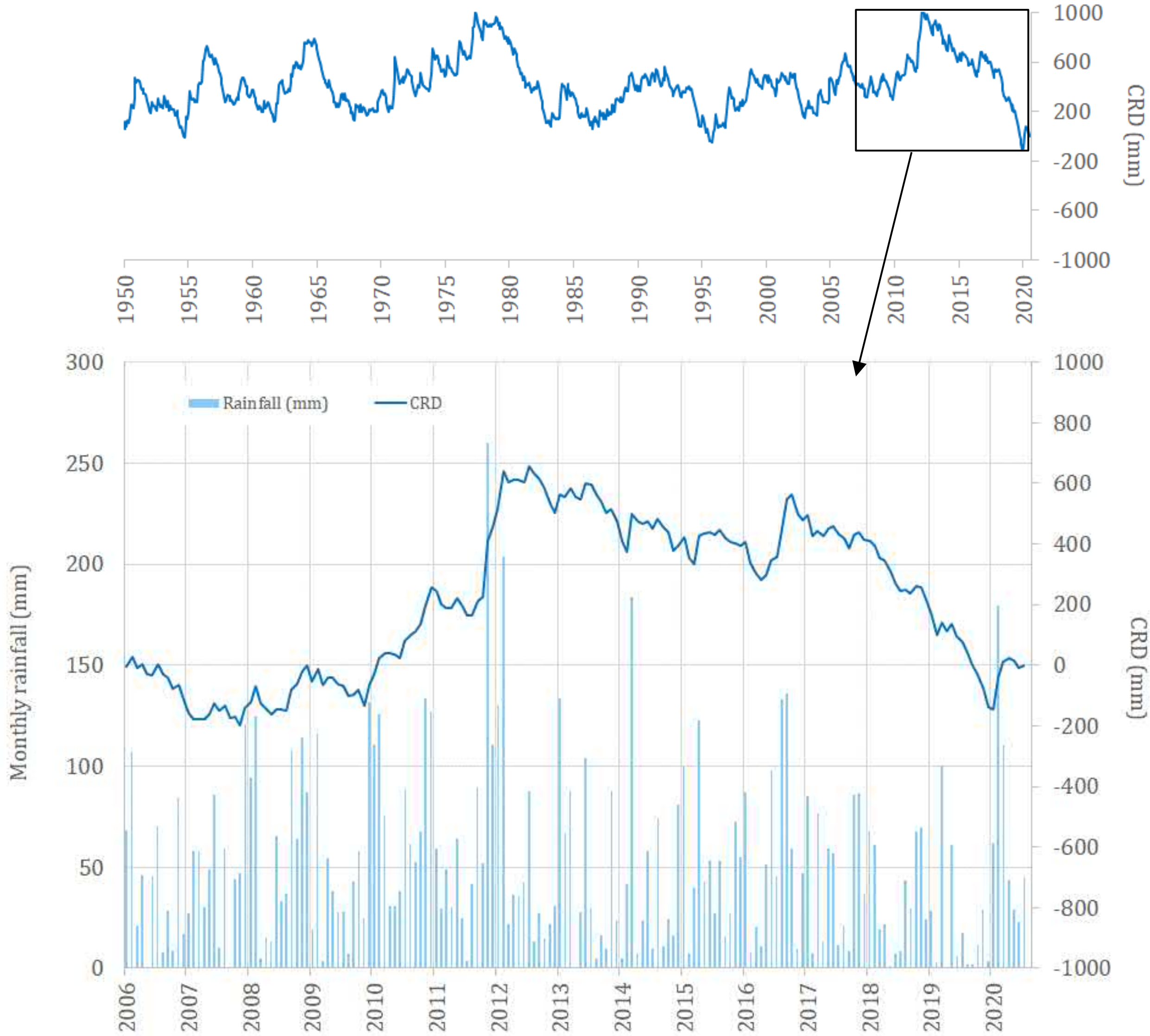
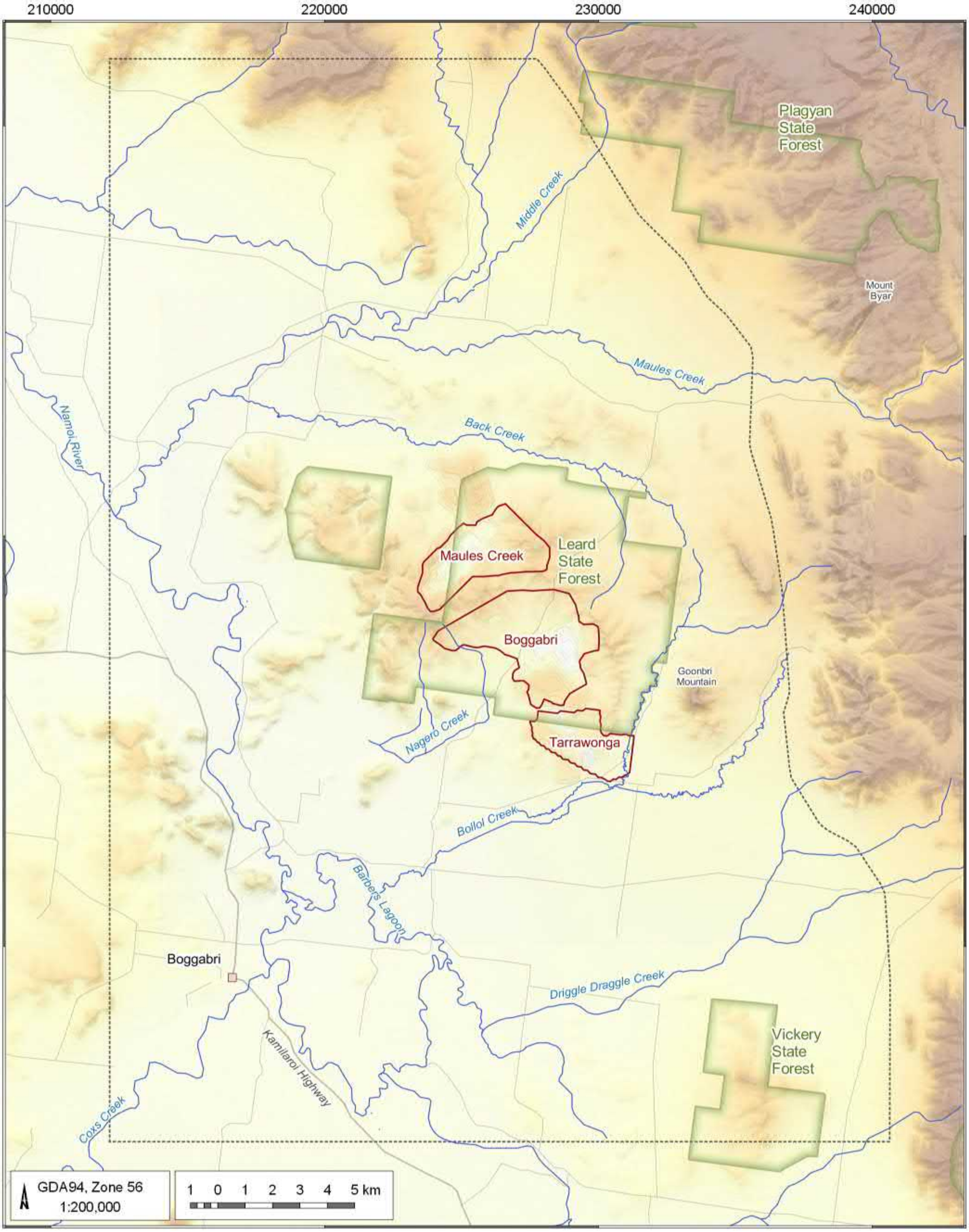


Figure 3.2 Cumulative rainfall departure

3.2 Terrain and drainage

The terrain of the investigation area and surrounds is characterised by wide and flat alluvial plains, bounded by wooded hills and ridgelines. Surface elevation is controlled by the underlying geology, with areas of higher elevation comprised of outcropping volcanic, overlain by alluvial sediments in low lying areas. BCM is the middle of three mines that form the BTM Complex and is bound by ridgelines to the north and east that rise to approximately 400 metres Australian Height Datum (mAHD) (Figure 3.3). Approximately 8 km to the east of BCM, the terrain changes to the notably more mountainous Nandewar Ranges, which form part of the Great Dividing Range. Elevations within the ranges can rise to over 1,000 mAHD.

The hills and slopes surrounding BCM are drained by a series of generally westerly flowing ephemeral creeks that meander across floodplains and discharge to the Namoi River. The Namoi River is about 8 km to 10 km west of BCM and is the most significant surface drainage feature in the area. Tributaries of the Namoi River include Maules Creek to the north of the BTM Complex and Bollol Creek to the south. These tributaries flow in a westerly direction and also have large, broad, gently sloping flood plains connecting to the Namoi River flood plain. The headwaters for the Maules Creek and Bollol Creek are both located within the Nandewar Ranges, and the upper catchments can provide large volumes of runoff to the creeks that persist for short durations. Surface water drainage from the catchment area that is occupied by BCM feeds into Nagero Creek, which is a minor tributary of the Namoi River and is located off the southwest corner of BCM The Namoi River surface flows are regulated through storage and release of water from upstream dams, which include Keepit Dam and Split Rock Dam.



LEGEND

- Road
- Drainage
- Extent of mining
- Investigation area
- State forest

Elevation (mAHD)

- 200
- 300
- 400
- 500
- 800
- 1000

Boggabri MOD8 (G1850W)

Topography

AGE

DATE 14/07/2021

FIGURE No: **3.3**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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3.3 Land use

3.3.1 Approved mining

BCM is one of three mines that form the BTM Complex, with adjacent mining taking place to the north in Maules Creek Mine and to the south in Tarrawonga Mine (Figure 3.3).

Construction of BCM commenced in 2005 with the first coal delivered to the ROM coal pad in October 2006. The current method of open cut mining allows coal extraction to occur in the uppermost seams of the Maules Creek Formation, including the Herndale, Onavale, Teston, Thornfield, Braymont, Bollol Creek, Jeralong and Merriown seams. BCM is currently approved to extract up to 8.6 Mtpa ROM coal until the end 2033 (SSD 09_0182). The mined-out areas of BCM are being progressively backfilled with waste rock as the working face advances. Rehabilitation has started over areas of the waste rock that have reached their final post-mining landform.

Mining at the Tarrawonga and Maules Creek mines commenced in 2006 and 2015 respectively, with the Tarrawonga Mine approved to extract up to 3.5 Mtpa until the end of 2030 (PA 11_0047) and the Maules Creek Mine approved to extract up to 13 Mtpa until the end of 2034 (PA 10_0318). A modification for Tarrawonga Mine (Modification 7) has recently been approved to increase the extraction rate to up to 3.5 Mtpa and modify the final landform design.

Other mining activities within the region include the Goonbri exploration licence (EL 7435) to the east of the Tarrawonga Mine, the Vickery Mine (located approximately 14 km south of BCM), and the Narrabri Mine (located approximately 27 km west-northwest of BCM). Modification 7 for the Tarrawonga Mine was approved in February 2021, which precedes the numerical modelling and reporting for this project.

3.3.2 Agriculture and forestry

BCM is situated within the Leard State Forest. Within the investigation area, forestry takes place in areas of relatively high elevation, with agricultural activities taking place in the alluvial plains and lower ridge country. The Namoi River alluvial floodplain (Figure 3.3) supports an array of agricultural enterprises. Parts of the investigation area are irrigated, using water sourced from the regulated Namoi River, or alluvial groundwater.

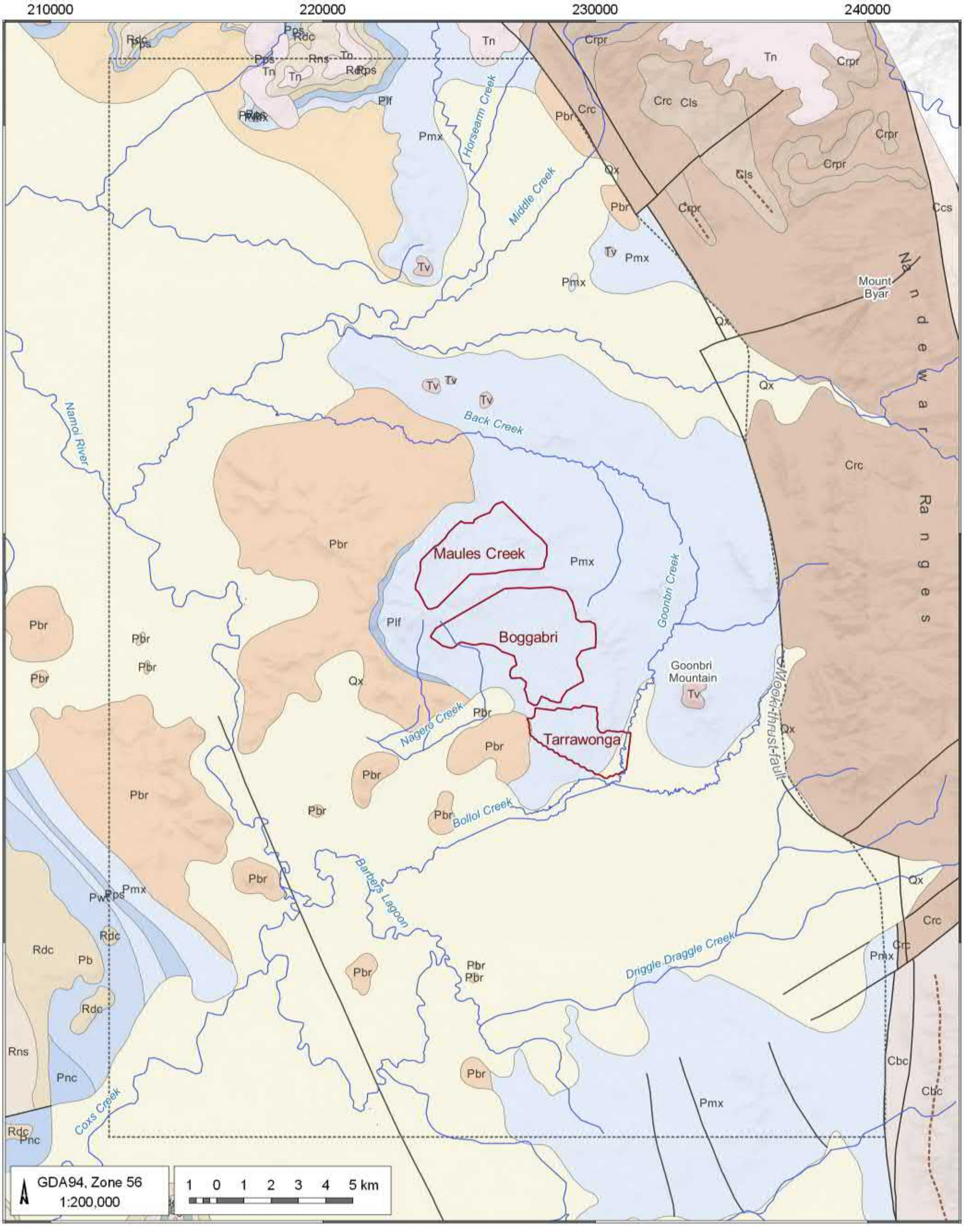
4 Geology

4.1 Regional setting and stratigraphy

BCM is located within the Maules Creek Sub-basin, which forms part of the larger Gunnedah Basin. The Maules Creek Sub-basin is separated from the Mullaley Sub-basin to the west by a north-south trending volcanic ridge (termed the Boggabri Ridge), with the Mooki Thrust Fault System forming the eastern boundary (Gunn, 2002). BCM is situated to the east of the Boggabri Ridge at the western edge of the Maules Creek Sub-basin where coal seams are present relatively close to the surface and are therefore suitable to open cut mining methods. The main stratigraphic units occurring within the investigation area and the dominant lithology within each are:

- Quaternary alluvium – unconsolidated clays, silts, sands, and gravels;
- Tertiary volcanics – basalt, dolerite, teschenite, nephelinite, and trachyte;
- Permian Maules Creek Formation – comprising multiple coal seams, interbedded with conglomerate, sandstone, and siltstone (Figure 4.2);
- Permian Leard Formation – claystone, conglomerate, sandstone, and siltstone; and
- Permian Boggabri Volcanics – Rhyolitic to dacitic lavas, tuff, and interbedded shale.

Surface geology mapping after Pratt (1998) shows that mining activities target coal seams within the Maules Creek Formation, where the coal measures subcrop to the west against the basal Boggabri Volcanics (Figure 4.1). Alluvial plains are present around Maules Creek, Bollol/Driggle Draggle Creeks and the Namoi River and are located to the north, south, and west of BCM respectively (Figure 4.1). Tertiary Volcanics and the Leard Formation are not widespread within the region.



LEGEND

- Fault
- Fold
- Drainage
- Extent of mining
- Investigation area

Gunnedah Coalfield rock unit (1:100k)

- Qx - Quaternary Sediments
- Tn - Tertiary Nandewar Volcanics
- Tv - Tertiary Volcanics
- Jgi - Glenrowan Intrusives
- Jgv - Garrawilla Volcanics
- Rns - Napperby Formation
- Rdc - Digby Formation
- Pnc - Black Jack Group
- Pb - Pamboola Formation
- Pwf - Watermark Formation
- Pps - Porcupine Formation
- Pmx - Maules Creek and Goonbri formations
- Plf - Leard Formation
- Pwb - Werrie Basalt
- Pbr - Boggabri Volcanics
- Cbc - Currabubula Formation
- Cls - Lark Hill Formation
- Crc - Rocky Creek Conglomerate
- Crpr - Plagyan Rhyodacite Tuff Member
- Ccs - Clifden Formation
- Cas - Caroda Formation

Boggabri MOD8 (G1850W)

Regional geology

AGE

DATE 14/07/2021

FIGURE No: **4.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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4.2 Alluvium

Alluvial plains surround the mined Permian outcrop (Figure 4.1) and include the:

- Maules Creek alluvium to the north of BCM;
- Bollol, Driggle Draggle and Barneys Spring Creek alluvium to the south of BCM; and
- Namoi River alluvium to the west of BCM.

There is also a small tongue of alluvium that is directly adjacent to the southwest corner of BCM, which is associated with the Nagero Creek, a minor watercourse that is fed from the catchment area occupied by BCM. Alluvium is typically divided vertically into two different geological units, namely the Narrabri Formation at surface and the underlying Gunnedah Formation. This distinction is adopted in order to characterise differences in alluvial sediments, which are generally upward-fining (Herr et al. 2018). Gates & Ross (1980) were the first to differentiate between the two alluvial units, noting that:

- the Narrabri Formation forms the surficial cover and comprises extensive overbank clays, with lesser channel sands/gravels, likely deposited by leveed meandering streams; and
- the underlying Gunnedah Formation fills the main palaeovalley floors and consists of moderately well sorted sands/gravel, with interbedded clays, likely deposited by braided streams.

Other studies of the Namoi alluvium suggest that this differentiation may be an oversimplification, where Acworth et al. (2015) states that:

> *'Detailed examination has failed to detect any evidence of a boundary between Narrabri and Gunnedah formations revealing rather a gradual change in dominance of clays and silts over sands and gravels embedded in a clay-rich matrix.'*

At a regional scale, the alluvium is generally thickest within the main Namoi River alluvial plain, thinning towards the edges of the plain and along the tributaries (McNeilage, 2006). A review of Narrabri Formation/Gunnedah Formation thicknesses indicates that alluvium is thickest where the Gunnedah Formation is present, indicating palaeochannels.

4.3 Weathering

The total thickness of surficial soils and weathered bedrock is variable and is dependent on factors such as the extent and frequency of fracturing. In the immediate vicinity of BCM, mine geological models show that the weathered thickness of the Maules Creek Formation and the Boggabri Volcanics generally ranges between 1 m and 30 m. Sandstones and conglomerates are most affected by the weathering process, while finer grained sediments can form an effective barrier to weathering. Deeper weathering profiles may occur along fractures and potential fault zones.

4.4 Coal measures

Stratigraphically, the Maules Creek Sub-basin is comprised of the Maules Creek Formation, which is underlain in part by the Leard Formation. Mining activities are limited to extraction of high quality coal seams from the Maules Creek Formation, with the underlying Leard Formation only containing a few minor coal seams of poor quality (Whitehouse, 1993). Relatively thick sequences of interburden separate coal seams and are predominately comprised of cemented conglomerate, with less frequent layers of sandstone and siltstone (Figure 4.2).

Sediments of the Maules Creek Formation generally dip between 2° and 5° to the east, although are steeper at the western edge of the basin. The sequence thickens to the east, reaching a maximum thickness between 745 m and 1,135 m near the Mooki Thrust Fault System. (Cowan, 1995). Coal seams are interpreted to have developed on a weathered palaeo-surface of varying topography, with seams in the eastern half of the basin highly split relative to mining areas at the western edge of the Maules Creek Sub-basin. The coal measures at the western edge of the Maules Creek Sub-basin either subcrop onto volcanics of the Boggabri Ridge, or weather out at this boundary if shallow (JB Mining, 2010).

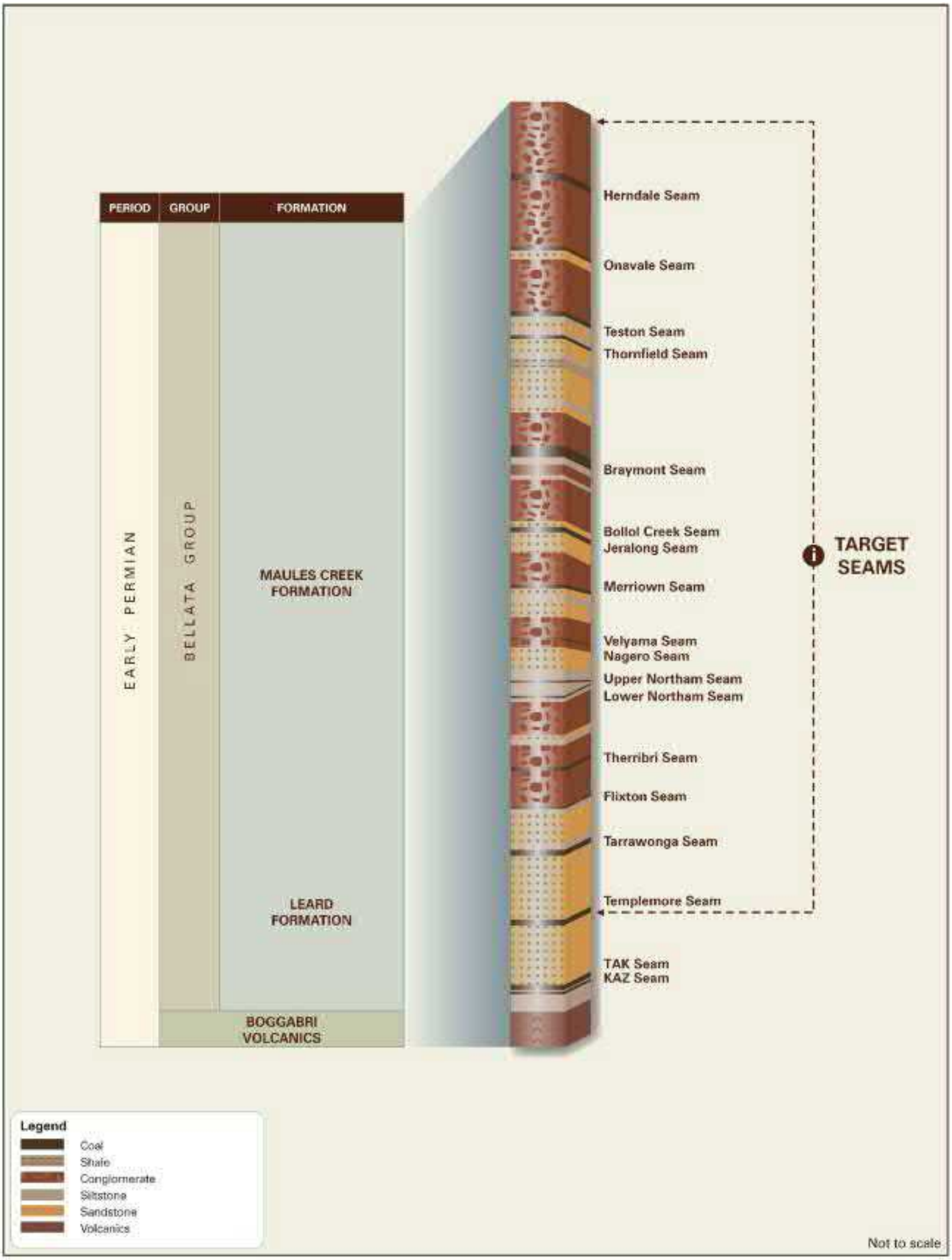


Figure 4.2 Local stratigraphic column

4.5 Boggabri Volcanics

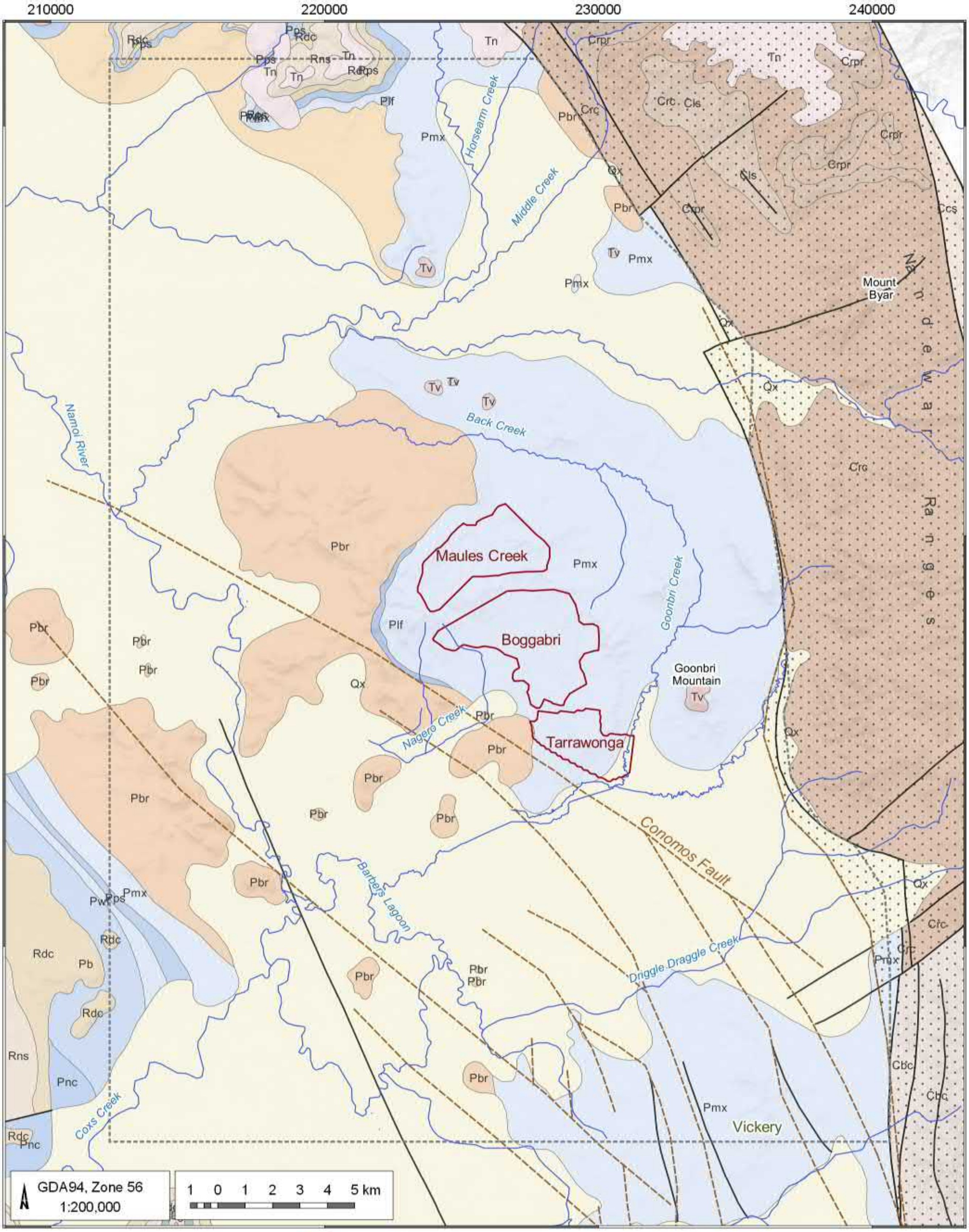
As discussed in Section 4.1, the Boggabri Ridge, which forms the western boundary of the Maules Creek Sub-basin, is comprised of silicic volcanics of the Boggabri Volcanics. The Boggabri Volcanics were formed in a small-scale rifting environment, during the late Carboniferous/early Permian (Tadros, 1995). These unconformable volcanics were then subject to extensive erosion and weathering during the very early Permian, resulting in the formation of an irregular palaeo-topography, onto which the sediments of the Maules Creek Formation were deposited.

4.6 Geological structures

A number of regional structural features have been identified within the investigation area and generally strike approximately north-south or northeast-southwest (Figure 4.3). Faulting is largely associated with the Mooki Thrust Fault System, which forms the eastern edge of the Maules Creek Sub-basin. Additional, unverified mapped faults are extensive to the south of the BCM (AGE, 2020). The Conomos Fault, which is found immediately south of BCM (Figure 4.3), has a displacement of 60 m to 90 m, north block up.

Unverified faults are consistent with the 1980s exploration work for Maules Creek Mine, which identified sub-parallel and perpendicular faulting to the Hunter-Mooki Thrust. These faults were tentatively identified within the exploration permit, with vertical throws ranging from 20 m to 50 m (AGE, 2014). This finding is again repeated in Whitehouse (1993) who noted that:

> *'… faulting, both subparallel and perpendicular to the Hunter-Mooki Fault system, has displaced a block in the southeast, with respect to the remainder of the area. Several of the other blocks have been displaced some 40 m to 50 m, by prominent faults.'*



LEGEND
- Drainage
- Regional faults and folds (Pratt 1998a)
- Regional faults (source unknown)
- Investigation area
- Mooki Thrust Fault System
- Extent of mining

Gunnedah Coalfield rock unit;(1:100k)

- Qx - Quaternary Sediments
- Tn - Tertiary Nandewar Volcanics
- Tv - Tertiary Volcanics
- Jgi - Glenrowan Intrusives
- Jgv - Garrawilla Volcanics
- Rns - Napperby Formation
- Rdc - Digby Formation
- Pnc - Black Jack Group
- Pb - Pamboola Formation
- Pwf - Watermark Formation
- Pps - Porcupine Formation
- Pmx - Maules Creek and Goonbri formations
- Plf - Leard Formation
- Pwb - Werrie Basalt
- Pbr - Boggabri Volcanics
- Cbc - Currabubula Formation
- Cls - Lark Hill Formation
- Crc - Rocky Creek Conglomerate
- Crpr - Plagyan Rhyodacite Tuff Member
- Ccs - Clifden Formation
- Cas - Caroda Formation

Boggabri MOD8 (G1850W)

Regional faulting

AGE

DATE 14/07/2021

FIGURE No: **4.3**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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5 Groundwater monitoring

Each of the BTM Complex mines have a network of monitoring bores and vibrating wire piezometers (VWP) around their mining area to monitor and detect impacts on groundwater levels and quality (Figure 5.1 and Figure 5.2). Additionally, there is a network installed further from the mining areas, which is designed to detect any cumulative impacts from the BTM Complex. The sections below describe the various campaigns previously undertaken to install the monitoring bores.

5.1 'IBC' and 'MB' series

Prior to the commencement of BCM, Parsons Brinkerhoff (2005) undertook a baseline groundwater assessment that included installing monitoring bores, permeability testing, and groundwater modelling for the first six years of the mine life. This project included the installation of the 'IBC' series of bores around the mining area, which was comprised of ten bores targeting coal seams between the Braymont and Merriown seams, as well as the volcanic basement. Many of these bores were within the approved footprint and have been removed as mining has progressed. Three bores are still active being IBC2110, IBC2111, and IBC2181.

BCOPL installed three additional 'MB' monitoring sites in late 2018 as part of groundwater management plan commitments. These sites comprised of two VWPs installed into the interburden/Merriown Seam and a single adjacent monitoring bore installed into alluvium.

5.2 'REG' series

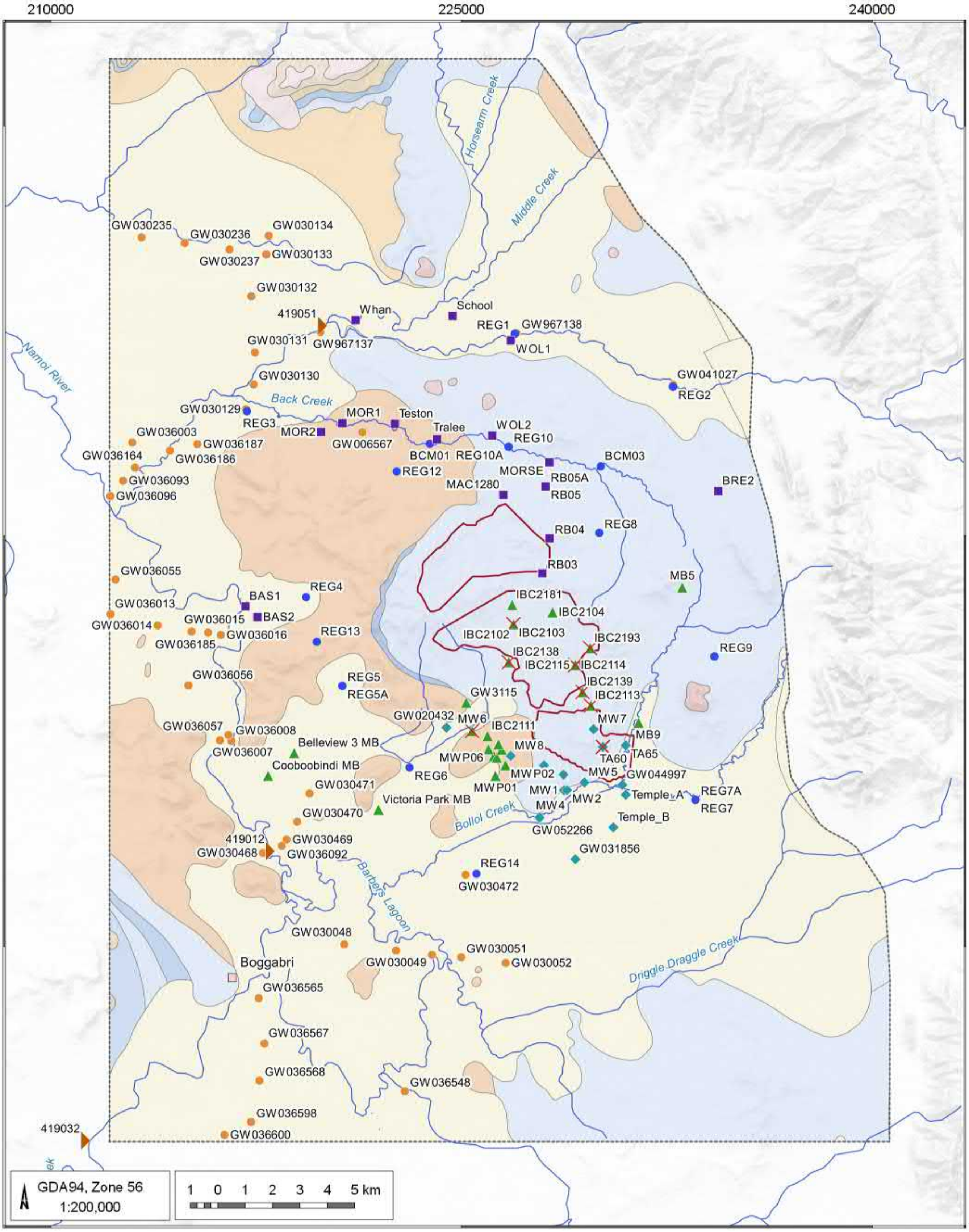
The 'REG' series comprises twelve groundwater monitoring bores and six multi-level VWPs designed to detect cumulative impacts from the BTM Complex. These are sampled by an independent contractor engaged by Maules Creek Mine, who also oversee the data management on behalf of the BTM Complex.

5.3 'GW' series

WaterNSW maintain a network of monitoring bores within the Namoi Valley alluvium that surrounds the BCM. The purpose of these bores is to monitor groundwater levels and quality within the Narrabri and Gunnedah Formations. Some of these bores have been monitored routinely since the mid-1970s, providing a long record of groundwater level trends. Several of the bores have telemetered electronic water level loggers, with real time datasets available online.

5.4 Tarrawonga/Maules Creek mine monitoring

While the Tarrawonga and Maules Creek mines maintain their own monitoring networks, this data has been shared between all three members of the BTM Complex since 2010.



LEGEND
- Drainage
- Extent of mining
- Investigation area

Monitoring bore

Group
- Boggabri-Active
- Boggabri-Destroyed
- Cumulative-Active
- Maules Creek-Active
- Tarrawonga-Active
- Tarrawonga-Destroyed
- WaterNSW-Active
- WaterNSW SW gauging station

Gunnedah Coalfield rock unit (1:100k)
- Qx - Quaternary Sediments
- Tn - Tertiary Nandewar Volcanics
- Tv - Tertiary Volcanics
- Rns - Napperby Formation
- Rdc - Digby Formation
- Pb - Pamboola Formation
- Pwf - Watermark Formation
- Pps - Porcupine Formation
- Pmx - Maules Creek and Goonbri formations
- Plf - Leard Formation
- Pwb - Werrie Basalt
- Pbr - Boggabri Volcanics
- Cbc - Currabubula Formation
- Crc - Rocky Creek Conglomerate

Boggabri MOD8 (G1850W)

Regional groundwater monitoring network

AGE

DATE 14/07/2021

FIGURE No: **5.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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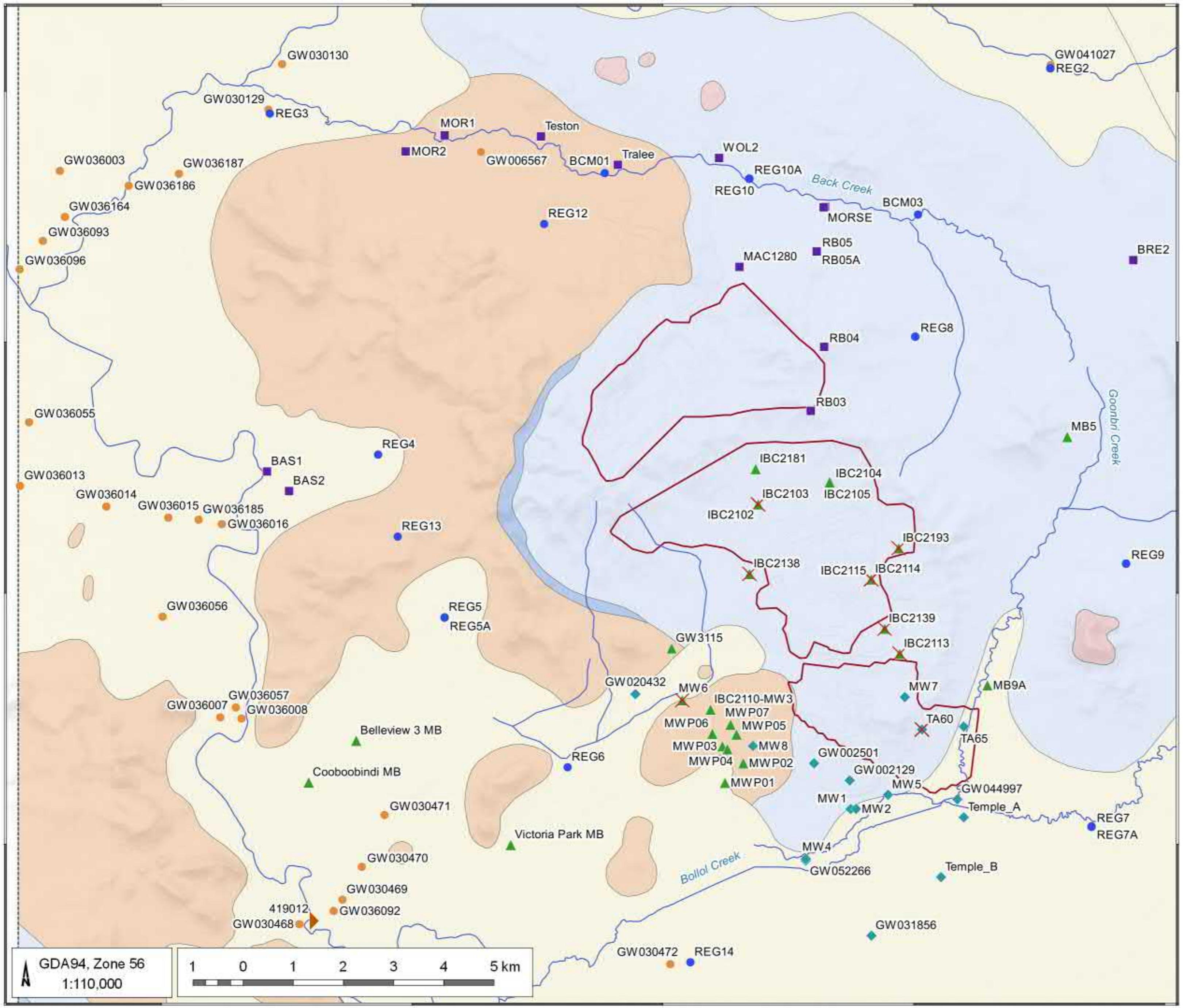

LEGEND

- Drainage
- Extent of mining
- Investigation area

Monitoring bore

Group

- Boggabri-Active
- Boggabri-Destroyed
- Cumulative-Active
- Maules Creek-Active
- Tarrawonga-Active
- Tarrawonga-Destroyed
- WaterNSW-Active
- WaterNSW SW gauging station

Gunnedah Coalfield rock unit (1:100k)

- Qx - Quaternary Sediments
- Tv - Tertiary Volcanics
- Pps - Porcupine Formation
- Pmx - Maules Creek and Goonbri formations
- Plf - Leard Formation
- Pbr - Boggabri Volcanics

Boggabri MOD8 (G1850W)

Regional groundwater monitoring network - zoomed

AGE

DATE
14/07/2021

FIGURE No:
5.2

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6 Conceptual groundwater model

6.1 Hydrostratigraphic units

Local stratigraphy can be broadly classified into four distinct hydrostratigraphic units, which include:

- two Quaternary alluvial groundwater systems (the Narrabri/Gunnedah formations);
- Permian groundwater systems of the Maules Creek Formation; and
- a late Carboniferous/early Permian groundwater system of the Boggabri Volcanics.

These units can be further defined based on lithology, with a summary of hydrogeological characteristics provided in Table 6.1.

Table 6.1 Overview of hydrogeological regime

Hydrostratigraphic unit	Groundwater bearing lithology	Hydrogeological characteristics
Narrabri Formation	Alluvium	Surface alluvial cover, comprising extensive overbank clays, with lesser channel sands/gravels. Relative to the underlying Gunnedah Formation, a greater presence of clay results in higher salinity and lower yields.
Gunnedah Formation	Alluvium	Basal paleochannel alluvium, comprising sands/gravel with interbedded clay. Can provide extremely high yields of fresh water to bores. Groundwater abstraction from aquifer is significant.
Maules Creek Formation	Coal seams	Prime water bearing lithology of the Maules Creek Formation. Coal seams are of variable thickness, with a cumulative thickness greater than 35 m. Low to moderately permeable and generally fresh to brackish close to the areas of mining.
	Interburden	Hydrogeologically ‘tight’ and therefore very low yielding to essentially dry conglomerate/sandstone that comprises the majority of the Maules Creek Formation.
	Weathered zone	Variable in thickness, with deeper weathering profiles found along fractures and potential fault zones. Interpreted to be more permeable than fresh rock, although still hydrogeologically ‘tight’. Limited information on water quality as it is commonly above the water table.
Boggabri Volcanics	Silicic volcanics	Small amount of outcrop in study area, generally forms basement of Maules Creek Sub-basin. Considered to be of very low permeability/impermeable, particularly at depth. Where present, groundwater likely stored in fractures and/or weathered material. Brackish to moderately saline water quality.

Bore yields and field measurements of hydraulic parameters indicate that the most productive groundwater system in the area is the deeper alluvium of the Gunnedah Formation. Less productive groundwater systems are also found within the overlying alluvium of the Narrabri Formation and the Permian coal seams. Permian interburden, which is largely comprised of cemented conglomerate and sandstone, is of lower permeability and serves as a confining layer, retarding groundwater flow between individual coal seams and the overlying alluvium. Basal volcanics also act as a relatively impermeable unit and are found underlying both the alluvium and the Maules Creek Formation.

6.2 Role of geological structures

Geological structures such as faults are known to occur in the investigations area; however, the hydraulic nature of individual faults can be variable and is typically unknown in great detail.

> *'Folding and faulting of sedimentary rocks can give rise to complex hydrogeological systems. Fault zones can act as either barriers to groundwater flow or as groundwater conduits, or have negligible influence, depending on the nature of the fault zone and the material within it.'* (Fetter, 2001)

In addition to displacing the geological units and 'breaking' the hydraulic pathway, the fault materials themselves can act as conduits where they are present as one or more open fractures. However, where the faulted rock consists of fine grained material, clayey material, or cementing material, these faults may have a lower permeability than the host rock.

Conceptually, the presence and potential impacts of faults are difficult to generalise across the investigation area. It is possible that faults reduce geological interconnectivity, with coal seams abutting the less permeable interburden, limiting groundwater flow. Alternatively, it is possible for faults to act as conduits either through increases in permeability, or through upthrow resulting in a greater propensity of coal seems in connection with more transmissive alluvial aquifers. A level of uncertainty around the behaviour of faults and their influence on the conceptual model therefore remains.

As discussed in Section 4.6 and the AGE (2020) model update report, available sources generally agree on the presence of regional faulting (at the scale of the investigation area). However, information on these features is generally limited to high level discussion, and detailed mapping and characterisation of these features is sparse.

6.3 Hydraulic parameters

A high level summary of all in-field hydraulic parameter testing to date is provided in Table 6.2, after the work of AGE (2020). Generally, higher permeabilities are limited to alluvial lithologies and the Maules Creek Formation, with the Boggabri Volcanics being relatively impermeable.

Table 6.2 Summary of hydraulic testing

Hydrostratigraphic unit	Types of testing [a]	Summary of results
Alluvium	Pumping tests and RHT/FHT	Coarser sediments of the Gunnedah Formation much more permeable than the overlying Narrabri Formation (median horizontal hydraulic conductivity of 6.18 m/day compared to 0.09 m/day). Although less permeable, data suggests that the Narrabri Formation still has the potential to store and transmit appreciable volumes of groundwater.
Maules Creek Formation	Pumping tests, lugeon tests, core permeability testing, and RHT/FHTs	Coal seam hydraulic conductivity is highly variable, with approximately four orders of magnitude separating the highest and lowest estimates (1 m/day to 1x10^{-4} m/day). Insufficient data to provide confidence in an inverse relationship with depth. The hydraulic conductivity of the interburden is variable with approximately three orders of magnitude separating the maximum and minimum (1 m/day to 1x10^{-3} m/day). There is a reasonably strong relationship between hydraulic conductivity and depth, with lower values found in deeper tests.
Boggabri Volcanics	Core permeability testing and RHT/FHT	Limited testing to date, with results indicating relatively impermeable rock (horizontal hydraulic conductivity vales less than 10^{-4} m/day).

Note: (a) RHT/FHT – rising head tests/falling head tests.

6.4 Groundwater recharge

Rainfall is the principal means for recharge to groundwater in the investigation area. The amount of water that will eventually reach underlying groundwater systems depends on the rate and duration of rainfall, soil/vegetation properties, depth of the water table and residual soil moisture. As part of recent updates to the BTM Complex model (AGE, 2020), a number of recharge zones were defined based on data review and conceptual understandings of recharge. These included zones for the coal measures/volcanics, the alluvial flood plain, drainage features within the alluvium, and break of slope areas (including a specific break of slope zone for Nandewar Ranges). The calibrated recharge to each of these zones was guided by estimates of recharge that were determined using the soil moisture balance method. This method was considered to be the most suitable to guide the calibration, with both the chloride mass balance and water table fluctuation methods also considered (AGE, 2020). The calibrated recharge to each zone is provided in Appendix A, Figure A 3.8, with the highest rates of recharge occurring in the break of slope zones and the lowest rates occurring on the Permian outcrops.

6.5 Groundwater levels and flow direction

6.5.1 Groundwater flow direction

The current direction of groundwater flow is generally east to west within the Maules Creek/Back Creek alluvial plain, and towards the southwest within the Bollol Creek/Driggle Draggle Creek alluvial plain (AGE, 2020), which is consistent with pre-mining conditions. Regional groundwater flow within the Namoi River alluvium generally follows the direction of the river, with flow either to the northwest or north (McNeilage, 2006).

Pre-mining groundwater flow within the Maules Creek Formation generally mimics topography, with a dominant direction of flow to the west (AGE, 2010). Existing mining activities have led to localised areas of depressurisation around the BTM Complex (see Section 6.5.3), which results in the mining areas acting as a local groundwater sink.

Groundwater flow within the Boggabri Volcanics is also consistent with topography and groundwater generally moves east to west (AGE, 2020).

6.5.2 Alluvial groundwater level trends

The alluvial sediments closest to BCM form a thin tongue shaped area to the southwest of the mine and are associated with the Nagero Creek, which is fed from the catchment area occupied by BCM. Groundwater monitoring bore MW6 is installed within these alluvial sediments. Groundwater level variations prior to 2014 are generally consistent with CRD, with a gradual rising trend observed after this period (Figure 6.1).

Several alluvial groundwater bores (including MW5 and GW044997) are installed directly to the south of the Tarrawonga Mine and are useful for investigating potential mining related impacts. Groundwater level variations for these bores (Figure 6.1) are generally consistent with CRD and no mining related declining levels are evident.

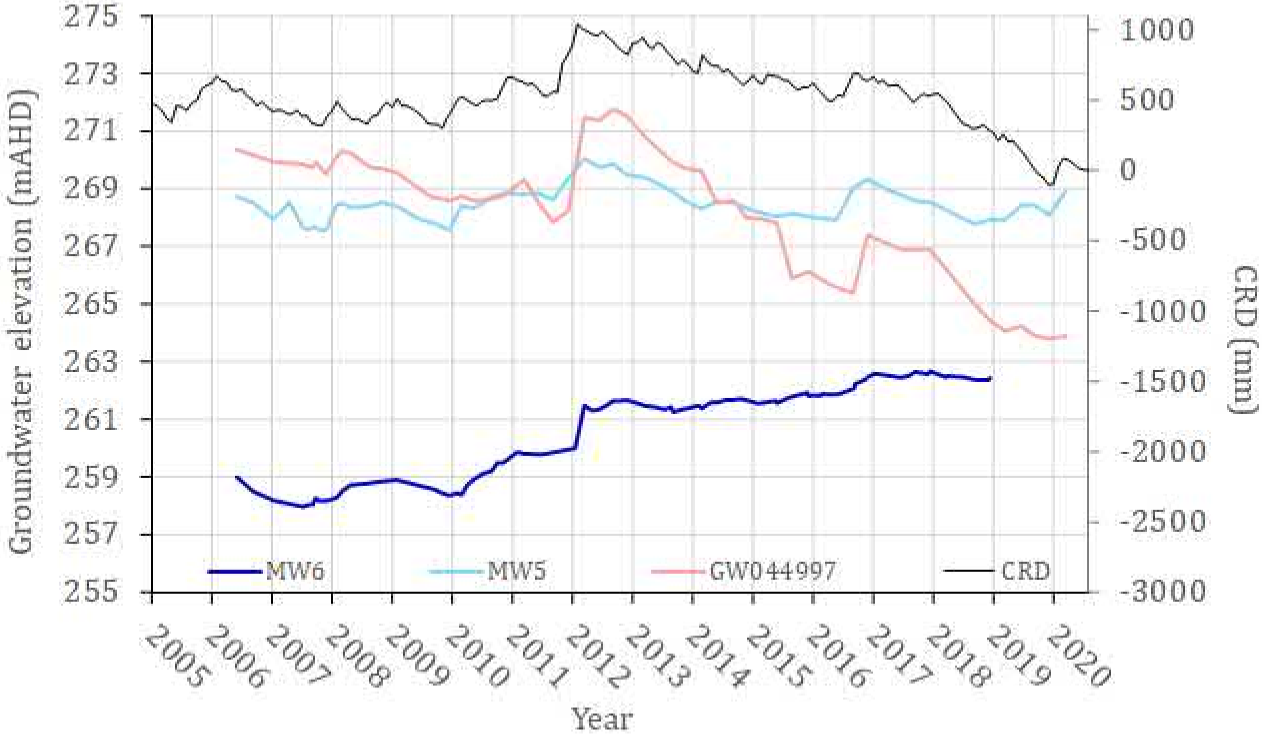


Figure 6.1 MW6, MW5 and GW044997 hydrographs

Regionally, alluvial extraction for irrigation is significant, particularly within the deeper higher yielding Gunnedah Formation. Hydrographs for registered bore GW036016, which is approximately 7.5 km west of BCM clearly demonstrate this. Prior to 1993, groundwater levels at all three depths were very similar, with a slight downwards gradient observed and only small (<1 m) changes in levels consistent with CRD (Figure 6.2). Since 1993, groundwater level variations demonstrate impacts that are associated with agricultural extraction, with large range pumping spikes becoming evident that lead to an overall falling trend, particularly within the deeper bores (Figure 6.2).

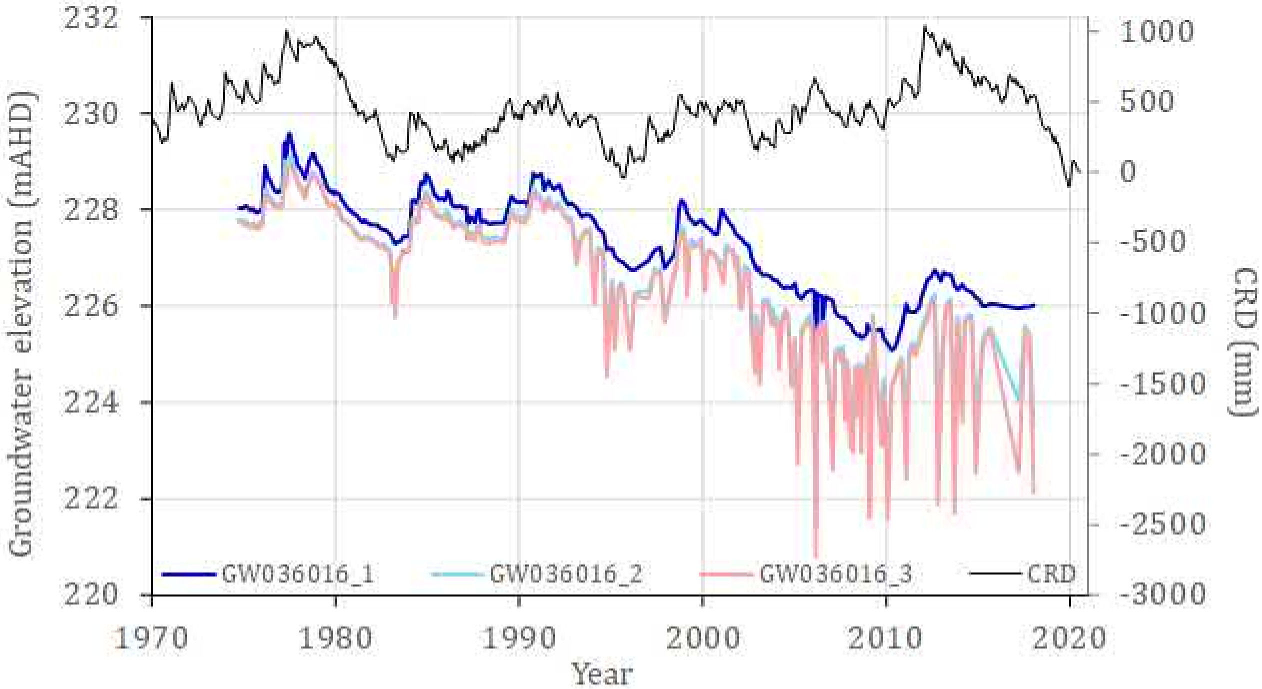


Figure 6.2 GW036016 hydrograph

6.5.3 Maules Creek Formation groundwater level trends

Mining at BCM has led to groundwater level declines (Figure 6.3) in the 'IBC' bores (Figure 5.1), many of which are installed into coal seams. Levels have fallen as the approved mining operations have expanded and removed materials below the water table, with the timing and rate of depressurisation related to the mining progression and the bore's location relative to these activities. This depressurisation has been observed at monitoring sites peripheral to mining (Figure 6.4 and Figure 6.5), although the zone of depressurisation has not extended to more distant monitoring sites to the east (Figure 6.6 and Figure 6.7). Available data indicates a downwards vertical hydraulic gradient through the Maules Creek Formation (Figure 6.4, Figure 6.6 and Figure 6.7).

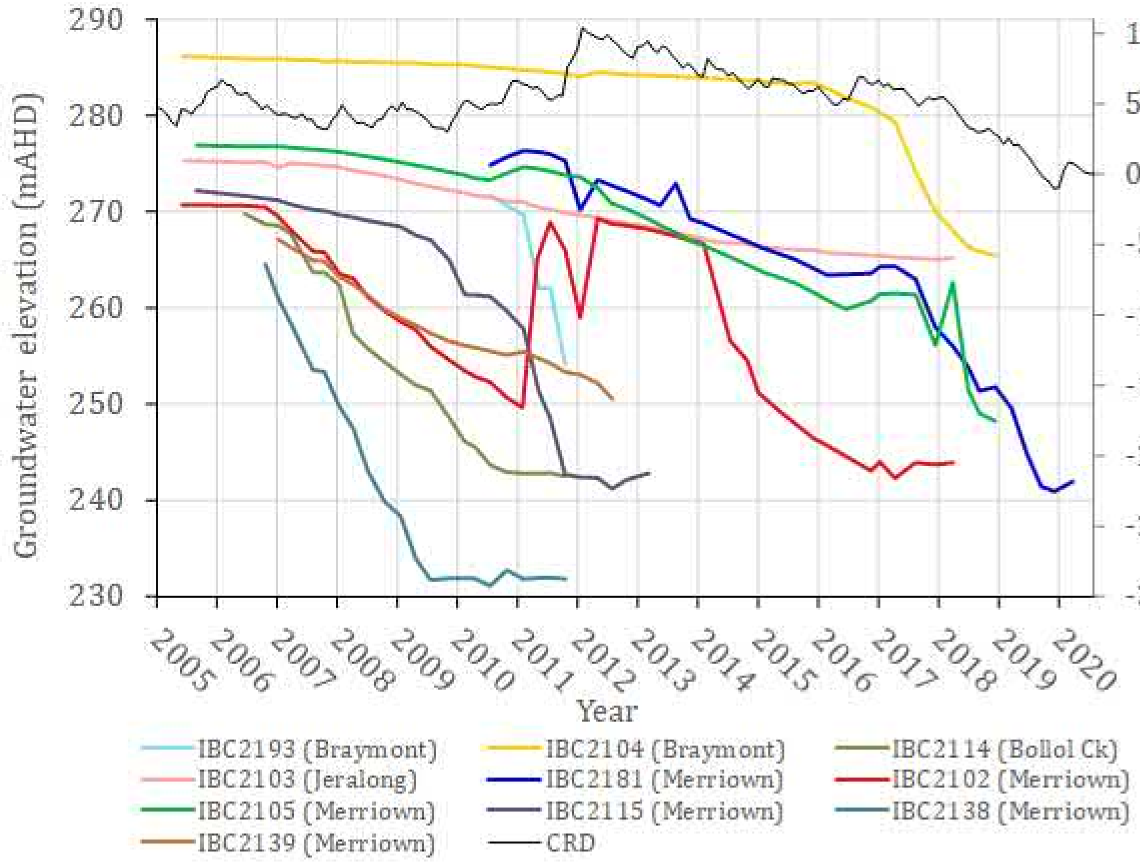


Figure 6.3 'IBC' coal seam hydrographs

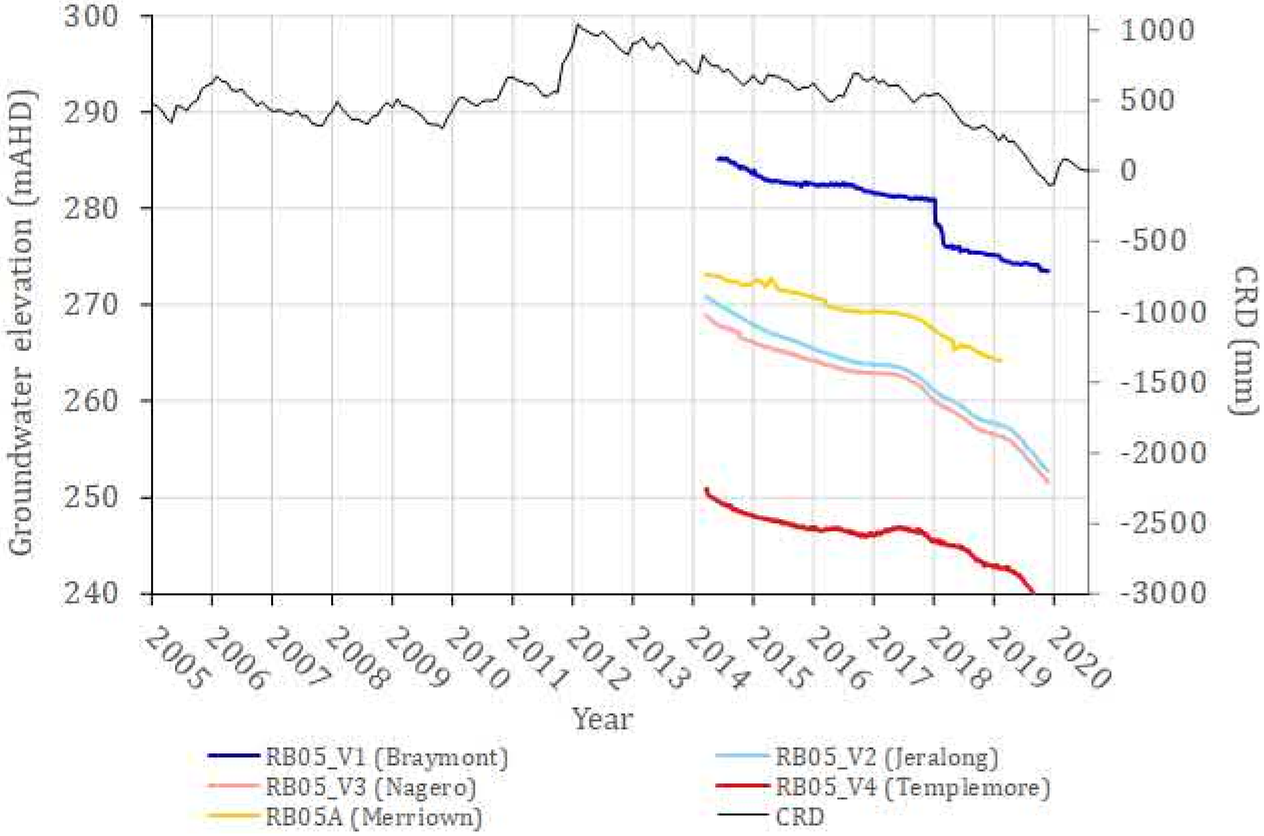


Figure 6.4 RB05 hydrograph

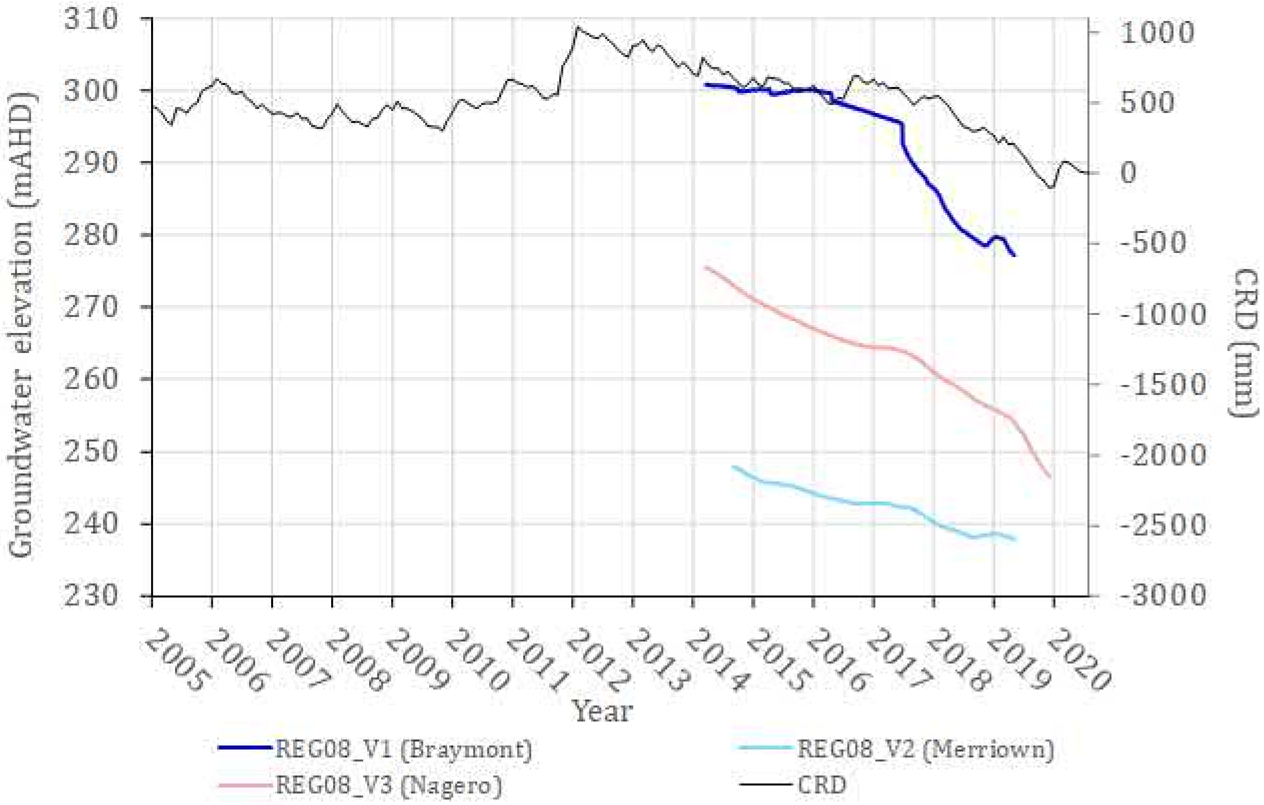


Figure 6.5 REG08 hydrograph

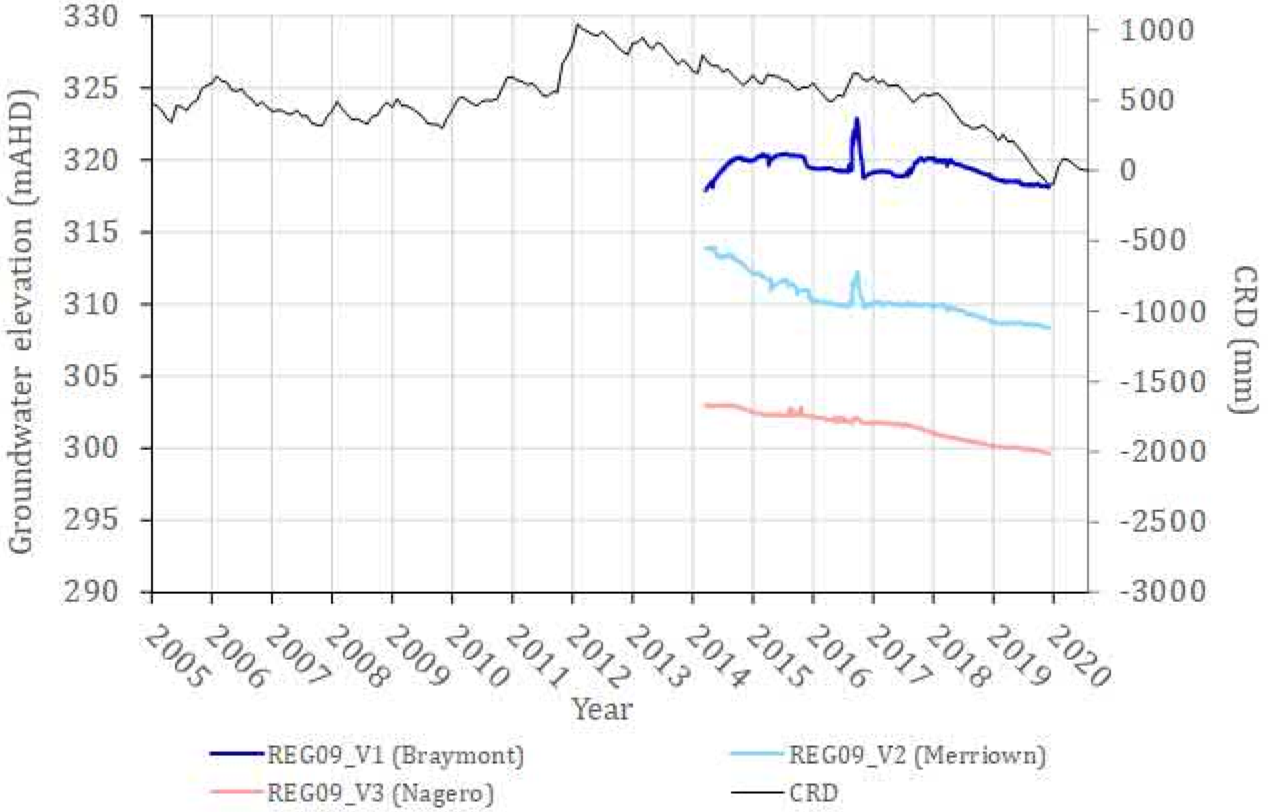


Figure 6.6 REG09 hydrograph

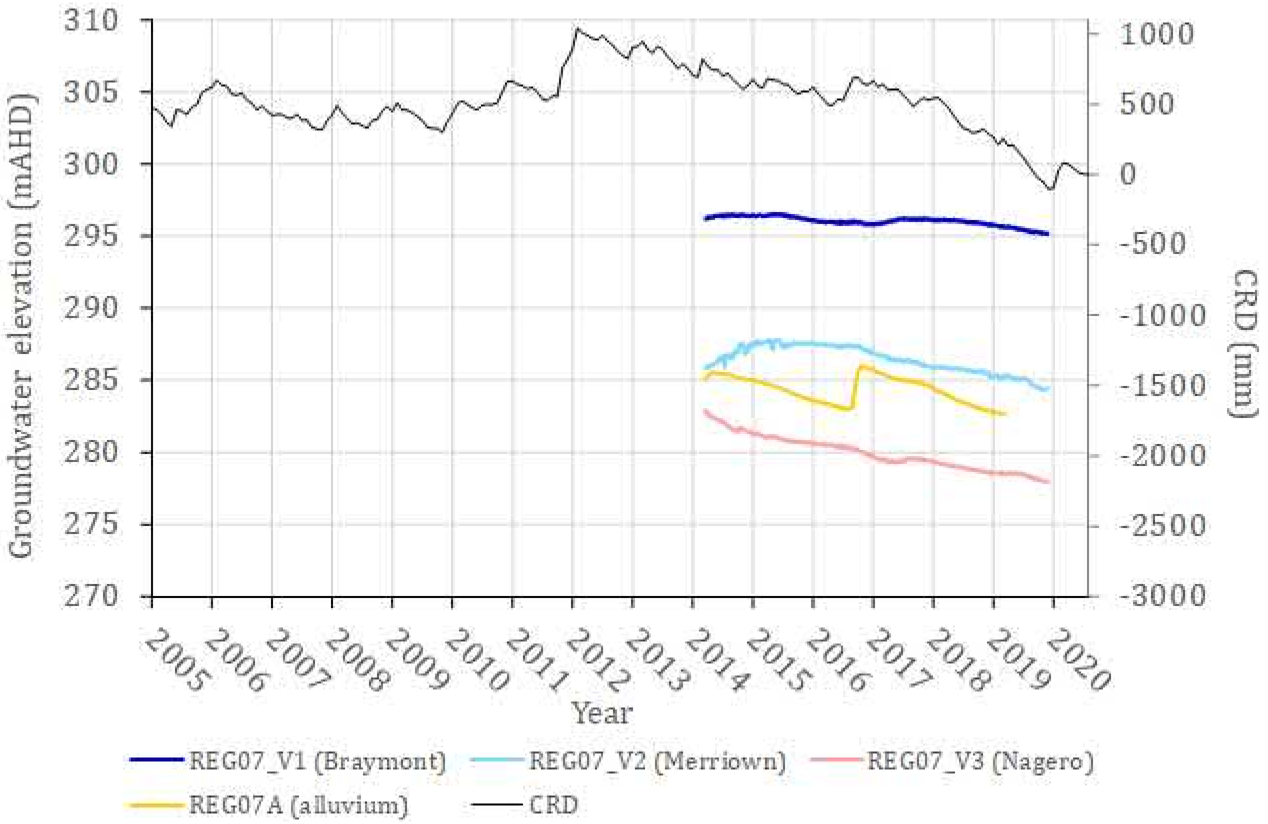


Figure 6.7 REG07 hydrograph

6.5.4 Boggabri Volcanics groundwater level trends

At groundwater monitoring points that are within 2 km of BCM, groundwater levels (Figure 6.8) show either a generally increasing trend (IBC2110 and IBC2111), or consistently stable levels (GW3115). Further afield, Boggabri Volcanics monitoring data shows that groundwater levels have generally remained stable (Figure 6.9). The stable levels recorded are considered a function of the relatively low hydraulic conductivity and poor interconnectivity of fracture network within the Boggabri volcanics. The rising trends observed in IBC2110 and IBC2111 are potentially influenced by seepage from parts of the mine's surface water management system.

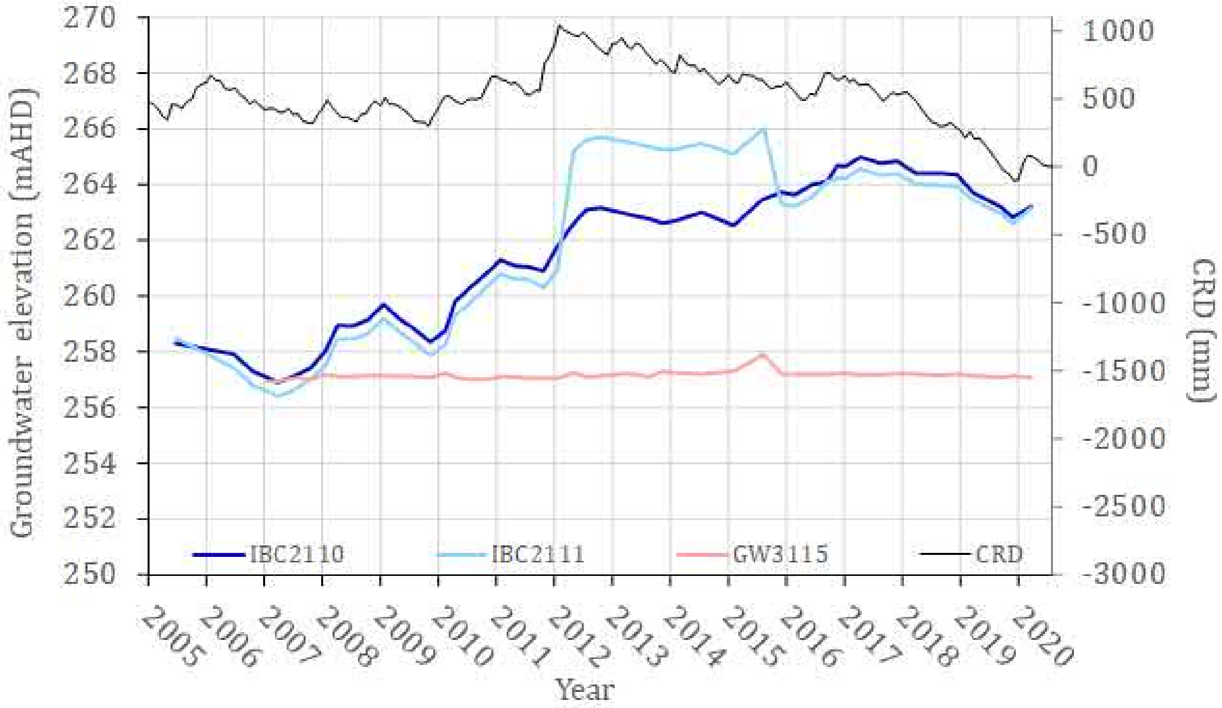


Figure 6.8 IBC2110, IBC2111 and GW3115 hydrographs

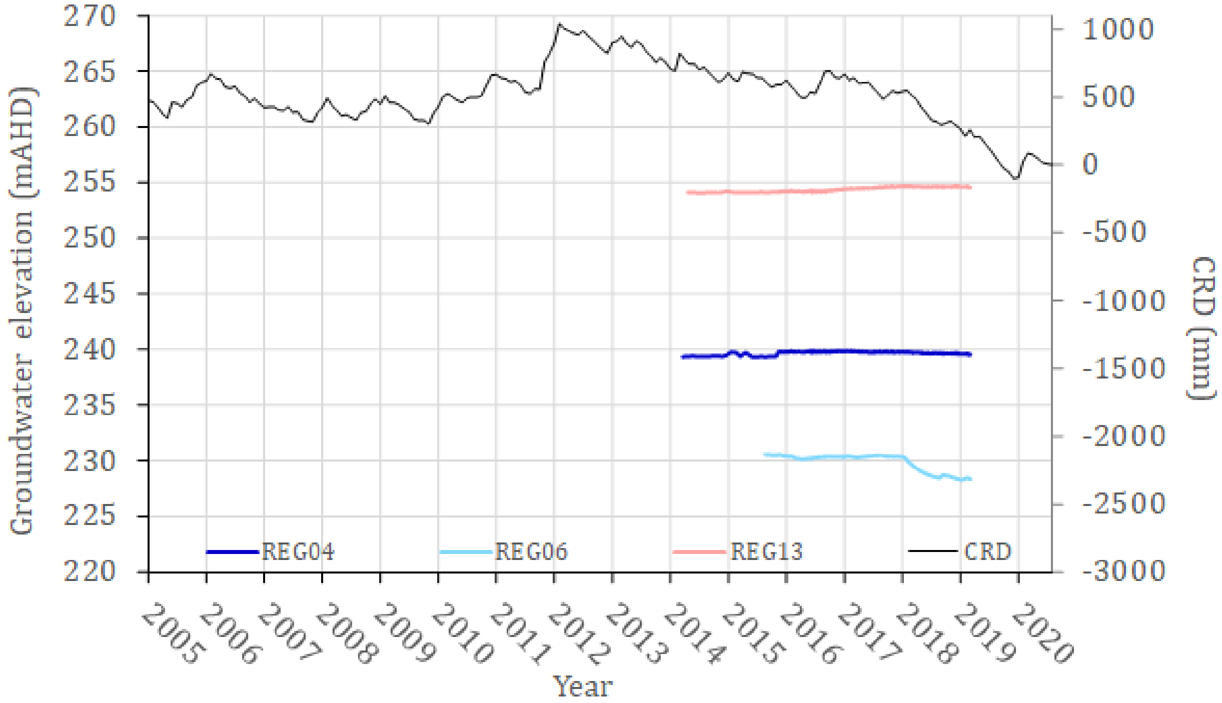


Figure 6.9 REG04, REG06 and REG13 hydrographs

6.5.5 Alluvial connectivity to coal measures

Multi-level monitoring that extends through both the alluvium and the coal measures is limited within the investigation area. Vertical differences in groundwater levels at monitoring sites REG01/GW967138 (Figure 6.10) strongly indicate a downwards hydraulic gradient from alluvium to the underlying coal seams. Responses to rainfall are visible in the alluvium and upper coal seams, with the magnitude of this response reducing at depth. Groundwater levels in REG02/GW041027 (Figure 6.11) also show a downwards hydraulic gradient, although the coal measures at this location may be influenced by faulting.

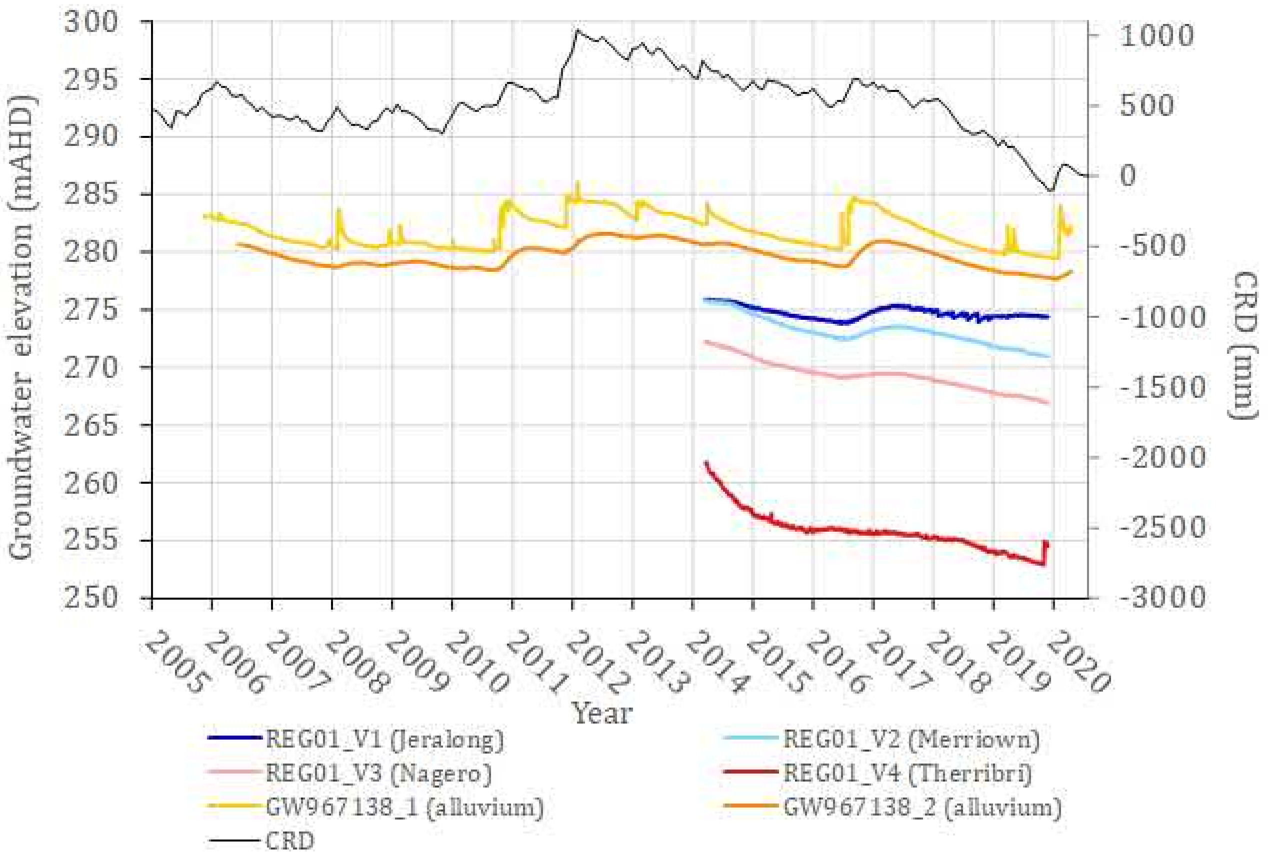


Figure 6.10 REG01 and GW967138 hydrographs

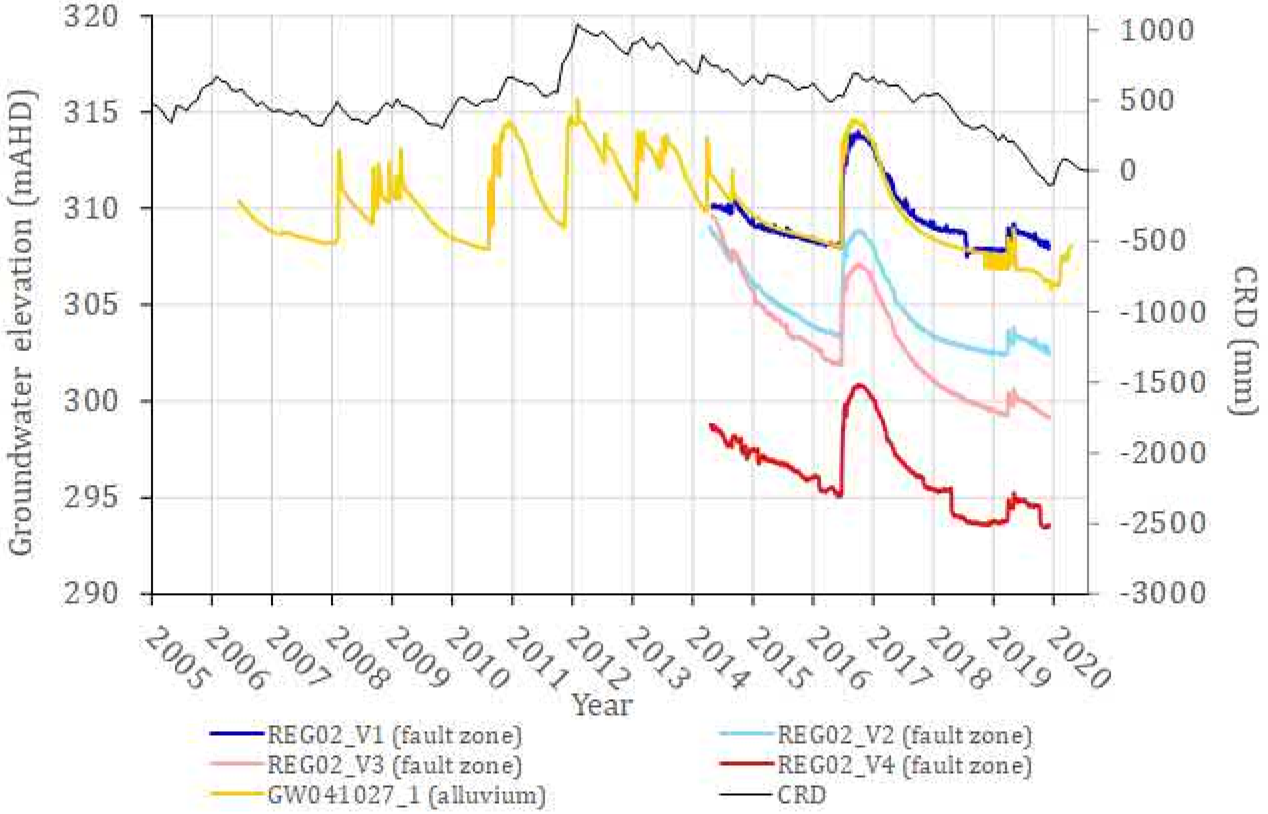


Figure 6.11 REG02 and GW041027 hydrographs

6.5.6 Surface water connectivity to groundwater

Small ephemeral creeks that surround BCM, including the nearby Nagero, Bollol, and Goonbri creeks, are conceptualised to act as 'losing streams', with the creeks recharging the underlying water table when flows occur. Conversely, monitoring data indicates that at times, groundwater flows into the Namoi River and parts of Maules Creek.

Comparisons between the river stage from WaterNSW's Namoi River gauging station (station 419012) and select alluvial groundwater levels from nearby bores indicates that water levels in the river are highly variable and have a larger range than the groundwater levels (Figure 6.12). Groundwater levels were typically over 1 m higher than the river stage between the start of the record and approximately 2005, with the Namoi River therefore expected to be gaining groundwater over this period. Conversely, post 2005, periods where groundwater levels are lower than the river stage occur more frequently, with the Namoi River losing to groundwater over these periods. This change in interconnectivity is likely linked to gradual groundwater level declines, which can be observed since the onset of monitoring. Declines of the average river stage are less pronounced over this period.

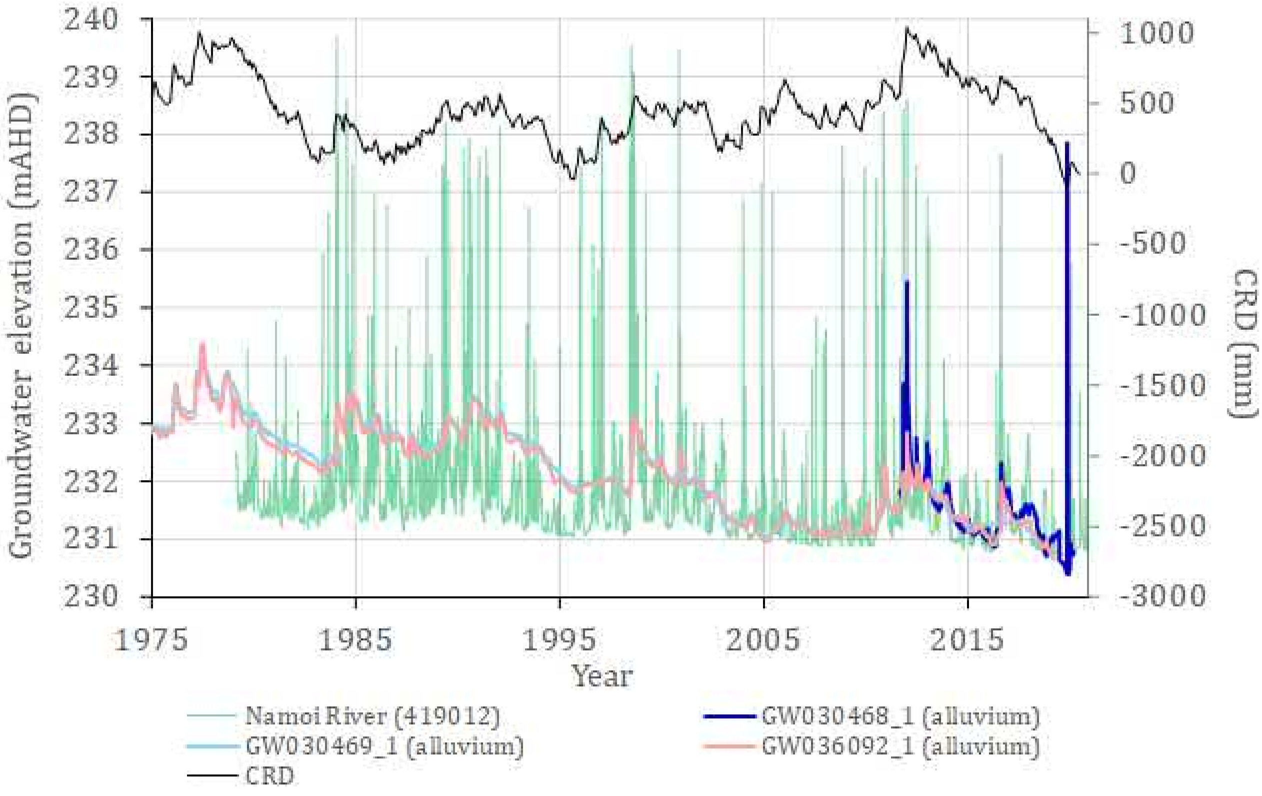


Figure 6.12 Namoi River level and surrounding groundwater hydrographs

6.6 Groundwater quality

Salinity has a significant influence on the beneficial use of groundwater and generally correlates to electrical conductivity (EC), which can be used to categorise groundwater quality using the following ranges (FAO, 2013):

- Fresh water <700 µS/cm
- Brackish (slightly saline) 700 to 2,000 µS/cm
- Moderately saline 2,000 to 10,000 µS/cm
- Saline 10,000 to 25,000 µS/cm
- Highly saline 25,000 to 45,000 µS/cm
- Brine >45,000 µS/cm

Pena-Arancibia et al. (2016) shows that the salinity of the investigation area is variable, with fresh groundwater generally limited to bores adjacent to the Namoi River, Barbers Lagoon, and Maules Creek. Moving away from these drainage features sees the groundwater salinity shift to brackish or moderately saline. Regionally, groundwater quality of the Namoi sub-region is typified by a median EC value of 1,013 µS/cm. A ten-year monitoring record for bore MW6 (2009 to 2019), which is directly southwest of BCM, demonstrate that the bore has been brackish to moderately saline on average, with a median EC of approximately 2,000 µS/cm.

Collective monitoring data of the BTM Complex (AGE, 2020) shows that groundwater within coal seams and interburden of the Maules Creek Formation is generally brackish to moderately saline, with a median EC of approximately 1,000 µS/cm and 2,300 µS/cm, respectively. These salinity levels are generally fresher than, or consistent with concentrations found in alluvial bore MW6.

Groundwater of the Boggabri Volcanics is also brackish to moderately saline, with a median EC of approximately 2,000 µS/cm.

The pH of each groundwater system within the investigation area generally falls between 7.0 and 7.5 and area typifies neutral conditions.

6.7 Mining groundwater use

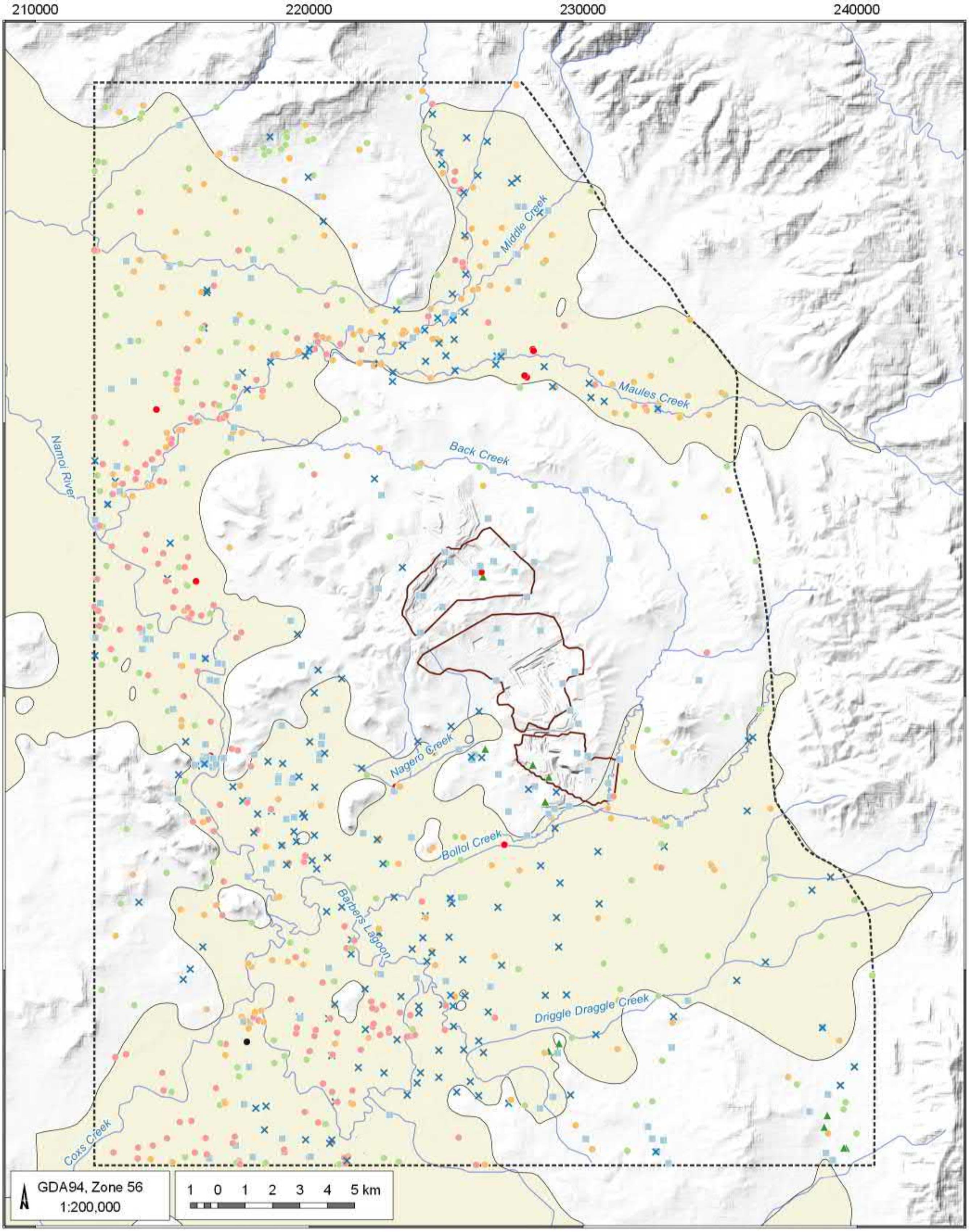
BCM does not directly intersect any highly productive aquifers, and therefore the volume of groundwater entering the mining area is not large compared to mining operations that operate in more permeable and porous environments. Groundwater is not problematic for mining activities and advanced dewatering prior to mining is not required. The groundwater intersected in the mining areas is commonly evident only as damp evaporating seeps in active mine faces. Since the onset of mining, groundwater inflow to the BCM void has peaked at about 350 ML/year to 370 ML/year in 2019.

BCOPL are also licenced to take groundwater from supply bores located approximately 7 km to the west of the mine in Zone 4 of the Upper Namoi Groundwater Source.

6.8 Groundwater dependent assets

6.8.1 Private groundwater bore users

There are 1,049 registered bores within the investigation area, of which WaterNSW records classify 252 as monitoring bores, 202 as water supply bores, 196 as irrigation bores, 180 as stock and domestic bores, 11 as commercial and industrial bores, 11 as exploration bores, and 197 bores with an unknown purpose (Figure 6.13). Bores that are licensed to extract groundwater are located primarily across the alluvial aquifers, with the greatest volumes extracted from bores adjacent to the Namoi River. These areas of high extraction generally coincide with identified irrigation areas (Janardhanan et al. 2018).



LEGEND

- Drainage
- Extent of mining
- Investigation area
- Alluvium extent

Registered bores [Purpose]

- Monitoring
- Water Supply
- Stock and Domestic
- Irrigation
- Exploration
- Commercial and Industrial
- Other
- Unknown

Boggabri MOD8 (G1850W)

Registered groundwater bores

AGE

DATE 14/07/2021

FIGURE No: **6.13**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1850W.Boggabri MOD8\3_GIS\Workspaces\002_Deliverable2\06.13_G1850W_Registered groundwater bores.qgs

6.8.2 Groundwater dependent ecosystems

Mapping that is available through the GDE Atlas of Australia (BoM, 2019) shows the presence of high potential aquatic/terrestrial GDEs (Figure 6.14) within the investigation area. Under 2020 updates to the WSPs for the NSW Murray Darling Basin Porous Rock Groundwater Sources and the Namoi Alluvial Groundwater Sources, these high potential terrestrial GDEs are now considered high priority GDEs under the *Water Management Act 2000* and are therefore assessable against the AIP.

As nominated under the EPBC Act, threatened ecological communities that have the potential to be groundwater dependent have also been mapped, with both field verified and regionally mapped communities shown (Figure 6.15 and Figure 6.16, respectively). As has been previously requested by DAWE, the following ecological communities were considered:

- Natural grasslands on basalt and fine-textured alluvial plains of northern New South Wales and southern Queensland;
- Poplar Box Grassy Woodland on Alluvial Plains; and
- White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland.

All GDE mapping was compared to relatively current simulations of the depth to the water table (AGE, 2020). The simulated depth to the water table is variable and is generally greater than 20 metres below ground level (mbgl) in areas where the coal measures/Boggabri Volcanics outcrop, including the area immediately surrounding the BTM Complex. Beneath drainage features and alluvium, depths are generally greater than 5 mbgl, except in the upper reaches of Back Creek, Goonbri Creek, and Bollol Creek, as well as parts of the Maules Creek alluvial plain. The simulated depth to the water table is largely consistent with observations, noting that groundwater monitoring along Back Creek indicates that the water table is greater than 10 mbgl.

High priority GDEs are present along several drainage features, which include the Namoi River, Barber’s Lagoon, Maules Creek/its unnamed tributaries, Back Creek, Goonbri Creek, the upper reaches of Bollol Creek, and parts of Driggle Draggle Creek (Figure 6.14). These high priority GDEs were reviewed as part of WSP’s (2021) GDE assessment for MOD 8, and findings are generally consistent to the GDE Atlas, with select communities being deemed to be groundwater dependent to some degree. EPBC nominated ecological communities are mapped throughout the investigation area, although with respect to high priority GDE mapping, they do not correlate as strongly with the location of drainage features.

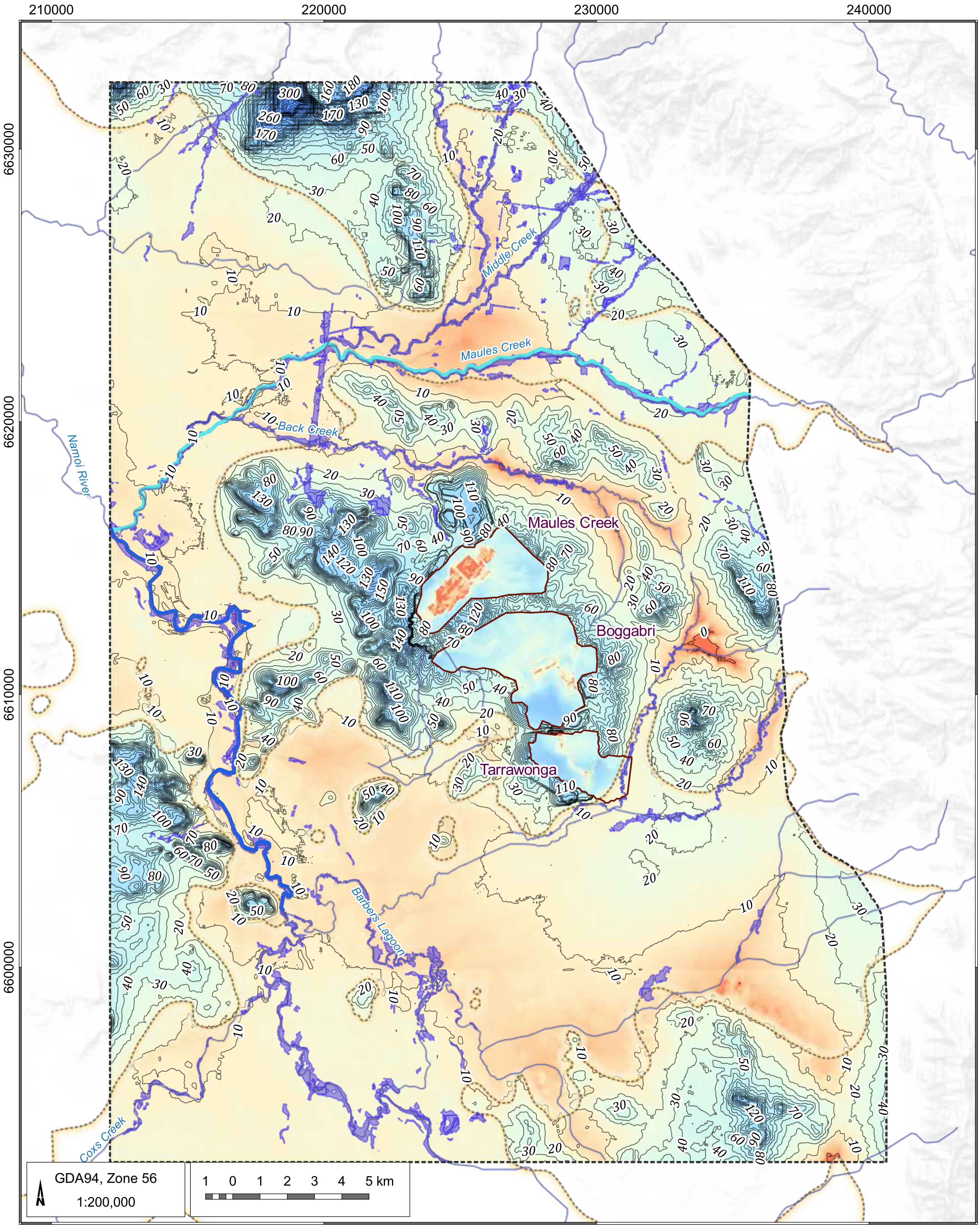
WSP (2021) determined that the GDEs that are mapped in the area immediately surrounding BCM (where the terrain is elevated) are likely vadophytic, and therefore are not groundwater dependent. This is consistent with the simulated depth to the water table generally being greater than 20 mbgl in the area immediately surrounding BCM. Notwithstanding, near BCM there are small patches of both Poplar Box Woodland and Box/Gum Woodland mapped along Nagero Creek, which is immediately adjacent to the existing BCM mine infrastructure area within the tongue of alluvium. The depth to the water table at this location is estimated to be less than 10 mbgl. WSP (2021) determined that these Poplar Box Woodland communities likely have a proportional dependence on groundwater, while Box/Gum Woodland communities have no apparent dependency on groundwater.

Further afield from BCM, the simulated depth to water beneath high priority GDEs is variable, with values generally greater than 5 m, except in the upper reaches of Back Creek, Goonbri Creek, and Bollol Creek, as well as beneath parts of the Maules Creek alluvial plain. Groundwater monitoring along Back Creek indicates that the water table is greater than 10 mbgl and therefore suggests that it is unlikely for the vegetation in this area to be accessing groundwater. Studies undertaken by Cumberland Ecology (2011) identified the presence of *Melaleuca sp* riparian woodland along the alignment of Back Creek, which are expected to have a root zone extending approximately 2 m to 3 m below the land surface.

In areas away from BCM and its immediate surrounds, ecological investigations that were completed to support MOD 8 (WSP, 2021; WSP, 2021b) have noted the following for each of the EPBC nominated ecological communities.

- **Poplar Box Grassy Woodland on Alluvial Plains** – *Eucalyptus spp.* have a dual (dimorphic) root system, with lateral roots that are close to the surface, and a taproot or 'sinker' that penetrates deep into the soil. *Eucalypt spp.* are therefore able to source water from multiple sources (i.e. surface water, soil moisture after flooding/rainfall, and/or groundwater). Their reliance and use of groundwater is therefore facultative. The mapped occurrences of this community are predominately associated with a water table of 10 mbgl or greater.
- **Natural grasslands on basalt and fine-textured alluvial plains** – This community is highly restricted to areas on the Namoi River floodplain where the water table is 5 to 10 mbgl. This vegetation is not considered to be dependent on groundwater given that the roots of grasses and other herbaceous plants are shallow and are unlikely to reach the water table.
- **White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland** – This woodland community is likely to be associated with moisture holding soils and/or shallow perched water tables over impermeable clay lenses, rather than phreatophytic vegetation fed by sub-surface aquifers. As such, it is considered unlikely that this woodland community would have a significant connection to the groundwater table and it is therefore considered unlikely to be a GDE. As stated above for the natural grassland ecological community, grassland areas are unlikely to be impacted or reliant on groundwater where the depth to the water table is 5 m or greater.

A single stygofauna species has been sampled from a single alluvial bore (MW6) in the tongue of alluvium adjacent to BCM (WSP, 2021). However, as stygofauna are limited to a single bore/species (which is present in other parts of the Namoi Valley), it is difficult to draw conclusions about the connectivity of the alluvial aquifer to support this and other stygofauna species (WSP, 2021). A wider range of stygofaunal species have been identified in the Gunnedah Coal Basin, which encompasses the Namoi River catchment and the BCM site. Korbel et al. (2013) found 21 taxa, which were dominated by copepods, amphipods and syncarids. Ongoing works as part of the University of New South Wales' connected waters initiative works have determined that semi-permanent groundwater discharge to parts of Maules Creek may be biological refuge for stygofauna.



LEGEND

- Drainage
- Depth to water table contour (m)
- Extent of mining
- Investigation area
- Alluvium extent

GDEs

- High potential terrestrial GDE - from regional studies
- High potential aquatic GDE - from national assessment
- Known aquatic GDE - from regional studies

Depth to water table (m)

0	50
1	100
2	200
5	400
10	
20	

Boggabri MOD8 (G1850W)

Groundwater dependent ecosystems - GDE Atlas of Australia

AGE

DATE
14/07/2021

FIGURE No:
6.14

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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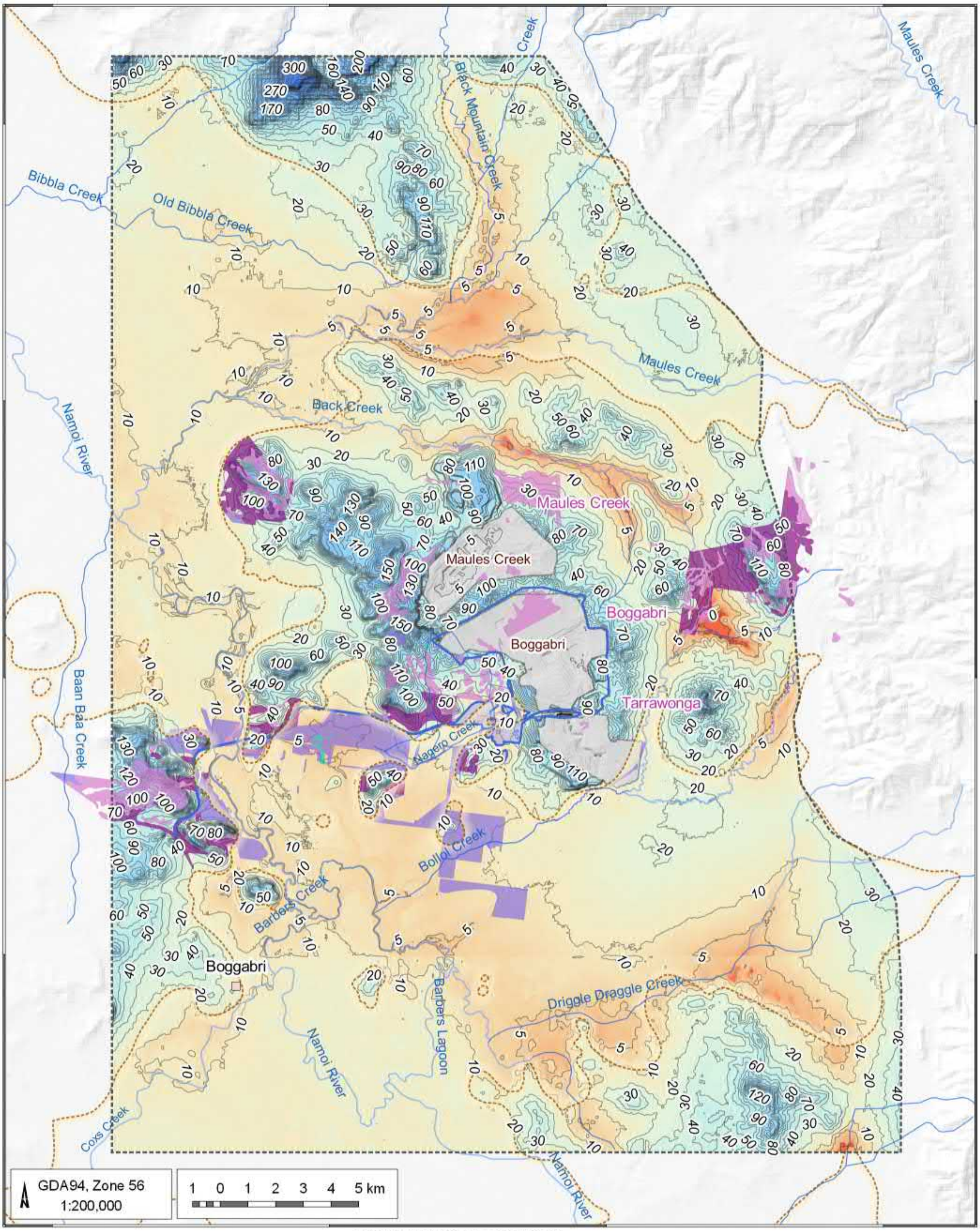

LEGEND

- Populated place
- Drainage
- Contour line
- Model extent
- BCM Infrastructure Disturbance
- Approved Disturbance Area
- Mining Areas
- Alluvium extent

GDEs (EPBC classification)

Source: WSP mapping

- Natural grasslands
- Poplar Box Grassy Woodland
- Box Gum Woodland
- Box Gum Woodland and Derived Native Grassland

Depth to water table (m)

0, 1, 2, 5, 10, 20, 50, 100, 200, 400

Boggabri MOD8 (G1850W)

Groundwater dependent ecosystems - verified field mapping of EPBC nominated ecological communities

AGE

DATE 05/07/2021

FIGURE No: **6.15**

Source: LiDAR DEM © Department Finance, Services and Innovation, 2016; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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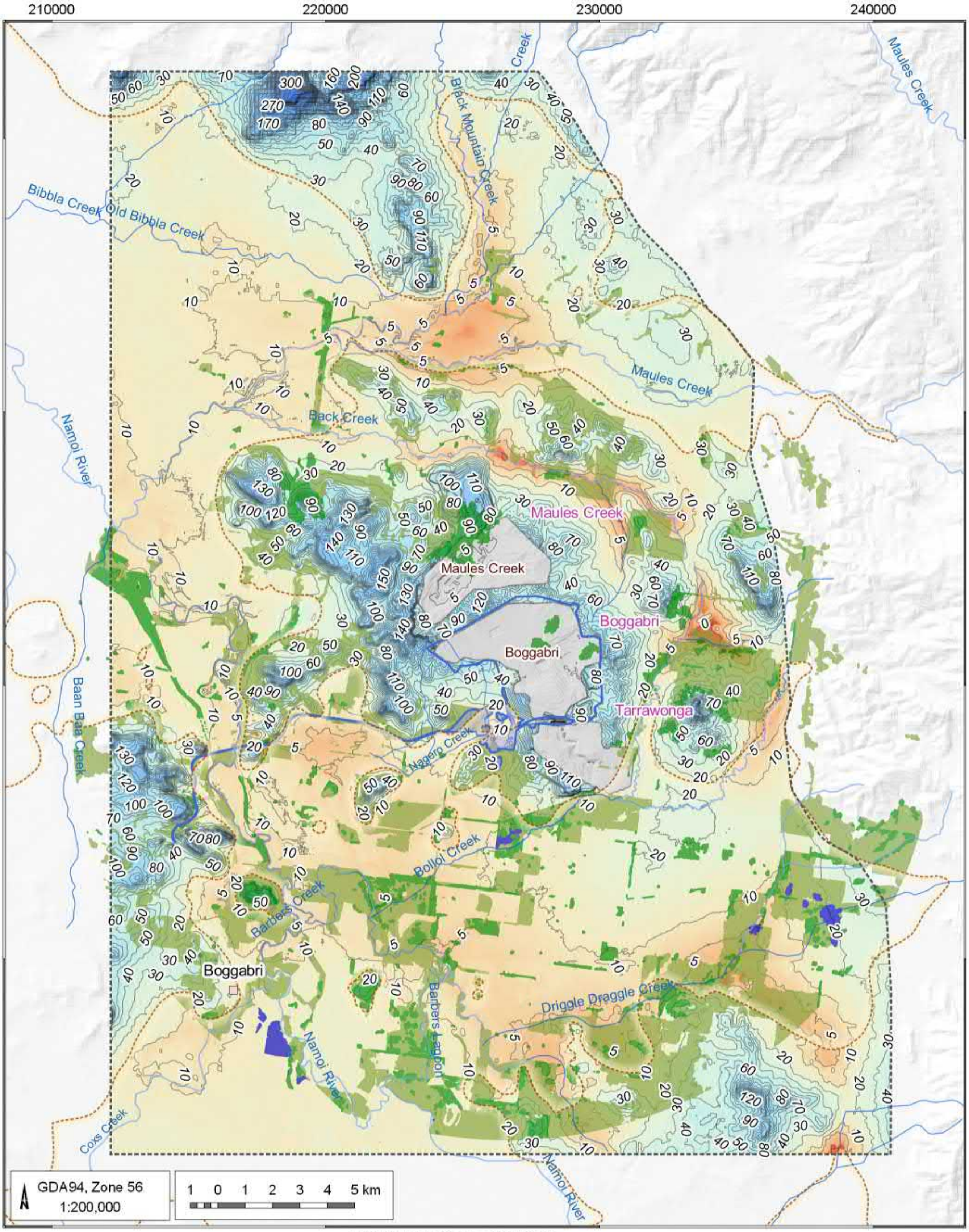

LEGEND

- Populated place
- Drainage
- Contour line
- Model extent
- BCM Infrastructure Disturbance
- Approved Disturbance Area
- Mining Areas
- Alluvium extent

GDEs (EPBC classification)

Source: State based mapping

- Native grasslands
- Natural grasslands
- Box Gum Woodland

Depth to water table (m)

0, 1, 2, 5, 10, 20, 50, 100, 200, 400

Boggabri MOD8 (G1850W)

Groundwater dependent ecosystems - nominated EPBC ecological communities

AGE

DATE 05/07/2021

FIGURE No: **6.16**

Source: LiDAR DEM © Department Finance, Services and Innovation, 2016; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1850W.Boggabri MOD8\3_GIS\Workspaces\002_Deliverable2\06.16_G1850W_Groundwater dependent ecosystems - nominated EPBC ecological communities.qgs

6.9 Overview of coal seam subcrop under alluvium

The Upper Namoi Alluvium is known to host the most productive aquifers in the region, with data indicating that it is accessed by a large number of private groundwater bores (Section 6.8.1), in addition to potentially supporting a variety of GDEs (Section 6.8.2). It is conceptualised that the most likely potential pathway for impacts to propagate from the mined coal measures to the surrounding alluvium is through the subcrop of coal seams beneath the alluvium. Without extensive and regional fieldwork investigations, it is difficult to confidently determine where this subcrop is taking place. However, current interpretations of subcrop, which are based on regional geological modelling (JB Mining, 2010) and geological modelling for each of the mining operations in the BTM Complex are presented in Appendix C. Select cross sections run parallel to the dip of the coal measures and extend through the Zone 11 Maules Creek alluvium (Cross section B) and through the southern Zone 4 alluvium, adjacent to Bollol Creek (Cross section D) and through the tongue of alluvium immediately to southwest of BCM (Cross section E). Generally, the deeper coal seams do not subcrop under the alluvium, with cross sections showing that:

- beneath the Maules Creek alluvium the Herndale, Onavale, Teston, Thornfield, and Braymont seams potentially subcrop;
- beneath the Bollol Creek alluvium the Braymont, Bollol Creek, Jeralong, Merriown, Velyama and Nagero seams potentially subcrop; and
- beneath the alluvial tongue adjacent to BCM the Merriown, Velyama, Nagero, and Northam seams potentially subcrop.

6.10 Inferred impacts of MOD 8

6.10.1 Alluvium

Beneficial uses of the alluvial groundwater system are significant. Surrounding landholders are heavily reliant on the resource and known/high potential aquatic and terrestrial GDEs occur along rivers and creeks that are connected to the alluvial groundwater system (WSP for Upper and Lower Namoi Groundwater Sources; BoM, 2019).

As discussed in Section 6.5.2, mining induced impacts to the alluvial groundwater system are yet to be observed and no groundwater modelling undertaken to date predicts any significant alluvial drawdown as a result of mining. Cumulative modelling that precedes this work (AGE, 2020) presents alluvial drawdown in 2036, which coincides with the end of approved mining for the BTM Complex (Maules Creek Mine). Drawdown at this time is limited to the small tongue of alluvium directly southwest of BCM and adjacent to areas where the Tarrawonga Mine void extends into the alluvium. Registered bores in these areas are all owned by members of the BTM Complex and are used for monitoring.

High potential terrestrial GDEs are mapped along several drainage features, which include the Namoi River, Barber’s Lagoon, Maules Creek/its unnamed tributaries, Back Creek, Goonbri Creek, the upper reaches of Bollol Creek, and parts of Driggle Draggle Creek. As discussed in Section 6.8.2, these high potential terrestrial GDEs are now considered high priority GDEs under 2020 updates to the WSP for the Namoi Alluvial Groundwater Sources, which came into effect June 2020.

Any increases in alluvial drawdown that can be attributed to MOD 8 are expected to be minimal, if any. The adjacent Maules Creek Mine is already approved to mine to the base of the Templemore Seam and the Tarrawonga Mine is already approved to mine to the base of the Nagero Seam. As such, current predictions already account for depressurisation of coal seams below the Merriown Seam, which are the coal seams to be extracted under MOD 8. Additionally, as discussed in Section 6.9, it is conceptualised that contributions to alluvial drawdown are greater when mining the upper coal seams of the Maules Creek Formation relative to the lower coal seams. This is expected as the upper coal seams are more likely to subcrop under the alluvium, with the deeper coal seams subcropping against the low permeability Boggabri Volcanics.

6.10.2 Coal measures

Approved mining activities have already impacted the groundwater within the Maules Creek Formation and further impacts are predicted as already approved mining continues. The increased depth of mining and larger volume of spoil that is associated with MOD 8 is expected to induce some additional drawdown and impacts within the coal measures, particularly the deeper seams that have not been intersected by BCM to date. However, neither the impacts associated with approved mining, nor further impacts likely to be associated with MOD 8 are likely to be significant.

Groundwater use within the coal measures is limited, with entitlements to extract from the NSW Murray Darling Basin Porous Rock Groundwater Source exclusive to BCM and adjacent mining operations. Surrounding groundwater bores with basic access rights are also limited and are largely on land owned by the BTM Complex.

High potential terrestrial GDEs are mapped along and adjacent to several drainage features within the Gunnedah-Oxley Basin MDB Groundwater Source, which include the unnamed tributaries of Maules Creek, Back Creek and its tributaries, and the upper reaches of Goonbri Creek. As discussed in Section 6.8.2, these high potential terrestrial GDEs are now considered high priority GDEs under 2020 updates to the WSP for the Murray Darling Basin Porous Rock Groundwater Sources, which came into effect June 2020.