West Muswellbrook Project

Gateway Application Supporting Document
Appendix C

Australasian
Groundwater
and Environmental
Consultants Pty Ltd
(AGE)

Report on

West Muswellbrook Project Gateway Application

Highly Productive Aquifer Groundwater Impact Assessment

Prepared for

Muswellbrook Coal Company Limited

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Executive Summary

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) were requested by Muswellbrook Coal Company Limited (MCC) to undertake a groundwater impact assessment for the West Muswellbrook Project (Project) Gateway application. The West Muswellbrook Project is a proposed open cut mine located approximately 12 kilometres northwest of Muswellbrook, New South Wales. Following start-up, mining is proposed to quickly ramp up to extract 19 Million tonnes per annum ROM coal from the Blakefield and overlying seams (of the Jerrys Plains Sub-Group). Two pits are proposed north and south of Sandy Creek North with mining progressing in a southerly direction. The anticipated mine disturbance area is referred to in this report as the Project Assessment Area (PAA). The PAA and the immediate surroundings (~5km) are referred to in this report as the Study Area.

The purpose of this study is to assess the potential impacts of the Project on the groundwater sources. The potential impacts will be contrasted with the Gateway Process Guidelines and the Minimal Impact Considerations for Aquifer Interference Activities in accordance with NSW Aquifer Interference Policy (AIP). The assessment will also provide the requisite supporting documentation for a Gateway application. Mining and Petroleum Gateway Process is an independent, scientific and upfront assessment of how a mining or CSG production proposal will impact the agricultural values of the land on which it is proposed to be located. It will consider proposals at a very early stage before a development application (DA) is lodged.

The AIP outlines the criteria against which projects are assessed with regards to highly productive and less productive aquifers. Within the Study Area, highly productive groundwater zones, as defined in the AIP, are present in the form of alluvium and sandstone units overlying the coal measures. The Permian coal measures and some areas of alluvium are mapped as less productive groundwater sources. The Triassic sandstone escarpment to the west is considered a low yielding, relatively low salinity aquifer and its connection to the underlying Permian groundwater strata is thought to be limited.

The predominant land use in the PAA is beef cattle pasture. Relatively small areas of other land uses exist. The PAA also contains areas of dispersed remnant native vegetation cover. Groundwater use within the catchment is dominated by shallow bores, predominantly installed within the alluvium for stock supply. Lesser numbers of bores used for domestic supply and limited use for irrigation.

From a conceptual groundwater model perspective, the groundwater system in the Study Area is considered to consist of four main groundwater bearing systems, as follows:

- Alluvium (and colluvium) along the major creeks (Highly Productive Groundwater);
- Weathered bedrock near ground surface (Less Productive Groundwater);
- Triassic sandstones to the west (Highly Productive Groundwater); and
- Permian coal seams of the Wollombi and Whittingham Coal Measures (Less Productive Groundwater).

Additionally, faulting, intrusive plugs and dykes may play a part within the PAA to compartmentalise the local scale groundwater flow regime.

The proponent recognised from an early stage the importance of obtaining baseline data and characterising the groundwater regime in the Study Area. Routine quarterly monitoring commenced in 2003 and has been used in this assessment and includes surface water quality field parameters at 18 sites and groundwater levels and field water quality parameters at 30 sites. Most of the monitored sites are located within the PAA and all of them are within the Study Area. These data have been augmented with data collected from a selection of local landholder water bores, PINNEENA NSW Government groundwater database and a field bore census of key properties. The oldest bores have a data set that spans over more than ten years, with the majority of the bores having between five and seven years of data, which means the project satisfies the requirement of the AIP to have a minimum of two years of baseline data.

The total available data record of 2003-2014 spans periods of below and above average rainfall which has allowed the response of the groundwater system to these extremes to be both observed and simulated. The installation of shallow alluvial bores that monitor alluvial groundwater level has allowed analysis of groundwater-surface water interaction in the ephemeral reaches under different climate conditions.

The baseline salinity in both the groundwater and surface water system is generally high, suggesting the baseline alluvial groundwater/surface water system has a significant connection to the underlying coal seams. The alluvial systems can be largely grouped into two zones: west of the Study Area, where the alluvial groundwater level appears to be above the Permian units (downward gradient); downstream within the PAA in the drainage systems where the alluvium and Permian groundwater levels are similar. This promotes less saline groundwater and surface waters which increase in salinity downstream. Despite this fact, waters are generally brackish to saline throughout the system and only a small number of sites or individual samples have Total Dissolved Solids (TDS) content less than 1,500 mg/L, as defined by the AIP as the limit for highly productive groundwater.

Currently, a number of groundwater sources within the Study Area are mapped as highly productive. Available baseline data indicate (based on both groundwater salinity and aquifer yield) that a number of these do not meet the AIP guideline criteria for highly productive groundwater sources and should potentially be reclassified as less productive groundwater; however, it is recommended that further field pumping tests be carried out to define the alluvial aquifer yield within the PAA to confirm both yield and EC do not meet the AIP guideline limits. For the purposes of this study, the existing mapping and classification has been used.

The data collected from field investigations allowed the development of a conceptual model and simple groundwater model to assess the potential impacts of the proposed mining on the highly productive groundwater sources. No drawdown impact is predicted for highly productive Triassic sandstone groundwater system located to the west of the Study Area, nor is an impact predicted for the highly productive alluvium associated with Dart Brook and the Hunter River.

The results of modelling indicate that 19 bores within highly productive alluvium will be impacted by drawdowns greater than 2.0 m. Twelve of these bores, in the Coal Creek alluvium, are proposed to be removed by mining. The maximum drawdown at the seven remaining bores is predicted to be between 2.0 to 5.9 m.

The groundwater model predicts that, during mining, the groundwater-take from highly productive alluvium will peak at approximately 225 ML/yr. This initial estimate of calculated water-take from alluvium includes groundwater lost due to mining of the Coal Creek alluvium.

Calculated water takes from highly productive alluvium groundwater sources within and adjacent to the PAA will require water licences from the Hunter River Alluvial water source (HRAWS). This water source has been fully allocated through the Water Sharing Plan for the Hunter Regulated River Water Source. It is anticipated that the proponent shall acquire some proportion of the required water-take through future land acquisition. The proponent shall commit to securing any water allocations or licences from existing users to meet the predicted water take, prior to commencement of development.

As well as calculating the water-take from highly productive aquifers as required by the AIP, the predictive model also reported water-take from the less productive Permian groundwater strata (188 ML/year at peak). Water-take from the Permian strata is currently allocated under the Water Act 1912. The proponent currently holds water licences for existing operations. The proponent will investigate the potential for a permanent transfer of the volumetric entitlement attached to those licences and whether a new licence is needed to account for the predicted water-take from the Permian sequence at the DA stage.

At the cessation of mining, there will be a relatively high groundwater gradient between the open void and the coal seam aquifers resulting in relatively rapid inflows. As a pit lake begins to form in the void, the gradient will reduce and the rate of groundwater inflow will slow. Eventually, a state of 'quasi' equilibrium will occur where inputs are balanced by outputs. Recovery of groundwater levels in the surrounding alluvial and coal seam aquifers will be dependent on rainfall, with years of below average rainfall extending the recovery period and wet years reducing the time for stabilisation. Groundwater levels will not fully recover to pre-mining levels if average evaporation losses exceed rainfall and runoff. This will result in the most likely scenario of a cone of depression in the aquifer. A water-take will potentially be required from both the highly productive alluvial groundwater and less productive Permian water source post closure. The post closure take being less than the peak during mining.

The north pit is proposed to be completely backfilled and may recover close to the original groundwater level pre-mining. Further post closure modelling will be completed as part of the detailed design phase of the development application and final landform design will include measures to reduce groundwater seepage from previously mined areas.

In addition to groundwater flow modelling, coal seam and interburden rock samples are currently undergoing kinetic leach tests. Initial water extract results indicate that spoil material will be fairly benign from an acid generating point of view and the salinity of the leachate will be similar to the levels within the current groundwater environment.

In summary, this document addresses the requirements of the Gateway Process Guidelines and the AIP. Further investigations and modelling using more detailed site specific data will be carried out at the DA stage so that potential impacts can be more accurately assessed.

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Glossary & Acronyms

AIP	Aquifer Interference Policy
AL	Assessment Lease
CIC	Critical Industry Cluster: Industry clusters that meet the following criteria: - there is a concentration of enterprises that provides clear development and marketing advantages and is based on an agricultural product; - the productive industries are interrelated; - it consists of a unique combination of factors such as location, infrastructure, heritage and natural resources; - it is of national and/or international importance; - it is an iconic industry that contributes to the region's identity; and - it is potentially substantially impacted by coal seam gas or mining proposals.
CRD	Cumulative Rainfall Departure
DGPS	Differential Global Positioning System
EC	Electrical Conductivity
EVT	Evapotranspiration
Gateway Process Guidelines	Guidelines which outline the Mining and Petroleum Gateway process ('Gateway Process'), which is an independent, scientific and upfront assessment of how a mining or CSG production proposal will impact the agricultural values of the land on which it is proposed to be located. It will consider proposals at a very early stage before a development application is lodged.
GDE	Groundwater Dependent Ecosystem
GIS	Geographic Information System
Goaf	The cavity behind an underground coal working face
MCC	Muswellbrook Coal Company
Mtpa	Million tonnes per annum
NOW	NSW Office of Water
PAA	Project Assessment Area is the actual proposed mine area
PEST	Parameter Estimation Software
PINNEENA NSW	NSW Office of Water supplied database of registered groundwater bores
Project	West Muswellbrook Mining Project
SAL	Strategic Agricultural Land West Muswellbrook Project
SMB	Soil Moisture Balance
SILO	SILO is a database of historical climate records for Australia
SRTM	NASA Shuttle Radar Topography Mission
Study Area	The Study Area is considered to be the PAA, the immediate surrounds (~5km) and the AL with the exception of the small area west of the Mt Ogilvie Fault Zone
TDS	Total Dissolved Solids

Report on

West Muswellbrook Project Gateway Application

Highly Productive Aquifer Groundwater Impact Assessment

1. Introduction

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) were commissioned by Muswellbrook Coal Company Limited (MCC) to undertake a groundwater impact assessment for the West Muswellbrook Project (the Project) Gateway application (the Application). The objective of this report is to address the groundwater related requirements outlined by the NSW Government in the *Guideline for Gateway Applicants,* dated September 2013 (Gateway Process Guidelines). This report addresses the groundwater related aspects of the Division 4, Gateway application – State Environmental Planning Policy (Mining, Petroleum Production and Extraction Industries 2007) and aspects of the NSW Aquifer Interference Policy (AIP) in regard to impacts on highly productive and less productive aquifers.

1.1 The West Muswellbrook Project

The Project is a proposed open cut mine located approximately 12 kilometres (km) northwest of Muswellbrook. Figure 1.1 shows the region and the PAA, while Figure 1.2 shows the extent of the proposed mining within the PAA (North Pit and South Pit). The PAA is the basis of the future Development Application (DA) area and includes the mine disturbance footprint and 100 metre buffer. The PAA, the immediate surrounds (~5km) and the Assessment Lease (AL), with the exception of the small area westof the Mt Ogilvie Fault Zone, are referred to in this report as the Study Area. As groundwater related impacts may extend beyond the PAA, the boundary of the groundwater technical study was extended to encapsulate the impact from the Project and any cumulative impacts from surrounding mining.

Following start-up, mining is proposed to quickly ramp up to mine 19 Million tonnes per annum (Mtpa) ROM coal. Currently, the Blakefield Seam (of the Jerry's Plain Sub-Group) will be the lowest mined seam. Mining will commence with development of a box-cut in the north and will progress southwards towards Sandy Creek North through years 3 to 13. At that stage, mining will relocate to the immediate south of Sandy Creek North where a second box-cut will be developed. The mine will progress southwards leading up to year 30, the proposed completion of mining. Sandy Creek North which is the centre of the operation will not be mined and will be crossed to transport coal and overburden to and from the northern pit. A section of Coal Creek (an ephemeral tributary of Sandy Creek South) is proposed to be mined through. One void will remain at the end of mining at year 30, in the south of the PAA.

1.2 The Gateway Process: Highly productive groundwater impact assessment

The Gateway Process Guidelines published by the NSW Government (2013) outlines information that applicants are required to provide with a Gateway Application in relation to "highly productive groundwater sources". These criteria are summarised in Table 1-1.

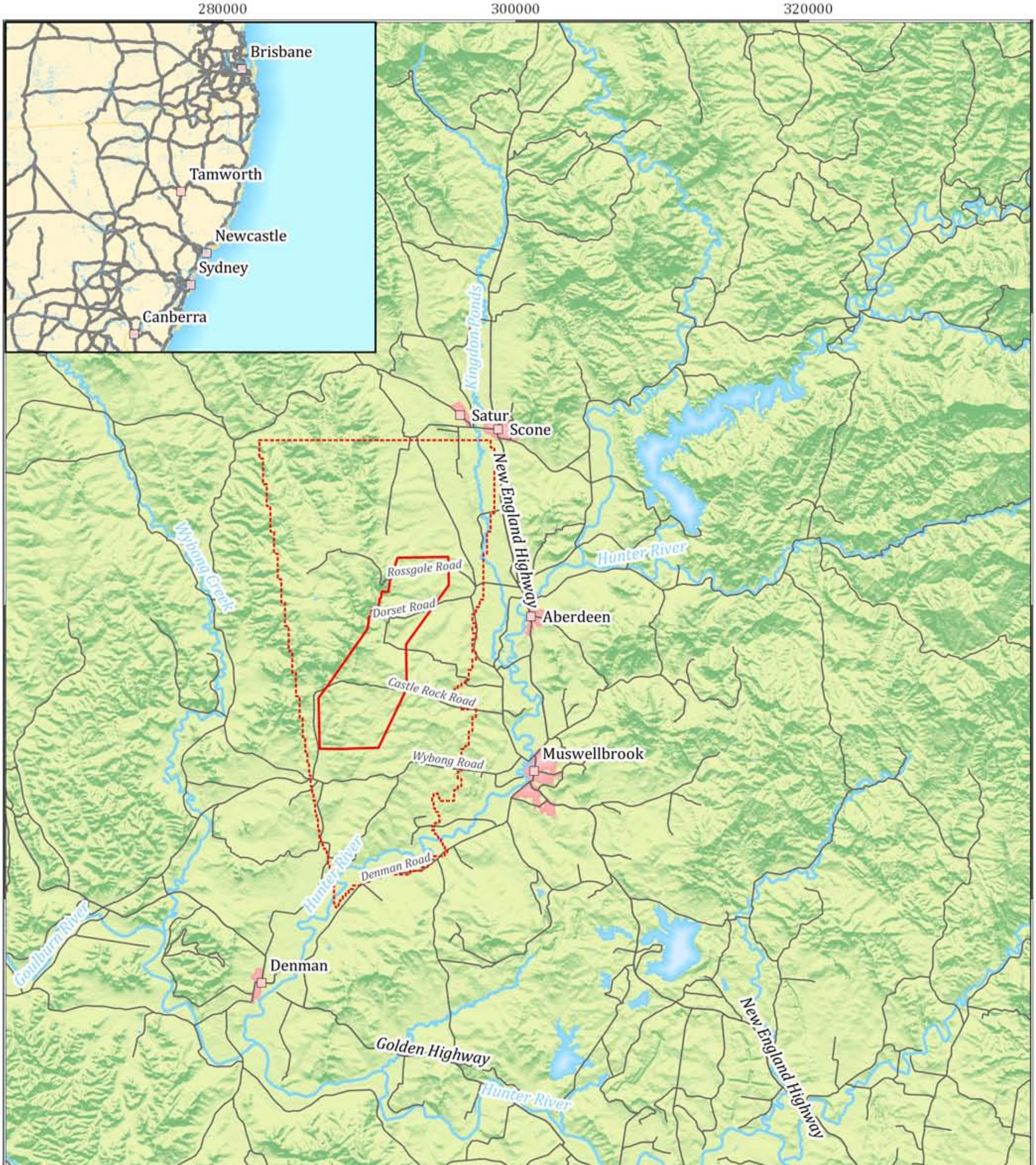
Table 1-1 Aquifer interference policy highly productive aquifers criteria:

Criteria	Section addressing this point
Estimates of all quantities of water that are likely to be taken from any water source on an annual basis during and following cessation of the activity.	See Section 5.1
A strategy for obtaining appropriate water licence/s for maximum predicted annual take.	See Section 5.2
Establishment of baseline groundwater conditions including groundwater depth, quality and flow based on sampling of all existing bores in the area, any existing monitoring bores and any new monitoring bores that may be required under an authorisation issued under the Mining Act 1992 or the Petroleum (Onshore) Act 1991.	See Sections 2 to Section 3.11 and Section 5.3
A strategy for complying with any water access rules applying to relevant categories of water access licences, as specified in relevant water sharing plans.	See Section 5.2
Estimates of potential water level, quality and pressure drawdown impacts on nearby water users who are exercising their right to take water under a basic landholder right.	See Section 5.4
Estimates of potential water level, quality and pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources.	See Section 5.4
Estimates of potential water level, quality and pressure drawdown impacts on groundwater dependent ecosystems.	See Section 5.5
Estimates of potential for increased saline and contaminated water inflows to aquifers and highly connected river systems.	See Section 5.6
Estimates of the potential to cause or enhance hydraulic connection between aquifers.	See Section 5.7
Estimates of the potential for river bank instability, or high wall instability or failure to occur.	See Section 5.8

The above requirements are also set out in Section 3.2.3 of the AIP. The Gateway Process Guidelines also states that:

> *'information should be based on a simple model that uses best available baseline data collected at an appropriate frequency and scale and that is determined to be fit-for-purpose to the satisfaction of the Minister for Primary Industries. Proponents should also provide a strategy for moving to modelling using more detailed site specific data that will be used at the development application stage to better assess potential impacts.*
>
> *The information detailed above will be used to assess the project against the criteria specified in 'Table 1 - Minimal Impact Considerations for Aquifer Interference Activities' in the Aquifer Interference Policy.'*

While the Gateway Process Guidelines states the information should be based on a 'simple model', it does require the applicant to predict a suite of impacts that is essentially the same as what is required for an EIS. The key differences between a Gateway Application Groundwater Model and one prepared for an EIS is the level of calibration achieved with the model, and the focus on highly productive aquifers.



LEGEND

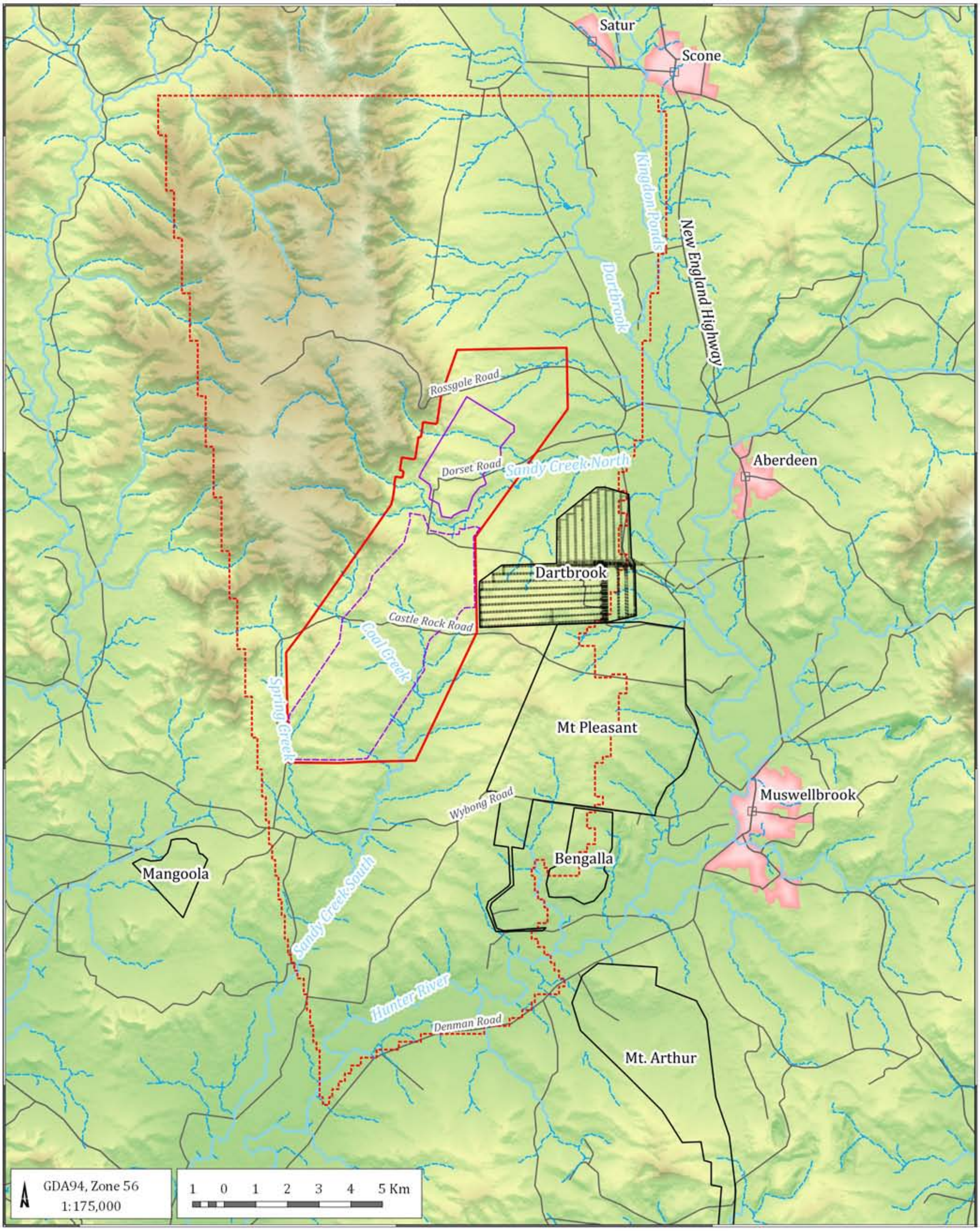
- Project Assessment Area
- Study Area
- Populated place
- Built up areas
- Road major
- Road
- Major watercourse
- Water area

West Muswellbrook (G1676)

Site Location

DATE 10/11/2014

FIGURE No: **1.1**



LEGEND

- North Pit
- South Pit
- Dartbrook underground mine plan
- Surrounding mine extents
- Project Assessment Area
- Study Area
- Populated place
- Built up areas
- Main streams
- Minor ephemeral streams
- Road major
- Road

West Muswellbrook (G1676)

WMB Project Assessment Area and surrounding mines

AGE GROUNDWATER & ENVIRONMENTAL

DATE 10/11/2014

FIGURE No: **1.2**

1.3 Highly productive groundwater sources

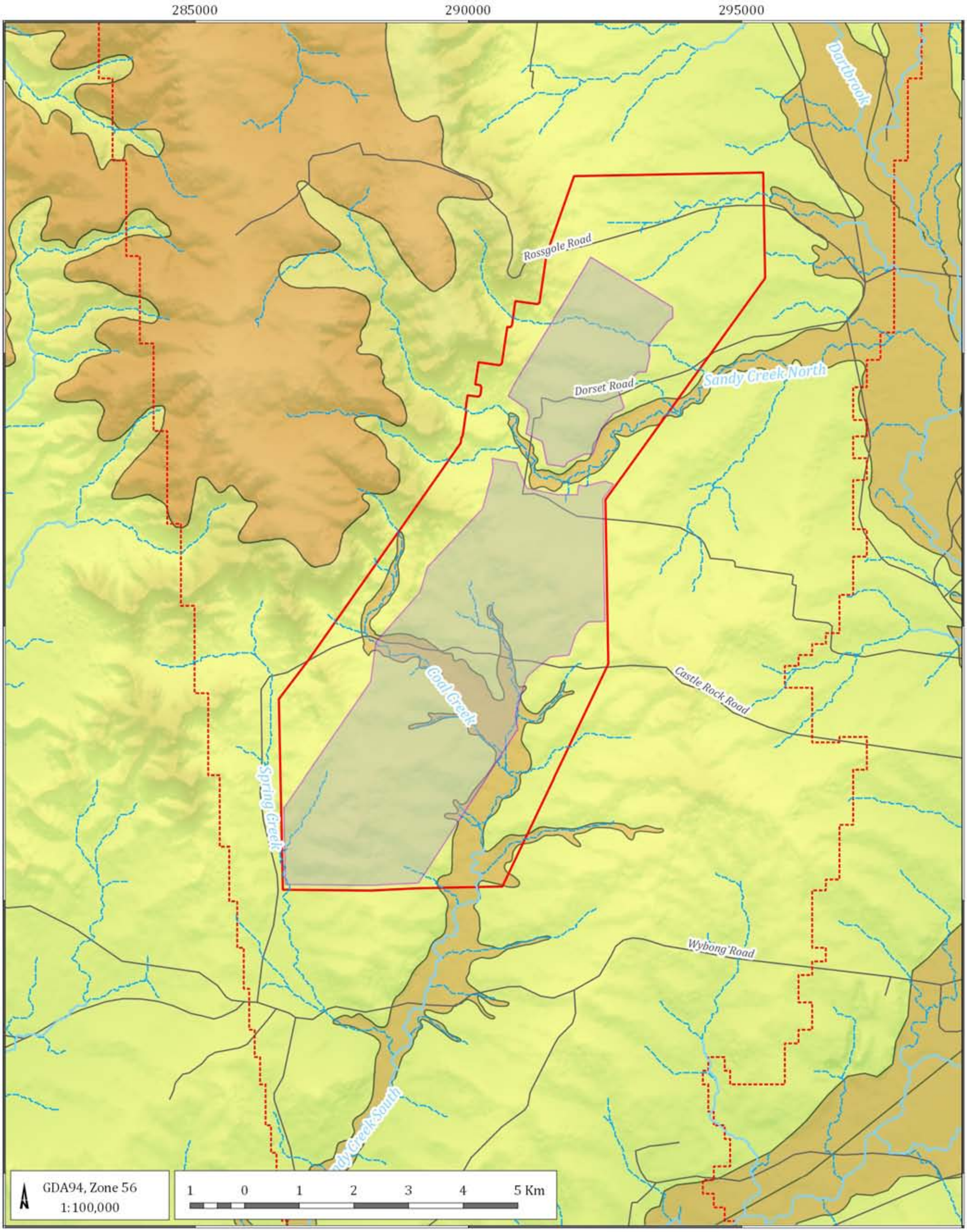
The AIP divides all groundwater sources within NSW into highly productive and less productive. Highly productive groundwater is defined as a groundwater source that is declared in the Regulations and based on the following criteria:

a) has total dissolved solids of less than 1,500 mg/L; and
b) contains water supply works that can yield water at a rate greater than 5 L/sec.

Figure 1.3 shows the mapped[1] extent of highly productive groundwater sources in the vicinity of the PAA. Within the PAA, the alluvium of Sandy Creek North and Sandy Creek South is mapped as highly productive. Outside the PAA, the sandstone escarpment to the west and the Hunter River alluvium to the south and east are also considered highly productive groundwater sources. The Permian Coal measures that are the target of the project are mapped as less productive groundwater sources.

Baseline data presented in this report and salinity measurements indicate that the alluvial aquifers of Sandy Creek North and South may be less productive aquifer than initially mapped . Section 3 includes the discussion regarding the groundwater regime and presents data supporting the above conclusion.

[1] New South Wales Office of Water (June 2013), "Classification by Productivity class of Groundwater Source areas based on NSW Water Sharing Plan", NSW Office of Water, Primary Industries, Dept. Trade, Investment and Regional Services, Digital Dataset (ArcGIS 10 file Geodatabase), Sydney NSW.



LEGEND

Groundwater productivity

- Highly
- Less
- Project Assessment Area
- Study Area
- North Pit
- South Pit
- Main streams
- Minor ephemeral streams
- Road

West Muswellbrook (G1676)

Highly and less productive aquifers mapped around the PAA

DATE 10/11/2014

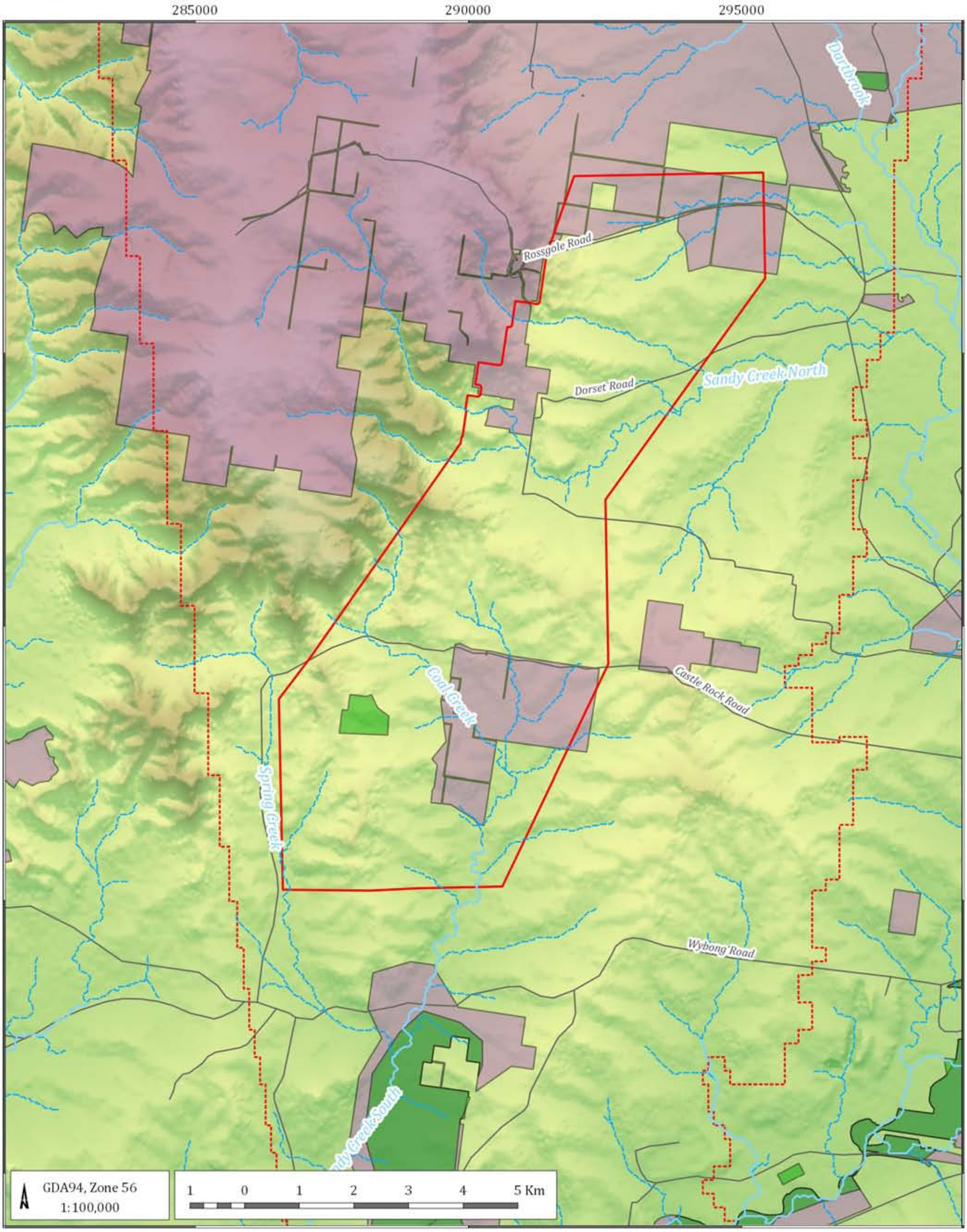
FIGURE No: **1.3**

1.4 Strategic agricultural land – Critical industry cluster

Strategic Agricultural Land (SAL) Critical Industry Clusters (CIC) are defined by the following criteria:

- a concentration of enterprises that provides clear development and marketing advantages and is based on an agricultural product;
- the productive industries are interrelated;
- a unique combination of factors such as location, infrastructure, heritage and natural resources;
- of national and/or international importance;
- an iconic industry that contributes to the region's identity; and
- potentially substantially impacted by coal seam gas or mining proposals.

Figure 1.4 shows the distribution of the mapped CICs in vicinity of the PAA.



LEGEND

- Critical Industry Clusters: SAL Equine*
- Critical Industry Clusters: SAL Viticulture*
- Project Assessment Area
- Study Area
- Main streams
- Minor ephemeral streams
- Road
- Road major

West Muswellbrook (G1676)

Strategic Agricultural Land (SAL) - viticulture and equine

DATE 10/11/2014

FIGURE No: **1.4**

Ref: New South Wales Planning & Environment (2013), "Strategic Agricultural Land", New South Wales Planning & Environment, Digital Dataset, Sydney NSW.*

1.5 Previous work

Exploration drilling in the Study Area was undertaken in the 1970's by Goldfields and Armco companies and then by MCC from 1998 to 2006 (Stage 1 to 6). Although primarily resource drilling, some hydrogeological information was also collected including groundwater levels[2], groundwater quality and hydraulic testing (MCC 2008).

MCC installed twenty piezometers between 1998 to 2006 as part of a coal exploration program. The piezometers targeted the coal seams and the alluvium of Sandy Creek North and South. MCC also installed data loggers in shallow piezometers to automatically record water levels within the beds of Sandy Creek North and South. Surface water stage (stream level) and groundwater level can be inferred from these sites providing some limited information of when the stream systems flow.

AGE (2008) prepared a groundwater study as part of a pre-feasibility study commissioned by MCC. This report considered some but not all baseline monitoring data and hydraulic testing from 2003 to 2008 from groundwater bores within the Study Area. It also presented a brief impact assessment and steady state mine inflow prediction. No groundwater modelling was undertaken for that study.

MCC have collected groundwater level and groundwater quality baseline data from late 2003 to 2014 that was available for this report. This is a significant temporal dataset for a green field project. The AIP requires two years of baseline data.

1.6 Methodology

The methodology for this study was based on the requirements of the Gateway Process Guidelines for highly productive groundwater (Section 1.2). In particular AGE has:

- Conducted a desktop review of available reports and literature review;
- Established a baseline data set;
- Compiled and analysed data from the Project and surrounding mines, including:
    - Temporal groundwater level data from the Project monitoring network, published reports from surrounding mines, the NSW Office of Water (NOW) groundwater monitoring network and PINNEENA[3] database; and
    - Temporal groundwater and surface water quality data from the Project network;
- Merged digital terrain data sets to create a detailed terrain model within the PAA and the wider region (site supplied detailed data merged with SRTM data[4]);
- Analysed topography data supplemented by a differential global positioning system (DGPS) survey to define river and stream bed elevations;
- Reviewed the existing geological data supplied for the PAA and extrapolated the data beyond the PAA based on public domain reports[5] from surrounding mines;
- Conducted an initial census of selected privately owned bores[6] within and surrounding the PAA by way of a site visits during June and July 2014;

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[2]Groundwater levels have been recorded in most open exploration holes following the completion of drilling.

[3] PINNEENA – NSW Office of Water supplied database of registered groundwater bores in the state.

[4] 1 arc second DEM-S (smoothed digital elevation model - 1 second SRTM derived) - © Commonwealth of Australia (Geoscience Australia) 2011

[5] The Bengalla EIS (AGE 2013), Dartbrook (AngloAmerican 2013) and Mangoola EIS (MER 2006)) groundwater studies.

- Developed a conceptual hydrogeological model of the groundwater regime for the purpose of defining any impact on highly productive aquifers;
- Developed a numerical flow model of the groundwater system and calibrated this to available temporal groundwater and surface water data to identify any potential for impact to the highly productive aquifers;
- Simulated the effect of the proposed mining on the groundwater regime using the calibrated model, including:
  - Water-take from all groundwater sources;
  - Drawdown at any private landholder bores;
  - Changes in baseflow to local streams;
  - Changes to groundwater salinity; and
  - Potential for interconnection between aquifers.
- Reported findings in this technical report to address the requirements of the Guideline as set out in Section 1.2.

1.7 Structure of this report

The report is set out as follows:

- Section 2 – outlines the regional setting;
- Section 3 – describes the hydrogeology, conceptual modelling and baseline conditions;
- Section 4 – describes numerical modelling and predicted impacts;
- Section 5 – compares the Project against the AIP requirements for highly productive groundwater which are also specified in the Gateway Process Guidelines;
- Section 6 – compares information gathered against the Minimal Impact Considerations for Aquifer Interference Activities in the AIP; and
- Section 7 and 8 - provides conclusions and recommendations for additional fieldwork and modelling during the DA.

[6] Only properties with landholder access arrangements were visited in the initial census.

2. Regional setting

2.1 Location

The PAA is 5.3 km from the western periphery of Aberdeen Township and approximately 10 km to the north-west of Muswellbrook in the Upper Hunter Valley of New South Wales. Exploration was completed under two licences: Rosehill Exploration Licence (EL 5431) and Castle Rock Exploration Licence (EL 5600).

A number of existing mining leases and existing or proposed mining projects join the eastern boundary of the PAA. These include from north to south the Dartbrook underground mine, the approved, but yet to be developed Mt. Pleasant open cut mine, the Bengalla open cut mine, to the south-west the Mangoola open cut mine and the Mount Arthur open cut mine across the Hunter River (Figure 1.2).

2.2 Climate

The regional climate is typical of temperate areas and is characterised by hot summers dominated by thunderstorms and mild dry winters. The Bureau of Meteorology (BOM) monitoring site at Aberdeen (Main Rd) provides rainfall records back to 1891 (BOM 2014). These data provide an insight into long term climatic cycles that influence groundwater recharge. In-filled SILO[7] rainfall data were also obtained from Aberdeen Main Road. SILO data was also used to supply simulated daily evaporation and evapotranspiration using the FAO56 method (Allen et al 1998).

Climate data on the top of the escarpment to the west were also investigated using the SILO Rossgole site. The escarpment is both a rainfall recharge source to the Triassic sandstone and source of run-off to both Sandy Creek systems within the PAA.

The long-term average annual rainfall at Aberdeen is 605 mm and higher on the escarpment at 726 mm, with December to February being the wettest months (60mm to 70 mm). Figure 2.1 shows average monthly rainfall at both sites with consistently more monthly rainfall for the elevated escarpment compared to the lower lying areas. The winter dry season from April to September is also clearly evident.

[7] http://www.longpaddock.qld.gov.au/silo - modelled rainfall supplies a complete record for the rainfall site when the rainfall gauge has no reported data.

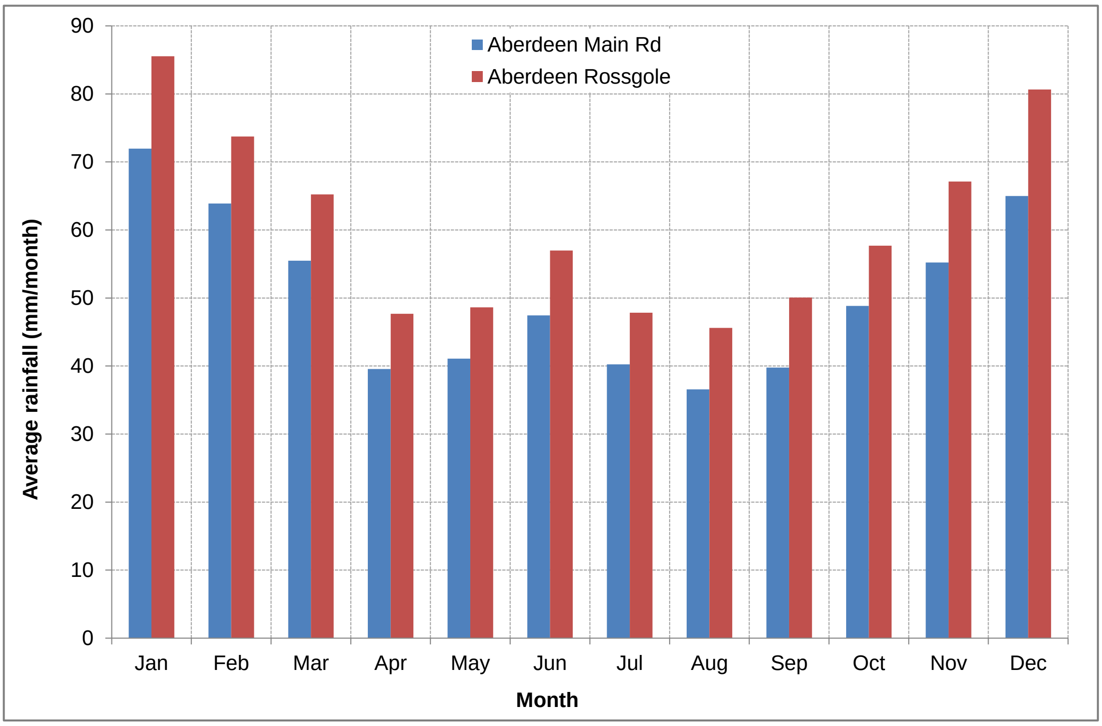

Figure 2.1 Monthly average rainfall at Aberdeen and Rossgole (top of escarpment)

The long-term annual average evaporation of 1,598 mm/year at Aberdeen and 1515 mm/year at Rossgole exceeds mean rainfall throughout most months of the year, the highest moisture deficit occurring during summer (Figure 2.2).

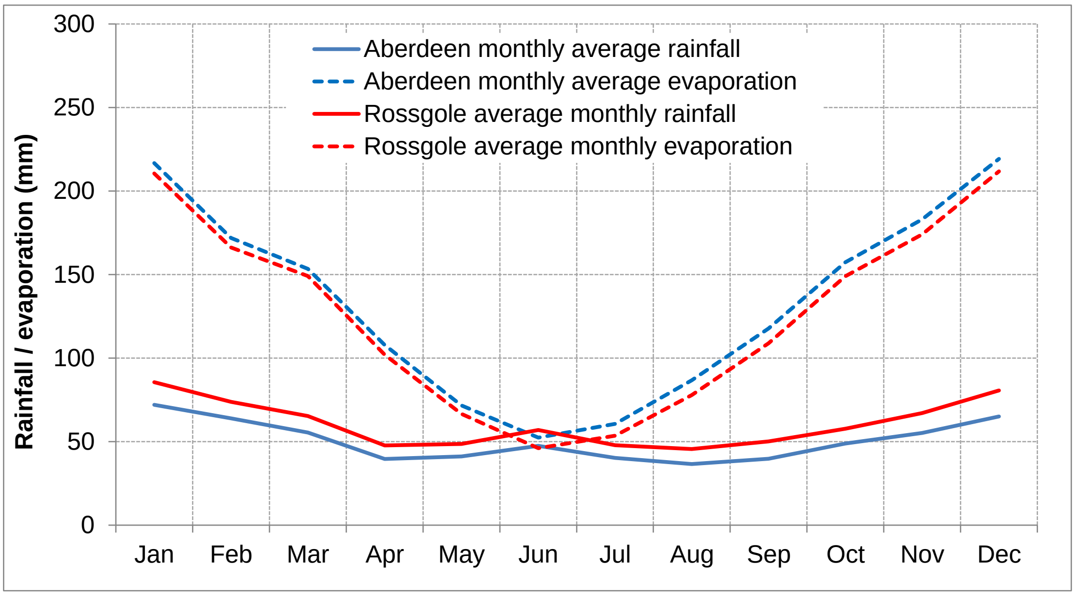

Figure 2.2 Monthly average evaporation versus rainfall at Aberdeen and Rossgole

The mean maximum temperature during the winter months varies in the range of 16.7°C to 18.7°C, while in summer, the mean maximum daily temperature reaches 32.0°C in January (Scone Station).

Monthly rainfall records were used to calculate the Cumulative Rainfall Departure (CRD – also known as rainfall residual mass) for the Aberdeen site. Figure 2.3 shows the calculated CRD.

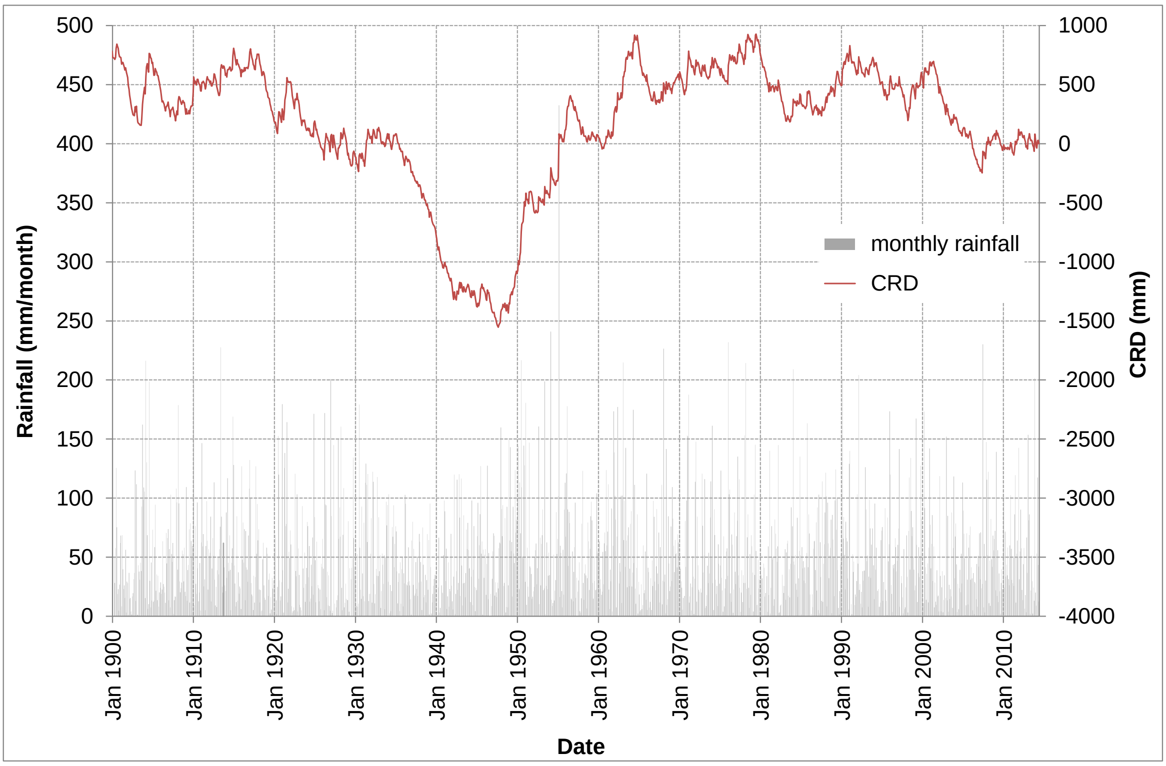

Figure 2.3 Monthly rainfall and cumulative rainfall departure Aberdeen

The CRD shows trends in rainfall relative to the long term average and provides an historical record of relatively wet periods and droughts. A rising trend in slope in the CRD plot indicates periods of above average rainfall, while a declining slope indicates periods when rainfall was below average. The CRD in Figure 2.3 indicates that the district experienced below average rainfall for an extended period from 2001 to 2007 followed by above average rainfall between 2007 and 2008, followed by a generally average rainfall until present. The CRD plot has been used throughout the subsequent sections of this report to discuss climatic trends with regards to water flows, groundwater levels and water quality results.

2.3 Topography and drainage

The Study Area occupies a gently rolling landscape (between 200-330 m Australian Height Datum (AHD) elevation) along the foot of a Triassic sandstone escarpment which lies immediately to the west and which rises to approximately 600 m AHD. The PAA is drained principally by Sandy Creek North and Sandy Creek South (including Coal Creek and Spring Creek). A drainage divide occurs between the two creeks parallel to and about 1 km north of Castle Rock Road. Figure 2.4 shows the topography for the Study Area, and the major and minor drainage lines (Dartbrook, Kingdom Ponds and the Hunter River).

Figure 2.4 is based on a digital elevation model (DEM) supplied for the Study Area[8], merged with regional SRTM[9] data to form the wider region. Drainage analysis was performed to plot stream lines at low points within the merged DEM. Based on field checking and airphoto interpretation this digital developed drainage network is more accurate than the published 1:250,000 topographic map data (see Figure 2.4). Surveyed stream bed elevations were checked against the merged DEM to help define river beds for further detailed modelling work (see Table 2-1). Surveyed stream bed elevation was on average 2.7 m below the DEM with a maximum difference in elevation areas of 10.5m.

Table 2-1 River bed elevation DGPS survey

Description	Easting (MGA 56)	Northing (MGA 56)	DGPS elevation (m AHD)[1]	DEM elevation (m AHD)	Difference (m)
Dartbrook	297682.87	6441584.0	166.41	168.91	2.50
Sandy Creek North	291097.32	6438131.4	232.66	233.10	0.44
Sandy Creek North	291088.16	6438135.8	230.68	233.34	2.66
Sandy Creek North	291323.31	6437733.2	228.59	227.81	-0.78
Sandy Creek North	297040.45	6439949.2	170.10	175.08	4.98
Sandy Creek North (tributary)	294880.20	6436066.3	235.53	245.99	10.46
Sandy Creek North (tributary)	294252.05	6436536.4	222.45	231.14	8.69
Sandy Creek North (tributary)	294004.83	6436689.0	220.53	221.71	1.18
Sandy Creek North (tributary)	293351.35	6439459.6	205.62	208.18	2.56
Sandy Creek North (tributary)	294112.30	6439704.2	195.70	196.28	0.58
Coal Creek	288156.17	6434859.7	252.06	253.09	1.03
Coal Creek	289614.96	6433950.0	222.74	222.69	-0.05
Coal Creek	290028.49	6433468.6	213.58	214.84	1.26
Coal Creek/ Sandy Creek South	290465.85	6432927.6	200.64	205.06	4.42
Sandy Creek South	290779.50	6434457.0	222.06	222.31	0.25
Sandy Creek South	290775.34	6434445.8	220.52	221.84	1.32
Sandy Creek South	290285.50	6431405.1	186.57	185.84	-0.73
Sandy Creek South	289183.69	6428132.7	156.78	159.46	2.68
Sandy Creek South	286922.68	6423781.9	134.03	135.55	1.52
Spring Creek	286325.31	6434029.2	252.42	256.75	4.33
Spring Creek	286233.15	6432463.7	225.53	231.71	6.18
Spring Creek	287371.15	6427973.0	164.06	167.07	3.01

Note: *[1] DGPS vertical accuracy approximately +/- 0.3m*

The Study Area lies within the catchment of the Hunter River[10] and the nearest point of the main river channel lies some 8 km to the south east (downstream of Muswellbrook). Sandy Creek South is the largest of the Hunter River tributaries (catchment area 137 km^2) within the Study Area and has perennial flows south of the confluence with Coal Creek (Figure 2.5). Upstream of the perennial flowing stage, the creek channel can be traced a further 7 km into the Project Area.

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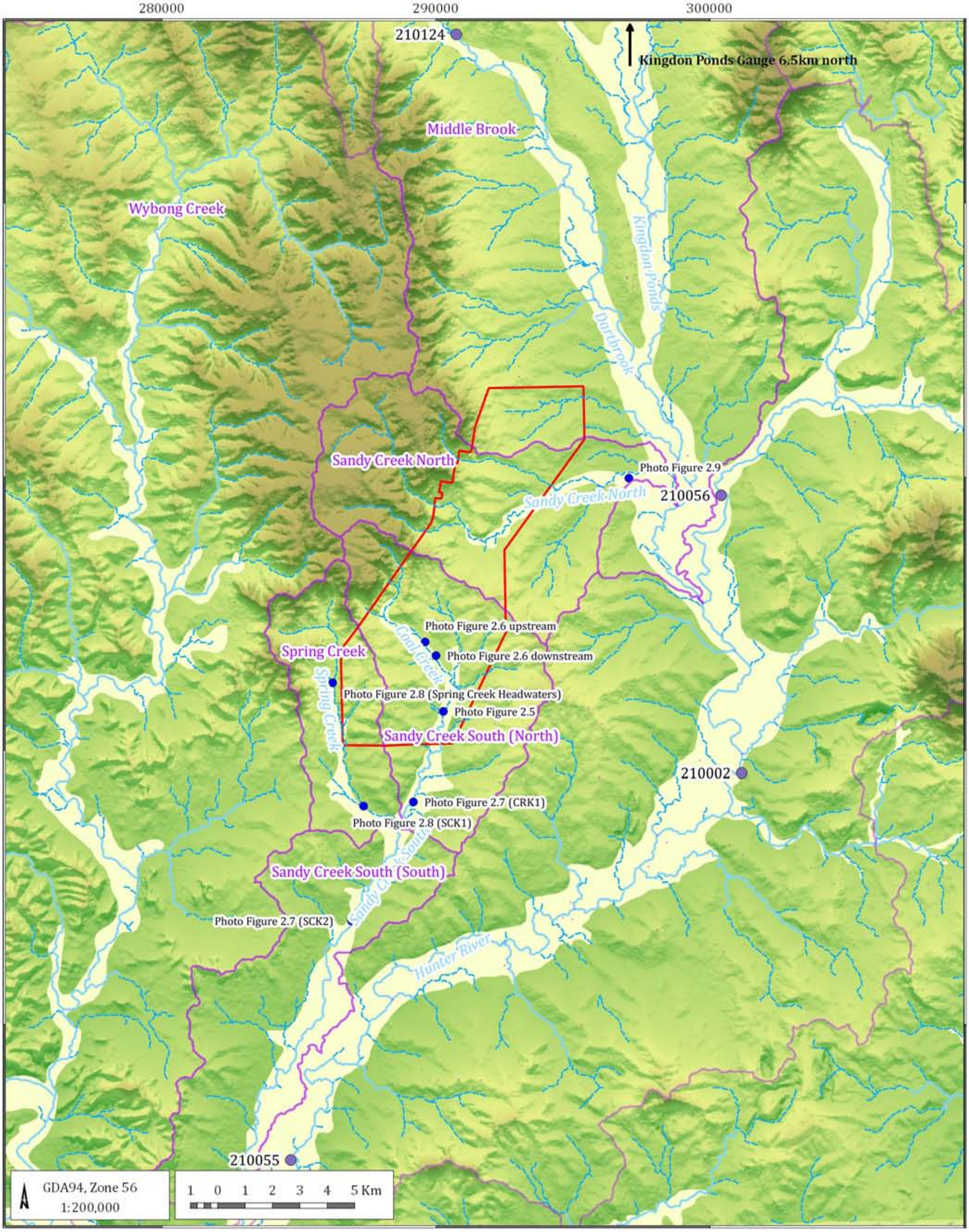
[8] No meta data documenting accuracy or source of the DEM was available.

[9] 1 arc second DEM-S (smoothed digital elevation model - 1 second SRTM derived)- © Commonwealth of Australia (Geoscience Australia) 2011

[10] The Project Area drainage system is managed under the Water Sharing Plan for the Hunter Regulated River Water Source (NSW Office of Water)



LEGEND

- Project Assessment Area
- Subcatchments
- DPI stream gauges
- Photo point
- Main streams
- Minor ephemeral streams
- Alluvium

Elevation (mAHD)

- 100 m
- 280 m
- 470 m
- 650 m

West Muswellbrook (G1676)

Topography and drainage

DATE 10/11/2014

FIGURE No: **2.4**

Figure 2.5 Photo - Sandy Creek South in vicinity of perennial flow point (location ID CCR3 see Figure 2.4)

Coal Creek is an ephemeral tributary of Sandy Creek South (Figure 2.6). The course of Coal Creek can be traced west across the Study Area to the foot slopes of the Triassic escarpment. Spring Creek joins Sandy Creek South approximately 4 km downstream of the perennial zone (Figure 2.7). Water in Sandy Creek South is not evident 6 km downstream of the Roxburgh Road crossing. The creek waters appear to sink into the bed as the creek enters the Hunter River flood plain. The channel continues parallel to the Hunter River for a further 10 km before joining the main channel at Denman. It is not known if and when water flows in this reach.

Upstream – minor flow June 2014

Downstream at CRRDH106 – dry June 2014

Figure 2.6 Photos - two locations on Coal Creek showing water upstream and dry downstream (location see Figure 2.4)

Sandy Creek South mid reach permanent flow (CRK1)

Sandy Creek South downstream of the confluence with Spring Creek – outflow from the Study Area (SCK2)

Figure 2.7 Photos – perennial reach of Sandy Creek South (location see Figure 2.4)

Spring Creek is a tributary of Sandy Creek South. During site visits on 17th to 19th June and 10th to 13th July 2014 (dry season) Spring Creek was noted to be the tributary of Sandy Creek South with the most sustained baseflow. Flowing sections (and pools) were evident from the headwaters at the base of the escarpment and within mid reach sections (Figure 2.8). In comparison, minor pools and flows noted in Coal Creek, near the escarpment, dried downstream to the confluence and perennial stretch of Sandy Creek South.

Flows Spring Creek headwaters June 2014

Flowing mid reach at SCK1 – June 2014

Figure 2.8 Photos – Spring Creek headwaters and flow mid reach (location see Figure 2.4)

Sandy Creek North is an ephemeral creek which crosses the northern section of the PAA. Sandy Creek North can be traced westwards from its confluence with Dart Brook, near Aberdeen, to its origin at the foot of the Triassic escarpment. The creek drains a catchment of 64 km^2 and appears to be drier than Sandy Creek South (based on field assessment 17th to 19th June 2014 - see Figure 2.9).

Figure 2.9 Photo – Sandy Creek North June 2014

Using the Strahler method for stream classification (which assigns each headwater perennial streams an order of 1) and the DIPNR (2005) guidelines, Sandy Creek North and Sandy Creek South, above their respective perennial heads are considered Schedule 1 streams – a first and second order watercourse and are usually intermittent. Sandy Creek South downstream of its perennial stage is considered a Schedule 2 stream.

Surface water stage and flow is monitored by the NOW on the main river systems (Hunter River, Dart Brook and Kingdon Ponds Creek) to the east of the Study Area. Figure 2.4 shows the position of these monitoring sites. Average daily and monthly stage and flow was analysed for these sites with monthly data presented in this report. Monthly data were utilised as this is the most relevant time step to the available groundwater data.

Figure 2.10 shows the monthly average flows from 1998 to 2014 for the three gauges on the main drainage systems to the east of the PAA. As would be expected, flows at all three sites correlate with the rainfall trends plotted in the CRD. For CRD explanation refer to Section 2.2.

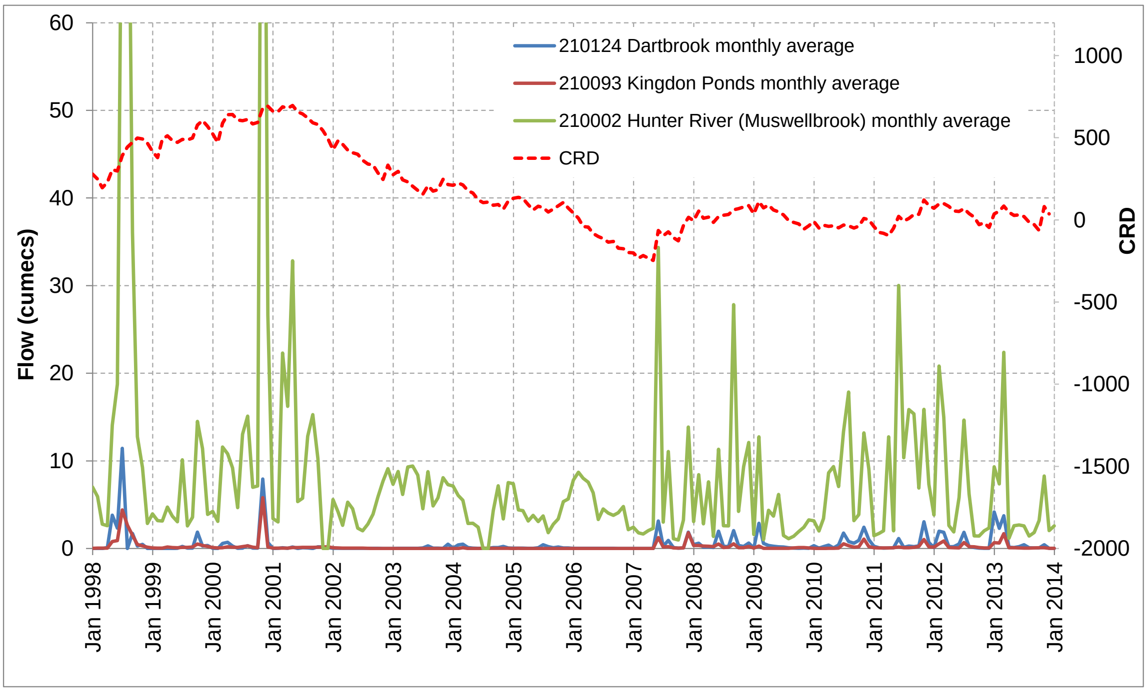


Figure 2.10 NOW stream gauge monthly flows compared to CRD

The time period from 1998 to 2014 was selected as it overlaps the period where data are available for the PAA and, based on CRD, represents both prolonged droughts and periods of above average rainfall. It should be noted that flows in the Hunter River are sustained by releases from Glenbawn Dam. As shown in Figure 2.4, while the gauges on Dartbrook and Kingdon Ponds are located a significant distance upstream from the Study Area, they provide an indication of possible flows in downstream reaches.

Figure 2.11 shows the monthly river stage heights for all sites. Generally, there is less than 1 m of water in the rivers at the gauging stations.

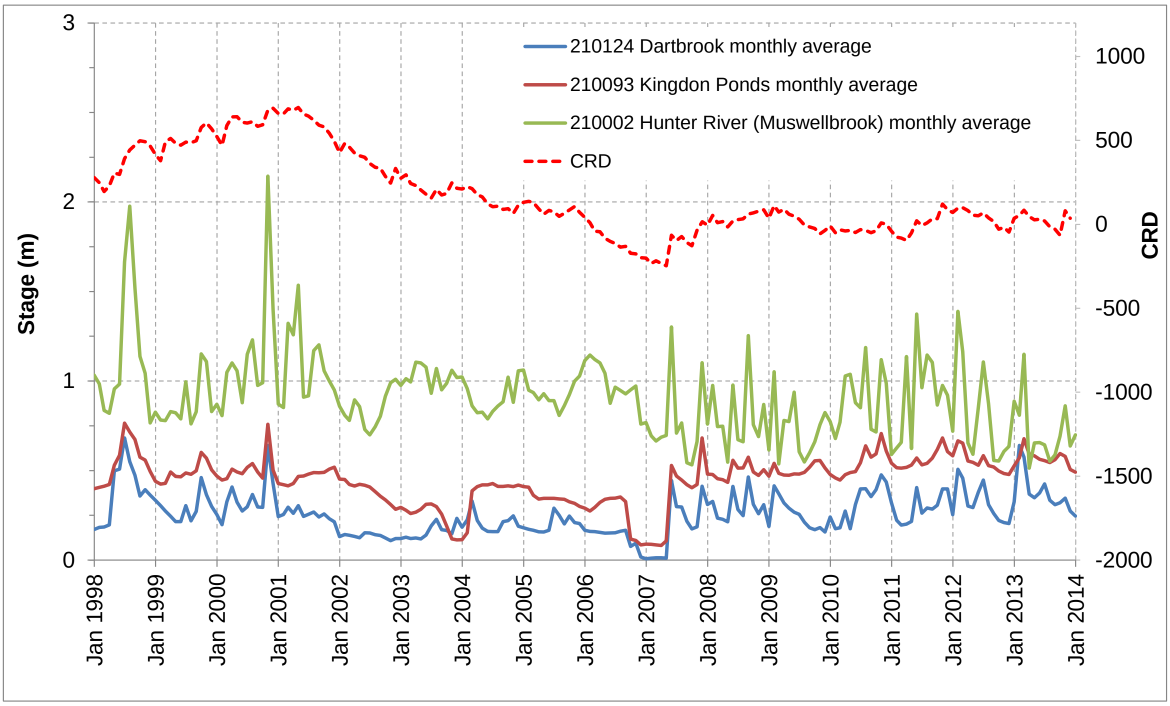


Figure 2.11 NOW stream gauge monthly stage compared to CRD

2.4 Geology

Stratigraphy across the PAA broadly comprises the Permian Whittingham and overlying Wollombi Coal Measures and Quaternary alluvium. The Permian strata dip to the west and are overlain, outside of the PAA, by Triassic age Hawkesbury Sandstone, which forms the escarpment to the west. The Triassic strata are in turn overlain by a relatively thin cap of Tertiary basalt.

The Whittingham Coal Measures, specifically the Jerrys Plains Group, contain the target coal seams for the Project (to the base of the Blakefield seam). A general lithological section for the mine area to the proposed depth of mining is presented in Table 2-2 and described in a more detail in the subsequent sections.

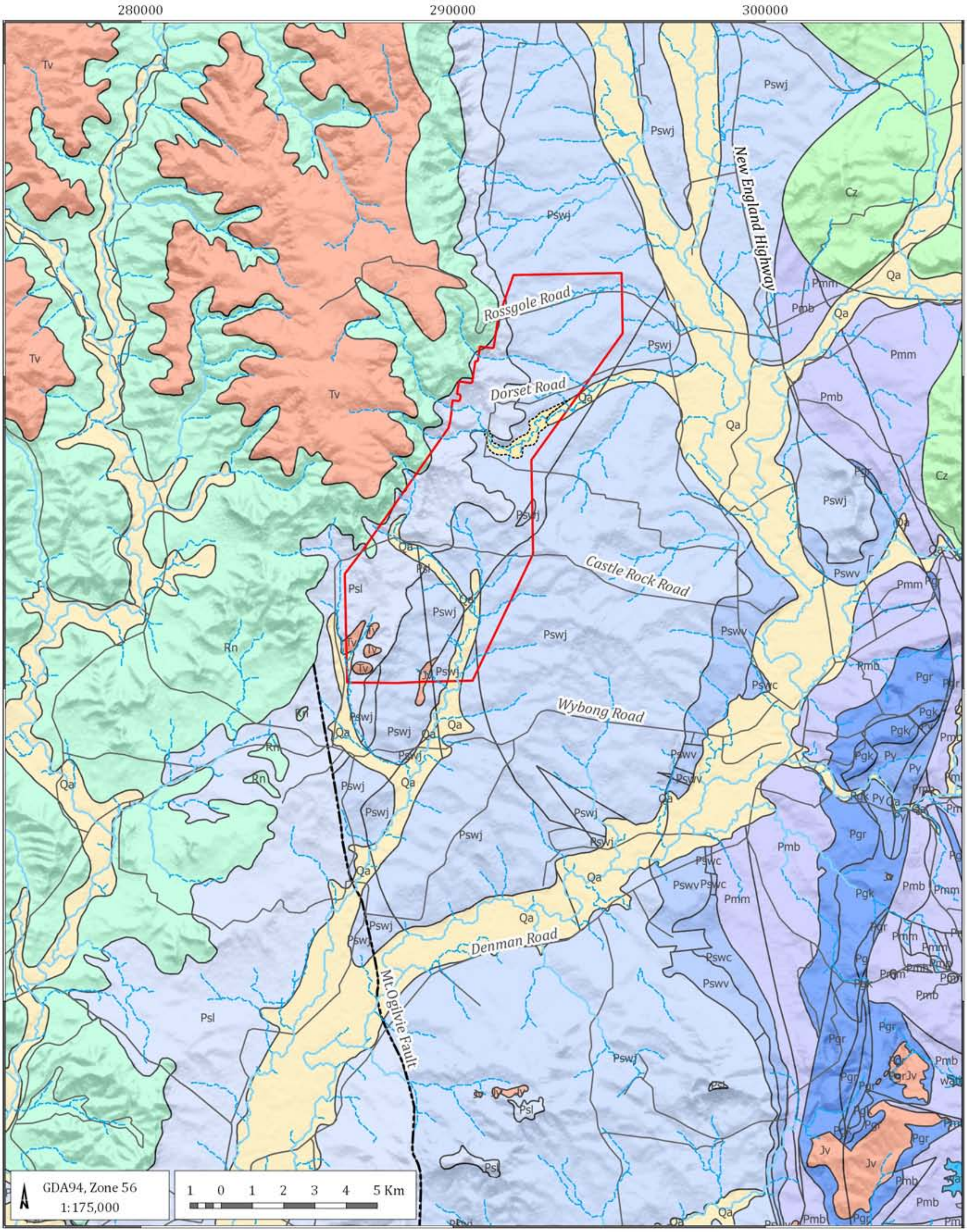
Figure 2.12 shows 1:100,000[11] published regional geology and structures of the wider project area. Figure 2.13 shows site specific geology collected by MCC including detailed structures, dykes, coal seam sub-crops and regions of surficial coal fired zones[12] (Idemitsu 2014).

[11] Hunter Coalfield Regional 1:100,000 Geology map.
[12] Area where coal seams have been burnt.

Table 2-2 Summary of site stratigraphy

Age	Group	Sub Group/ Formation	Seam (with approx. thickness m)	Thick-ness (m)	Description	Occurrence
Quaternary	Alluvium (Qa)			5 - 12 Av≈7	Ranges from clean sand to sand, silt sandy clay, clayey sand and clay. Gravel is fine to medium, sub-rounded to sub-angular and up to 12mm in diameter	Deposits associated with Sandy Creek (north) and Sandy Creek (south)
Triassic	Hawkesbury Sandstone (Rn)			800m	Massive cross bedded quartz sandstone	North-west section of EL5431
Permian	Wollombi Coal Measures (Psi)	Glen Gallic	Fassifern Seam, Great northern Seam,	55m	Coal seams, claystone (tuffaceous), siltstone, sandstone, conglomerate.	Mangoola Mine
		Doyles Creek	Generally contains uneconomic coal seams	60		Subcrops in the western part of the leases west of Sandy Creek (north and south)
		Horseshoe Ck		110		
		Apple Tree Flat	Abbey Ck Upper (9)	30		
			Abbey Ck Lower (3)			
		Watts Sandstone		30-60	Medium to coarse-grained massive sandstone	
	Whittingham Coal Measures (Pswj)	Denman Formation		30	Sandstone-siltstone laminate and siltstone	
		Jerrys Plains Subgroup /Mount Leonard Formation	Whybrow and Abbey Green (3)	12	Fine-to-coarse grained sandstone with siltstone and tuffaceous claystone interbeds, with persistent coal seams	Subcrops with a north-east/south west strike in the central and eastern part of the EL's
		/Malabar Formation	Redbank Ck (3)	160		
			Wambo (3)			
			Whynot (3)			
			Blakefield (4)			
		Mount Ogilvie Formation	Glen Munro (4)	100		
			Woodlands Hill (4)			

Note: *i) shaded cells indicate the coal seams identified for mining as part of the Project*
ii) Group/sub group/formation thickness is a regional maximum (Geoscience Australia)



LEGEND

- Qa - Quaternary alluvium
- Tv/Jv - Basalt
- Rn - Hawkesbury Ss and Narrabeen Group
- Psl - Wollombi Coal Measures
- Pswj - Jerrys Plains Subgroup
- Pswv - Archerfield Ss and Vane Subgroup
- Pswc - Saltwater Creek Formation
- Pmm, Pmb - Maitland Group
- Pg - Greta Coal Measures
- Pd - Dalwood Group
- Cz - Carboniferous

- Mt.Ogilvie Fault
- MCC Alluvium* **
- Project Assessment Area
- Main streams
- Minor ephemeral streams
- Road major
- Road

West Muswellbrook (G1676)

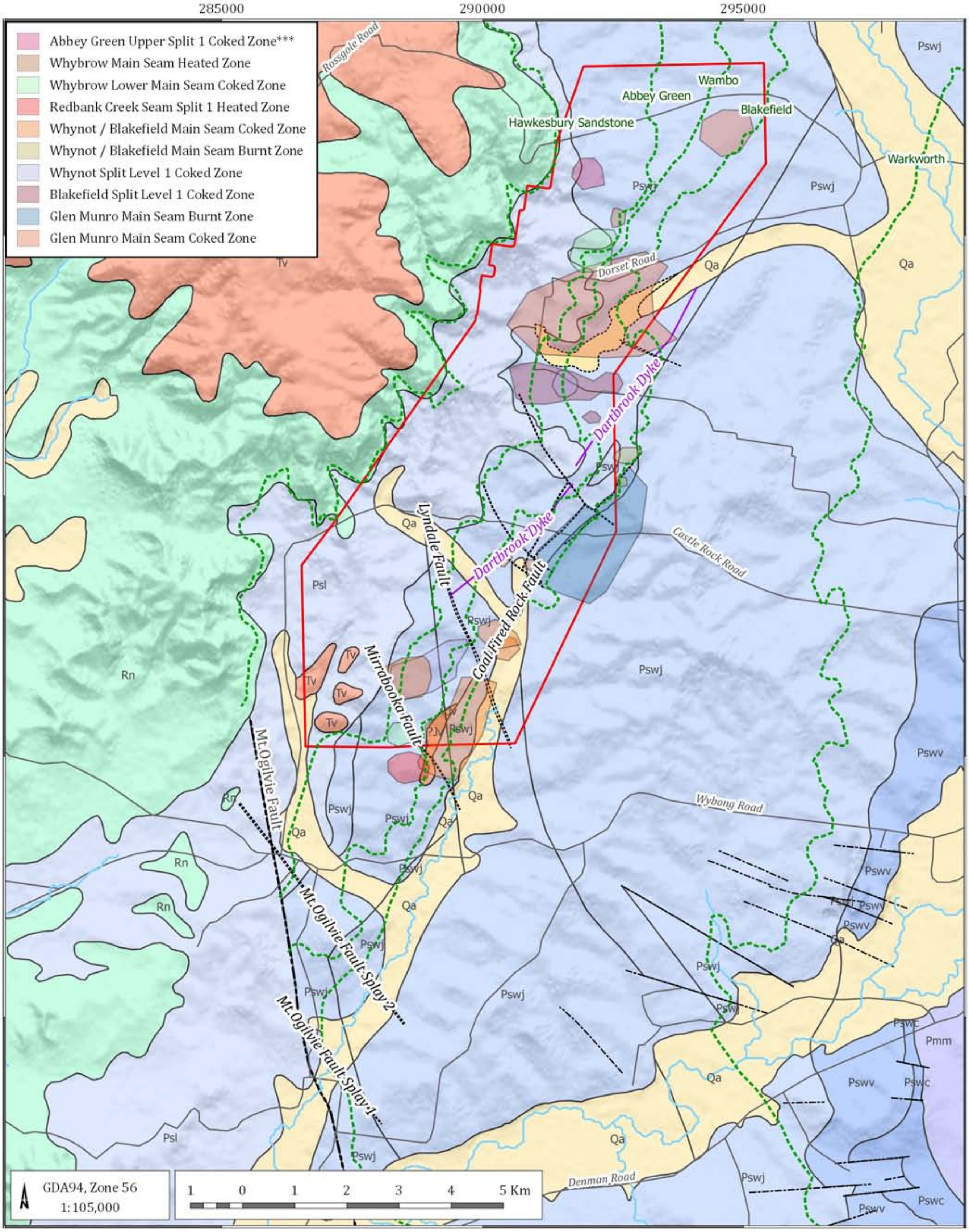
Regional Geology

AGE GROUNDWATER & ENVIRONMENTAL

DATE 10/11/2014

FIGURE No: **2.12**

Ref: Muswellbrook Coal Company Data*, Hunter Coalfield Regional 1:100 000 Geology Map**



LEGEND

- Unit/layer floor subcrop lines
- Mt.Ogilvie Fault
- MCC Faults*
- Dartbrook Dyke*
- Faults**
- MCC Alluvium* **
- Project Assessment Area
- Main streams
- Road major
- Road

- Qa - Quaternary Alluvium
- Tv/Jv - Basalt
- Rn - Hawkesbury Ss and Narrabeen Group
- Psl - Wollombi Coal Measures
- Pswj - Jerrys Plains Subgroup
- Pswv - Archerfield Ss and Vane Subgroup
- Pswc - Saltwater Creek Formation

West Muswellbrook (G1676)

Project area geology

AGE GROUNDWATER & ENVIRONMENTAL

DATE 10/11/2014

FIGURE No: **2.13**

Ref: Muswellbrook Coal Company Data*, Hunter Coalfield Regional 1:100 000 Geology Map**, Coked Zones - Idemitsu Company Data***

2.4.1 *Quaternary alluvium*

The Hunter Coalfield 1:100,000 mapped Quaternary alluvium (refer Figure 2.12) shows the extent of alluvium along the drainage lines. Shallow Quaternary alluvium is present within the Study Area associated with the current drainage systems of Sandy Creek North and Sandy Creek South including Coal and Spring Creeks. In the PAA, MCC has mapped additional alluvium in the upper reaches of Sandy Creek North, the area of additional mapping being shown on Figure 2.13.

Figure 2.14 shows slopes in the region calculated from the Study Area DEM. Gently sloping areas associated with current water courses are shown in darker red, whereas steeper areas are blue. Drilling logs indicate the flatter dark red areas on the image represent the current alluvial plain. MCC records indicate a total of 44 exploration holes intersected alluvium within the PAA. Figure 2.14 shows the position of the holes and the depth of alluvium. The thickness of the alluvium along Sandy Creek North and South ranges from less than one metre up to 16 m with an average thickness of 7 m. Drill logs describe a clayey to sandy gravel base to the alluvium overlain with finer grained deposits.

Colluvium is present at the base of the Triassic sandstone escarpment to the west, and in some case may extend east along present day tributary drainage lines to merge with alluvium. Exploration drilling, field reconnaissance mapping and slope analysis in GIS indicate the alluvium mapping requires further refinement during the DA stage.

2.4.2 *Tertiary basalt*

Tertiary basalt caps the Triassic Sandstone escarpment to the west of the Study Area. No lithological logs are available to confirm the thickness of this basalt cap. However, anecdotal evidence indicates the Tertiary Basalt is thin and generally eroded to weathered soil. Minor Tertiary and Jurassic basalts are also mapped within the Study Area between Spring Creek and Sandy Creek South (see Figure 2.13).

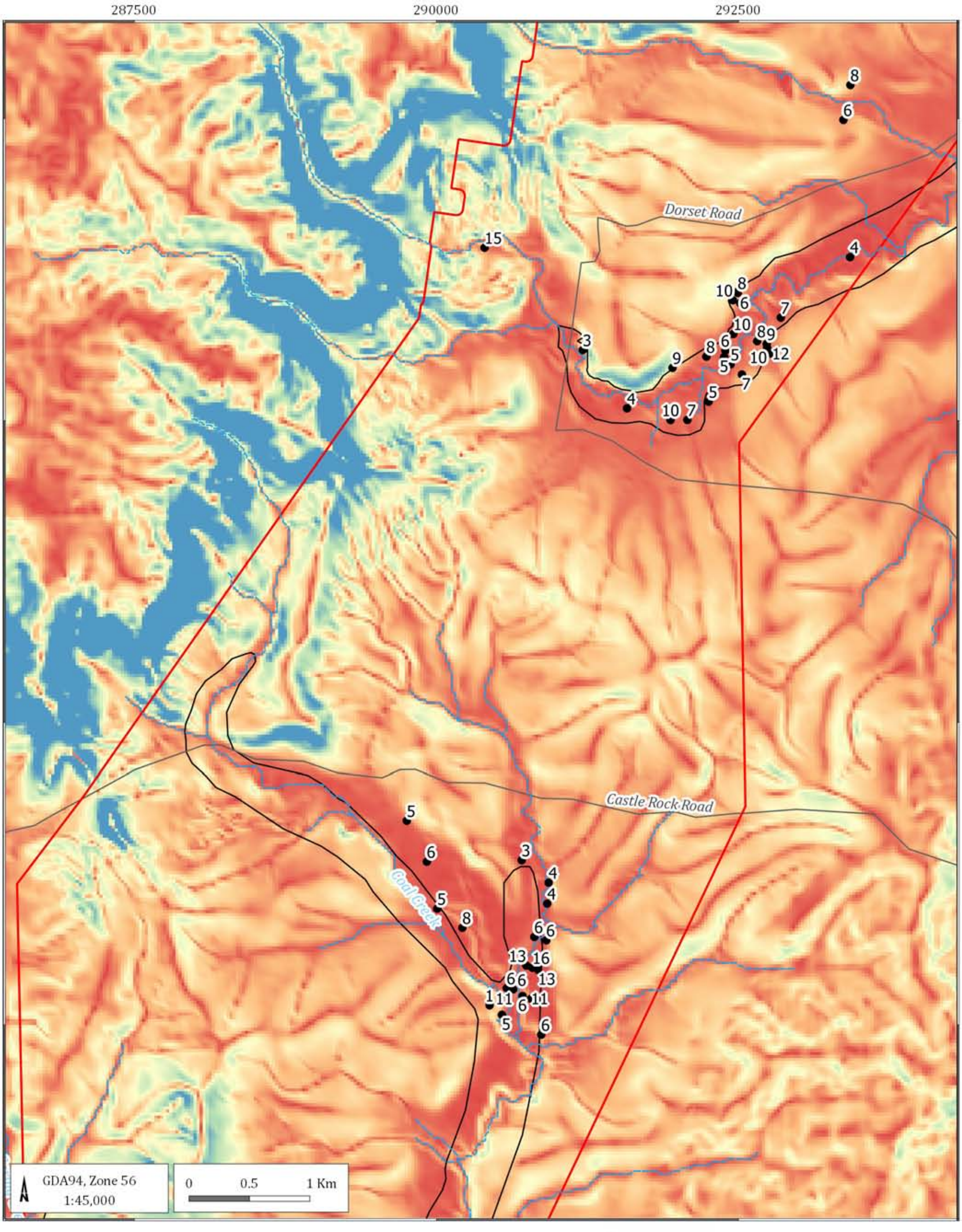
2.4.3 *Triassic Sandstone*

The Triassic Narrabeen Group, which includes the Hawkesbury Sandstone Formation, is a non-coal bearing sequence of coarse sandstone and conglomerate, unconformably overlying the Permian Wollombi Coal measures. The Hawkesbury sandstone reaches a thickness of some 100 m to 150 m in the escarpment to the west of the Project. Regionally, the Hawkesbury sandstone is known to reach up to 800 m in thickness.

2.4.4 *Permian Coal Measures*

The Wollombi Coal Measures outcrop to the west of the PAA and extend west below the Triassic Sandstones. Only the lower most coal seam is of economic interest to the Project. The Wollombi Coal Measures vary from some 150 m to 285 m in thickness, with the upper section being commonly intruded (MCC 2008). Apart from the Abbey Green Seam, coal seams are generally poorly developed. Many tuffaceous units are present throughout the sequence.

The Watts/Denman Formation separate the Wollombi Coal Measures from the underlying Whittingham Coal Measures. MCC (2008) indicates in the north of the Rosehill area, the sequence may pinch out.



LEGEND

Slope in degrees

- 0
- 5
- 10
- 15
- >20

- Alluvium outline
- Depth of alluvium (m) from exploration drill logs*
- Project Assessment Area
- Minor ephemeral streams
- Road

West Muswellbrook (G1676)

Alluvium mapping and slope analysis

DATE 10/11/2014

FIGURE No: **2.14**

Ref: Muswellbrook Coal Company Data*

2.4.5 *Whittingham Coal Measures / Jerrys Plain Subgroup (Permian)*

The upper coal seams of the Whittingham Coal Measures (Mt Leonard and Malabar Formations) are the main target[13] for the Project. Figure 2.15 shows the sub-crop of the Whybrow, Redbank, Wambo, Whynot and Blakefield coal seams. Lower seams with the Jerrys Plains Subgroup subcrop east of the PAA and are targeted at Dartbrook, Bengalla and Mt. Arthur mines. The lower portion of the Jerrys Plains Subgroup forms the basal sequence to this PAA.

The total thickness of the Wittingham Coal Measures is about 600 m (MCC 2008). A persistent, heavily bioturbated laminite unit of some 20 m to 30 m thickness has developed in the Malabar Formation within the Project area. It lies between the Wambo and Whynot Seams, and is visually identical to the Denman Formation. Previous workers have referred to this unit as the "false Denman". Due to its regional persistence and value as a correlation unit. MCC has informally named it the Rossgole Formation after a local geographic feature. It is hard to distinguish between the Watts/Denman and Sandstone/Rossgole sequences, as they are visually identical. MCC has relied on the recognition of the Althorpe Formation, thinner tuffaceous bands within the Whybrow, Redbank Creek and Wambo Seams and the presence of thin tuffaceous bands within the Rossgole Formation (the Denman Formation is tuff-free in this area) to validate its correlation.

2.4.6 *Heated and altered rock*

Crop zones within the Study Area that have been subject to coal firing (coked coal zones) (Figure 2.13). Coal firing causes the strata above the seam to turn a brick red/pink/orange colour, and the heat in the process also causes the strata to harden and become more resistant to weathering. This strata has formed prominent ridges within the area.

One area of Blakefield Seam that has been coal fired was delineated by the ground magnetic surveys in the area surrounding Castle Rock Road (GRS 2012). The seam has been fired to a depth of approximately 52 metres. No impact on coal quality is observed in areas adjacent to coal firing.

Heated or coal fired rock zones have the potential for increased or decreased permeability. While not investigated further at this stage, this issue should be addressed during the DA stage.

2.4.7 *Geological modelling*

MCC supplied a detailed geological model of the Study Area for use in the groundwater study. Figure 2.15 shows the extent of the supplied model. The surfaces of the coal seam roof and floor of major seams were extracted from the detailed model and used for further analysis. The extent of the coal seam surfaces was extrapolated to a wider extent using public domain documents. To the east major coal seam structure contours were digitised from a published hydrogeological study for Bengalla Mine (AGE 2013) in combination with the Hunter Coalfields geological maps to extend the coal seam surfaces. To the west the regional dip of the existing mapped units was maintained. Figure 2.15 shows extent of the wider interpolated geological surfaces.

Figure 2.16 shows three schematic geological cross-sections through the interpolated geological model with the position of the section shown in Figure 2.15. Section A- A' and Section B-B' shows the prominent Triassic escarpment to the west of the Study Area and the westerly dipping coal seams. The southerly Section C-C' shows the escarpment to the west is less prominent in this area.

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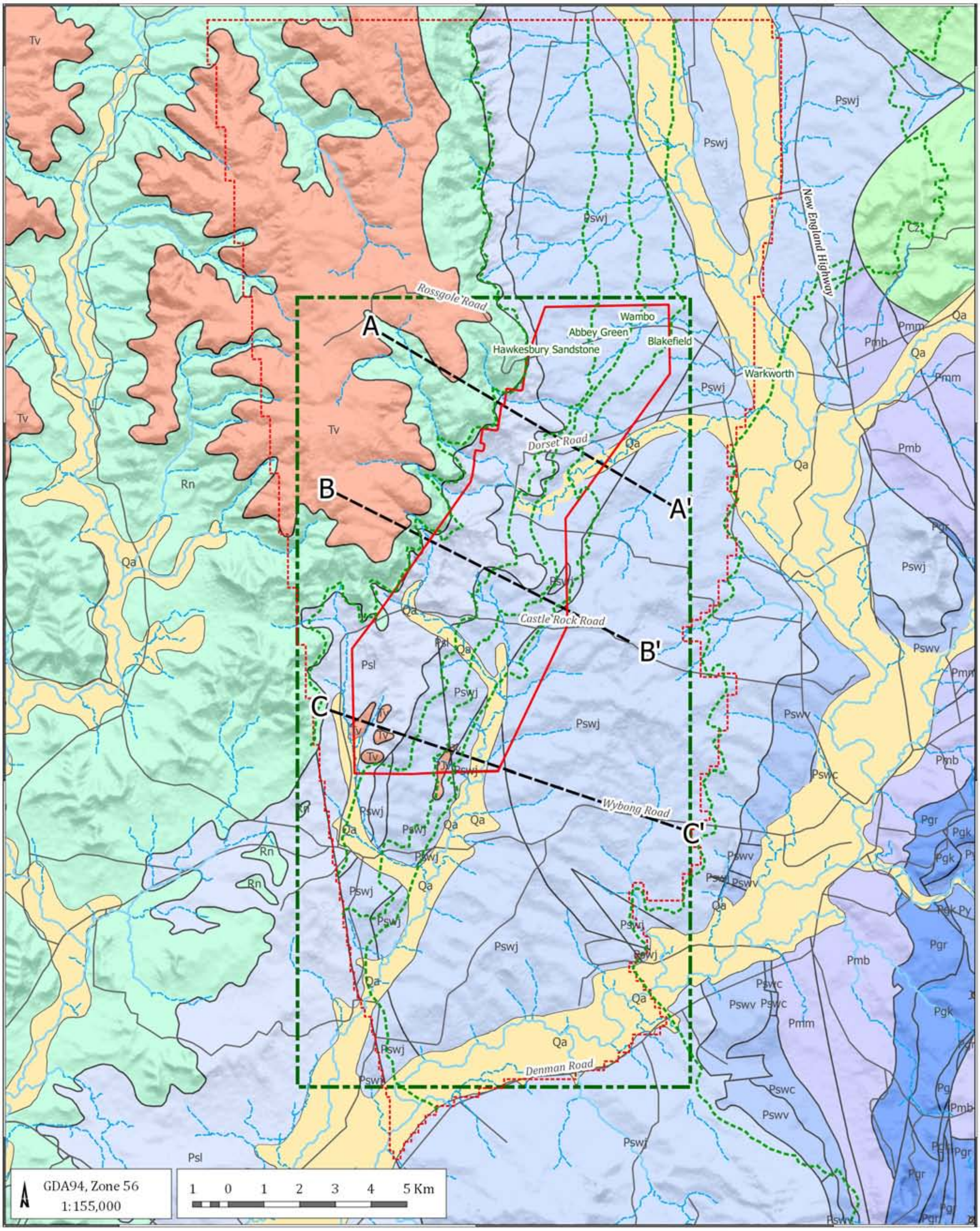
[13] Whybrow, Redbank, Wambo, Wynot and Blakefield Seams



LEGEND

- Study area / extent of interp. geological model
- Geological cross sections
- MCC geological model
- Project Assessment Area (PAA)
- Main streams
- Ephemeral streams
- Road
- Road major
- Unit / layer floor subcrop line

- Qa - Quaternary Alluvium
- Tv/Jv - Basalt
- Rn - Hawkesbury Ss and Narrabeen Group
- Psl - Wollombi Coal Measures
- Pswj - Jerrys Plains Subgroup
- Pswv - Archerfield Ss and Vane Subgroup
- Pswc - Saltwater Creek Formation

West Muswellbrook (G1676)

Geological model extents, subcrop lines and cross section locations

AGE GROUNDWATER & ENVIRONMENTAL

DATE 26/11/2014

FIGURE No: **2.15**

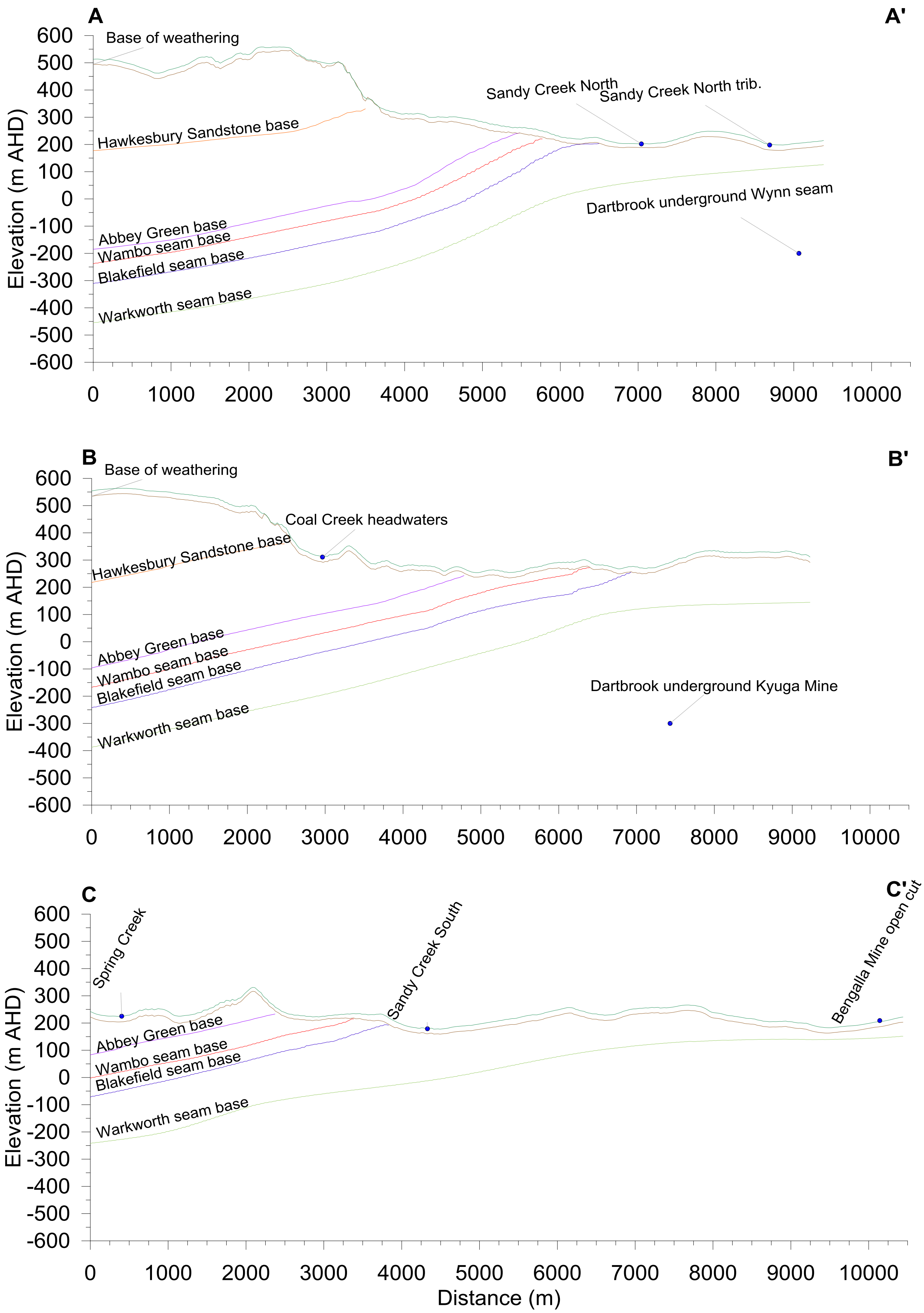


Figure 2.16 Schematic geological sections

2.4.8 *Structures*

The Mount Ogilvie Fault is a major thrust fault of the Upper Hunter Valley running for approximately 30 km NNW-SSE from just east of Denman to just north of Castle Rock (Figure 2.12).

The Mt. Ogilvie Fault has a throw of approximately 125 m to the north and 150 m to the south (Hunter Coalfield 1:100,000 mapping). It is associated with several smaller parallel thrust faults, namely the Mirrabooka Fault and the Lindale Fault. Locally, the throw on the Lindale fault is 20 m to 30 m .

The Mt. Ogilvie Fault lies to the west of the PAA, where its position is inferred only. To the south of Wybong Road and as far as the Sandy Creek South its position is mapped with more confidence. Associated with the Mt. Ogilvie Fault are a number of splay faults.

The Mt. Ogilvie Fault aligns the top of the Jerrys Plains Subgroup to the east with the Wollombi Coal Measures to the west.

In the context of hydrogeological investigation, faults have the potential to compartmentalise groundwater systems acting as either impermeable barriers, zones of higher transmissivity or a combination of both. Compartmentalisation can lead to short periods of high inflows when mining breaks through faults exposing a compartment which has not drained.

Zones of higher transmissivity may also occur in areas where bedding dip and flexure increase markedly. In these cases, joint frequency and connectivity is likely to be higher than for more uniform coal measures and can be the source of high water inflows when intersected by mining. Fault structure systems can cause changes to groundwater flows and chemistry and thus groundwater flows and chemistry can be used to identify areas of variable structure. Currently, groundwater data are insufficient within the Study Area to delineate the fault systems and to assess compartmentalisation of groundwater flow and open, highly transmissive zones.

Igneous intrusions known to be present within the PAA also have the potential to form barriers and influence groundwater flow pathways.

2.5 Land uses

The predominant land use in the PAA is beef cattle pasture. Relatively small areas of other land uses exist. The Gateway Application Supporting Document prepared by La Tierra provides a more comprehensive assessment of current and historical land use. Figure 1.4 shows CIC mapping for the PAA.

2.6 Existing mines

2.6.1 *Dartbrook*

Anglo Coal Pty Ltd operated the underground Dartbrook Coal Mine (Dartbrook) between 1996 and 2006. The mine is located west of the Hunter River, north of Muswellbrook (Figure 2.17). Longwall mining extracted coal from the Wynn and Kayuga Seams. The Wynn Seam was mined from 1996 to May 2004 and the Kayuga Seam, which is situated about 175 m above the Wynn Seam, from June 2004 to September 2006. Underground mining at Dartbrook officially ceased on January 1, 2007 and the mine has been on care and maintenance since that date. According to the Anglo American website *"exploration and conceptual studies are currently progressing to explore options for these resources using the existing infrastructure".* It is understood that open cut and further underground mining has been considered.

Longwall mining of the Wynn Seam, at a depth of 180 m to 350 m below surface, took place at the Dartbrook Mine between 1996 and May 2004. The layout comprised eleven longwall panels orientated in a north-south direction, of which panels DB108 and the majority of DB107 were not mined due to high gas levels. Figure 2.17 shows the layout of the longwall panels. Mining of the shallower Kayuga Seam which is 160-170 m above the Wynn Seam commenced in June 2004 in panels orientated in an east-west direction, and mining ceased in September 2006.

The Wynn Seam goaf is being allowed to flood from groundwater inflow, and from drainage from the overlying Kayuga Seam and seepage pumped from the conveyor tunnel. The water level in the Wynn Seam is reported to be at RL52.5 mAHD, that is about 107 m below the level of the Hunter River flood plain (Anglo American 2013).

Dartbrook is the nearest mine to the Study Area as shown in plain view in Figure 2.17, although it mined significantly deeper seams than those proposed to be mined for the Project.

Figure 2.16 shows the approximate location of the western most extent of Dartbrook underground in the schematic cross-sections. No cumulative effect is expected due to low permeability interburden between the recovering groundwater levels in the Dartbrook mine footprint and the stratigraphically younger coal seams of the Project. Section 3.3.4 discusses vertical permeability within the Permian strata further.

2.6.2 *Bengalla*

The Bengalla mine located approximately 6 km east south east of the Study Area commenced operations in 1999. The mine extracts the Warkworth to the Edderton Seams using open cut methods (AGE 2013). Figure 2.17 shows the location of Bengalla Mine compared to the Project area. The available data shows that to date, mining at Bengalla has depressurised the coal seams in the surrounding area and shallow groundwater only in the immediate area around the mine open cut.

The potential for a cumulative impact on groundwater levels between the PAA and Bengalla is very low. This is because the seams mined at Bengalla are too deep to be mined in the Project Area, and are separated from the Project seams by a significant thickness of low permeability interburden sediments that will prevent any significant hydraulic interaction and cumulative drawdown between the two projects. AGE (2013) concluded the predicted drawdown from the combined Bengalla and Mt Pleasant Mines will not reach as far as the PAA with the lower coal seams mined in these operations. Section 5 outlines results of modelling that indicate very limited drawdown in underlying coal seams to the east of the PAA.

2.6.3 *Mangoola*

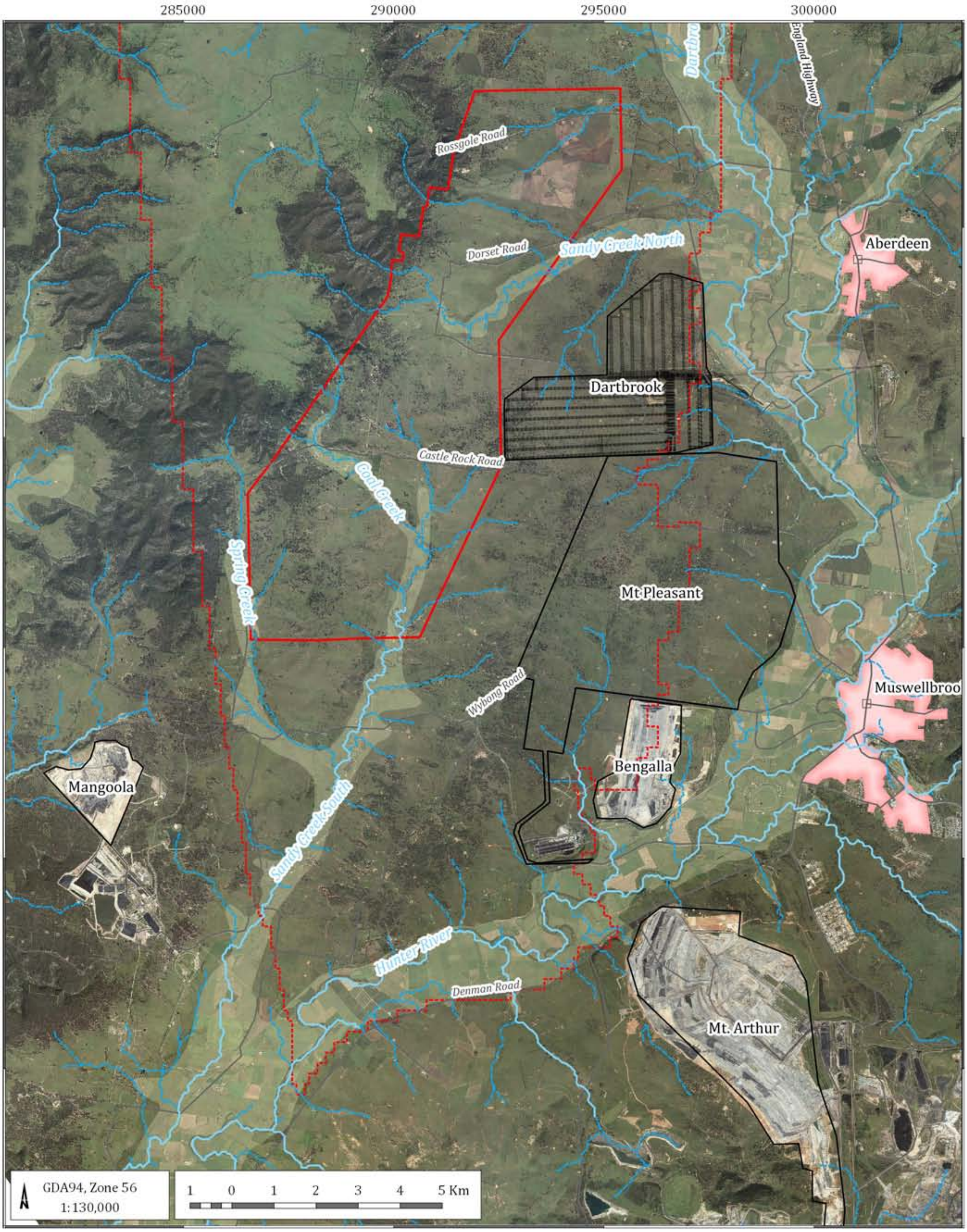
The Mangoola Coal Mine, formerly known as the Anvil Hill Project, is located some 4 km south west of the PAA. The NSW Government approved the Mangoola Coal Project in June 2007, with the operations commencing in late 2010. The approval authorises the extraction of 150 Mtpa of ROM coal over 21 years (until 2029), at a rate of up to 10.5 million tonnes of ROM coal a year. The groundwater system around the Mangoola Mine, is hydraulically separated from the study area by the Mt. Ogilvie Fault. The Mt. Ogilvie Fault is a significant structural feature in the region fully offsetting the coal seams against lower permeability interburden, and therefore forming a barrier to depressurisation beyond the fault. Therefore, no cumulative impact is expected between the PAA and the Mangoola Mine.

2.6.4 *Mount Pleasant*

The NSW Government granted development consent for the Mount Pleasant Mine (MTP) project in 1999, and a subsequent modification in 2011. The mine is approved to extract up to 10.5 Mtpa for a period of 21 years (until 2020) using open cut mining methods. The Mount Pleasant Project commenced in 2004 with the construction of Environmental Dam 1, however no additional construction or coal mining has occurred. The MTP proposes to target the same coal seams mined at Bengalla.

2.6.5 *Existing mines summary*

No existing or former mines in the local vicinity of the PAA are extracting from the same coal seams that are being targeted in the Study Area. Dartbrook, Bengalla and Mt Pleasant Mines all extracted, or are approved to extract, coal seams stratigraphically lower (Warkworth Seam and below) than the seams proposed to be mined (Blakefield and above) within the Study Area. Numerous inteburden layers that will retard the depressurisation from existing projects and prevent significant cumulative hydraulic impacts between the operations. Similarly, the Mangoola Coal Mine is hydraulically separated from the Study Area by the Mt. Ogilvie Fault.



LEGEND

- Surrounding mines
- Dartbrook underground mine plan
- Project Assessment Area
- Study Area
- Populated place
- Built up area
- Main streams
- Minor ephemeral streams
- Alluvium
- Roads
- Road major

West Muswellbrook (G1676)

Surrounding mines

AGE GROUNDWATER & ENVIRONMENTAL

DATE 10/11/2014

FIGURE No: **2.17**

3. Hydrogeology and conceptual model

This section of the report presents baseline hydrogeology data and the conceptual model of the groundwater regime developed using these data. The Gateway Process Guidelines requires baseline groundwater conditions be defined, and therefore Section 3.11 presents the baseline data in the context of highly productive and less productive aquifers.

3.1 Hydrostratigraphy

Alluvial and colluvial deposits within the Study Area are present along Sandy Creek North, Sandy Creek South, Coal Creek, Spring Creek (and possibly unmapped minor tributary creeks). Exploration drilling data indicates that most alluvium contains a basal sand or gravel layer. Where saturated this would be expected to form a low yielding aquifer.

Although data is limited, the Triassic sandstone escarpment to the west appears to form a low yielding relatively low salinity aquifer. The hydraulic connection to the underlying Permian groundwater strata is expected to be retarded by layering of low permeability fine grained sediments.

The coal seams within the Permian Wollombi and Wittingham Coal Measures are considered the more permeable of the consolidated strata, but are not considered to be significant aquifers. While some coal seams may show an elevated hydraulic conductivity, the dominant interburden sections are of very low hydraulic conductivity. Only the weathered bedrock (regolith) directly below the ground surface may have a somewhat higher hydraulic conductivity (other than alluvium).

Therefore, from a conceptual groundwater model perspective, the groundwater system in the Study Area consists of four main groundwater systems, as follows:

- alluvium and colluvium along the major creeks;
- weathered bedrock near ground surface;
- Triassic sandstones to the west; and
- Permian coal seams (Wollombi and Whittingham Coal Measures).

Additionally, faulting, intrusive plugs and dykes may play a part within the PAA to compartmentalise the local scale groundwater flow regime. The following sections characterise the different groundwater systems and discuss the available data.

3.1.1 *Alluvium*

Section 2.4.1 outlines the distribution of the Quaternary alluvium and colluvium. The saturated Quaternary sequence forms an unconfined aquifer within the Study Area primarily associated with Sandy Creek North and Sandy Creek South (including Coal Creek and Spring Creek), with possibly minor unmapped saturated alluvium in some tributary creeks. Based on exploration drill logs the alluvium within the PAA varies in thickness between about 1 m and 16 m with the average thickness intersected about 7 m. Exploration drill logs indicate the alluvial sediments typically comprise shallow sands overlying silty and clayey sands with coarser and often cleaner sand/gravel zones towards the base. Colluvium is present at the base of the Triassic sandstone escarpment to the west and in some case may extend east along present day tributary drainage lines to merge with alluvium.

The data from exploration holes indicates that a number of the holes were dry and that in others the groundwater occurs within the gravel basal sequence. To the east of the Study Area, Sandy Creek north alluvium merges with alluvium associated with Dartbrook and Sandy Creek south alluvium merges with Hunter River alluvium.

GRS (2012) discussed additional geophysical interpretation of the modern active drainage deposition, modern non-active drainage and paleo drainage features. This geophysical interpretation suggested some paleo drainage features which are not active, nor obvious by vegetation. The best example is to the immediate east of the central northern portion of the PAA. This feature warrants further investigation as part of any future works.

The alluvium of Sandy Creek north, Sandy Creek south, Coal Creek, Hunter River alluvium and Dartbrook alluvium are mapped by the NOW as highly productive groundwater sources under the AIP. The baseline data in this report indicates that the alluvial aquifers should potentially be reclassified as being less productive (see Section 3.11).

3.1.2 *Regolith*

The regolith/shallow bedrock sediments comprise surficial soils and weathered bedrock. The depth of the unit varies depending on such factors as:

- depth of weathering;
- extent and frequency of permeable fracture systems; and
- areas where coal fired rock (see Section 2.4.6) may also have promoted or restricted weathering to different depths.

The base of weathering has been noted in over 300 MCC exploration logs with an average depth of 18 m and a maximum of 44 m. A number of shallow farm bores (see Section 3.10) are screened in shallow bedrock. Lateral flow of groundwater within the weathered zone is expected to be towards local water courses and the associated alluvium.

In areas of coal fired or heated rock (see map extents in Figure 2.13) areas of enhanced weathering and permeability may exist.

The weathered Permian derived regolith is mapped by the NOW as a less productive groundwater source.

3.1.3 *Triassic Sandstone*

The Triassic Hawkesbury Sandstone escarpment to the west of the PAA has the potential to be a low yielding aquifer; however, this assumption will need to be confirmed after additional yield data is obtained. Downward leakage through the base of the Triassic is expected to be limited by the low vertical permeability of Permian units. The Hawkesbury Sandstone is assumed to form an aquifer, with little interconnection to the underlying target seams of the PAA. Figure 2.16 shows a cross section through the Triassic escarpment west of the PAA, with the sandstone dipping westward.

For the purposes of the modelling the Hawkesbury Sandstone is considered to form an aquifer system essentially separate to the Permian Coal measures. It it is included in this study due to its relative proximity and influence of surface water run-off to Sandy Creek north, Coal Creek and Spring Creek, which is a main source of coal measure groundwater recharge.

There is the potential for groundwater to discharge in the form of springs and as baseflow to creeks at the base of the unit. A good example of this is Spring Creek and headwater sections of Coal Creek (see Section Figure 2.8), where springs and baseflow are evident in the upper stream reaches. In many areas, the spring location and discharge may be masked by the colluvium present at the base of the escarpment.

The Triassic Sandstones are also mapped as highly productive groundwater by NOW and have therefore been included in both the conceptual and numerical models to confirm that mining induced drawdown does not impact this aquifer.

3.1.4 *Permian*

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

- hydrogeologically "tight" and hence very low yielding sandstone and lesser siltstone that comprise the majority of the Permian interburden / overburden; and
- low to moderately permeable coal seams which are the prime water bearing strata within the Permian sequence, (the bedrock aquifer).

The Permian occurs across the whole of the PAA as a regular layered sedimentary sequence dipping at 3 to 6 degrees to the west. Schematic west to east cross-sections in Figure 2.16 shows the regional dip.

Groundwater storage is predominantly within the coal seam cleats or within occasional joints in interburden / overburden. MER (2000) states that *'more often, interburden is poorly jointed as evidenced by low rates of groundwater seepage to Dartbrook longwall operations and to other existing mine pits in the area.'*

The Permian strata is mapped by the NOW as a less productive groundwater source.

3.1.5 *Intrusions and volcanics*

A series of historical geophysical surveys identified a series of five major dykes (1 m to 5 m thick), eight minor dykes (<2 m thick), two sills and two volcanic plugs (MCC 2008). Each of these igneous bodies has the potential to compartmentalise groundwater flow with the Permian strata. GRS (2012) discusses a total of 76 magnetic features within, or close to, the PAA, including:

- 26 magnetic lineaments;
- 4 magnetic linears that may indicate intrusive dykes; and
- 7 higher amplitude discrete magnetic effects that may be indicators of poorly resolved intrusive plugs.

GRS (2012) also suggests that any extrusive flows occuring within the Study Area are either non-magnetic or weathered.

3.2 Structure

MCC (2008) discusses a defined number of north-north-west to south-south-east trending reverse/ normal faults which have been identified or inferred from mapping and geophysics. The most complex is the Mt. Ogilvie fault system to the southeast of the PAA that displaces strata about 150m (upthrown to the east). Splays of the Mt. Ogilvie fault and the Mirrabooka and Lyndale faults all have the potential to compartmentalise local groundwater flow patterns and hydraulic heads, mainly within the coal seams.

The Mt. Ogilvie fault is considered a significant regional barrier to groundwater flow within the coal seams due to its large off-set and has been selected as a western "no-flow" boundary for this assessment. This fault is assumed to hydraulically separate the Study Area from Mangoola mine located further to the south-west.

While not investigated in significant detail in this Gateway level assessment, faults should be considered during any further detailed groundwater investigations to understand hydraulic heads and gradients within the Permian groundwater bearing strata.

3.3 Hydraulic properties

3.3.1 *Alluvium*

GeoTerra (2006) reports that no yield information is available for the alluvium. However, it is anticipated that the generally shallow valley fill in both creeks allows only a low to moderate water supply to be obtained from bores within the alluvium.

No permeability data have been obtained for the alluvial sediments within the PAA; however, the hydraulic characteristics of the aquifer are expected to be quite variable given that the sediments range from clay bound, to clean sands and gravels. Data from similar areas in the Upper Hunter region indicate a highly variable permeability distribution of the alluvium.

The lack of any permeability data and yield measures for alluvium within the PAA makes categorising the groundwater source as either highly productive or less productive uncertain. Further field tests are recommended during the DA stage to ascertain the yield of the alluvium through pumping tests on local landholders bores.

3.3.2 *Triassic Sandstones*

No local data are available for the permeability of the Triassic Sandstones to the west of the PAA. Ross (2014) discusses extensive investigations in groundwater resource potential of the southern Sydney basin Triassic Sandstones, while south of the Hunter Valley this research does show the potential for the Hawkesbury Sandstone and other Triassic units to yield relatively fresh groundwater. This study comments that yield from the Hawkesbury Sandstone was entirely dependent on the degree of fracturing at each test location, with most sandstone transmissivities (T) in the range of 4 – 10 m^2/day for less fractured sandstone and up to 130 m^2/day for fractured rock. Most test intervals were between 50 – 100 m in thickness; hence, a plausible horizontal hydraulic conductivity (k) range for productive areas of sandstone could be from 0.05 to 1 m/day.

3.3.3 *Regolith*

No permeability data have been obtained for the regolith within the Study Area. This strata is expected to be less permeable that than alluvium but greater than the underlying coal seams and interburden.

3.3.4 *Permian*

The coal seams generally have a low to moderate permeability and low yields. MCC commissioned falling head tests in the monitoring bores established in the coal seams (see Section 3.4.1) and packer tests were undertaken in selected open exploration holes within the PAA. GeoTerra (2003) summarised the results of these tests which are reproduced in Table 3-1 below.

Table 3-1 Open hole packer and falling head testing within the project area

Bore	Depth tested (m)	Strata/Seam	Horizontal hydraulic conductivity m/day	Comment	Test type
DDH4	83.5	Blakefield Seam	7.60×10^{-03}	Monitoring Bore	FHT
DDH16	53.6 – 69.9	Blakefield Seam	1.12×10^{-03}	Monitoring Bore	FHT
DDH2	15 - 25	Overburden	3.20×10^{-03}	Open Hole	FHT
DDH5	20 - 73	Blakefield/Whynot Seam	1.73×10^{-03}	Open Hole	FHT
DDH11	283	Blakefield/Whynot Seam	1.04×10^{-03}	Open Hole	FHT
DDH18	18.6 – 24.6	Wambo Seam	6.05×10^{-01}	Open Hole	DP
DDH19	33.9 - 39.7	Blakefield Seam	3.46×10^{-01}	Open Hole	DP
DDH20	31.9 – 45.7	Blakefield Seam	1.04×10^{-03}	Monitoring Bore	FHT
DDH20	39.6 – 45.75	Blakefield Seam	1.12	Open Hole	DP
DDH21	37.14 – 41.55	Blakefield Seam	3.11×10^{-03}	Open Hole	DP
DDH21	37.14 – 51.62	Blakefield Seam	1.21×10^{-01}	Open Hole	DP
DDH22	12.7 – 15.7	Sandstone roof	8.64×10^{-02}	Open Hole	DP
DDH23	15.68 – 18.68	Sandstone roof	6.31×10^{-01}	Open Hole	DP
DDH24	42.72 – 48.72	Blakefield Seam	2.76×10^{-01}	Open Hole	DP
DDH25	63.44 – 72.74	Blakefield Seam	1.21×10^{-02}	Open Hole	DP
DDH27	51.51 – 54.51	Sandstone/Siltstone	1.90×10^{-02}	Open Hole	DP
DDH29	33.64 – 41.14	Blakefield Seam	7.43×10^{-02}	Open Hole	DP

Note: *FHT - falling head tests - all other values are from packer tests converted to m/sec from lugeonsb (From Geoterra 2003)*

The data indicate that the coal seams and overburden / interburden are of very low permeability with falling head tests giving lower permeability results than packer tests. The tests indicate little distinction between the coal seams and overburden / interburden, however as discussed the coal seams are generally more permeable, water bearing and are bounded by the "tight" overburden / interburden. The available site data are limited to coal seams only and relatively shallow depths. MER (2000) collated permeability data for weathered overburden, coal seams and interburden from the local Dartbrook area originally sourced from AGC (1984). Figure 3.1 shows this collated data plotted with data from the project site. As noted in other previous studies such as Mackie (2009) a reduction in permeability with depth occurs in both coal seam and interburden sediments. The slope of the local data correlates with the previously published slope from Mackie (2009).

The data for the Study Area shown in Figure 3.1 are slightly less permeable than the bulk average for the Upper Hunter (shown by the grey line). This supports findings in a report for Dartbrook mine which noted that in Dartbrook mine area, permeability appear to be generally lower than areas to the south (attributed to reduced jointing). The permeability of seams in the Bengalla – Mt Arthur North area is in the range 0.0005 m/day to more than 1 m/day.

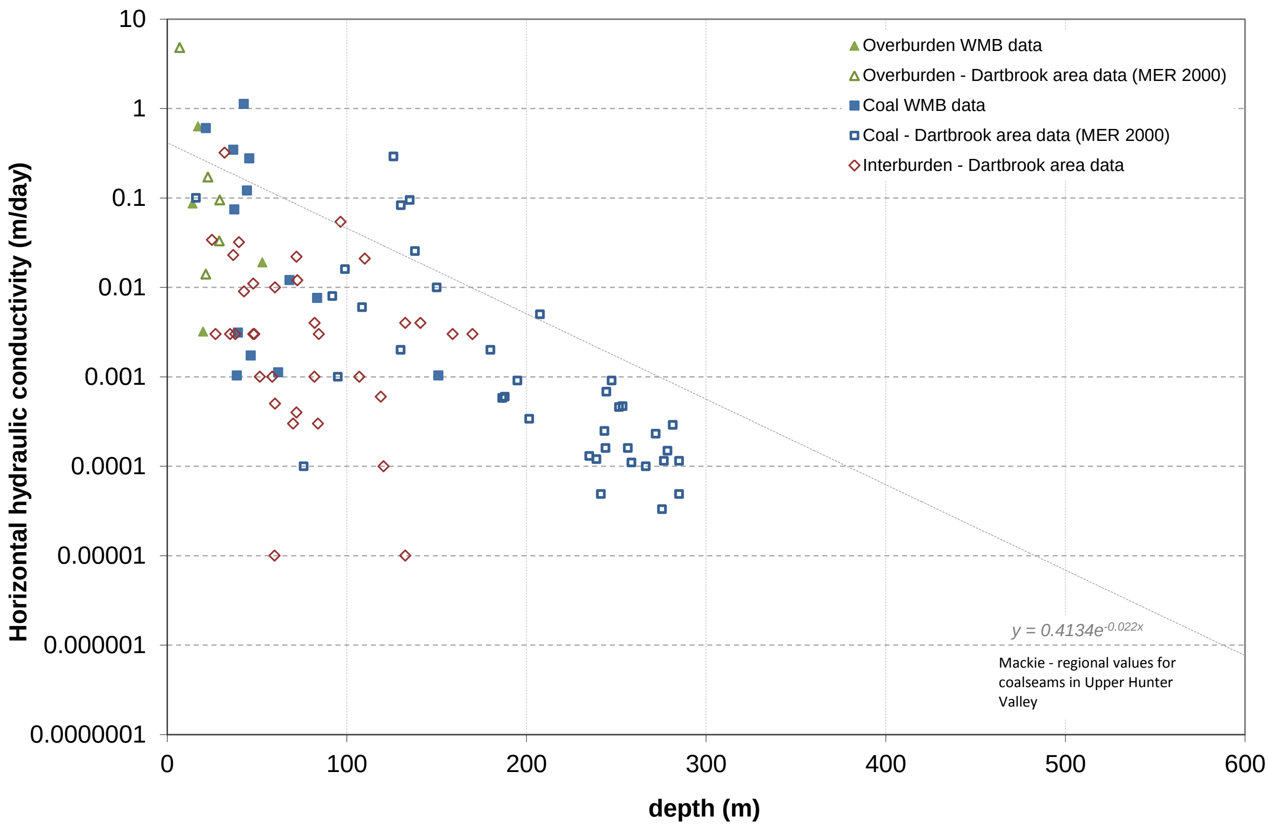


Figure 3.1 Permeability measurements versus depth relationship

3.3.5 *Aquifer storage*

No data could be sourced for storage parameters for unconsolidated or consolidated strata within the Study Area or surrounding areas. Measurement of storage parameters requires pumping tests. Mackie (2009) estimated specific storage for the Hunter Region using Young's modulus, and results ranged between 1 x 10^{-4} and 3 x 10^{-6} (l/m). These results are based on similar stratigraphy to the Study Area and are therefore considered applicable to this study.

3.4 Monitoring

3.4.1 *Groundwater monitoring data*

The groundwater monitoring network within the Study Area currently consists of 30 bores. All bores are within the PAA, with the exception of two. MCC has constructed 18 dedicated monitoring bores and uses 12 private landholder production bores for additional monitoring. Appendix A (Table A-1) details the available construction information and target formation for each of the bores. Figure 3.2 shows the location of the sites, which are clustered around the Sandy Creek North alluvium and northern portion of Sandy Creek South. Ten of the 18 monitoring bores are used for groundwater level and field based physio-chemical water quality measurement, with results for most of the 10 sites from 2004. Major ion and trace metals analysis is available from four monitoring bores all screened across the coal seams.

Groundwater level and field based physio-chemical water quality results have been collected from the 12 private bores from 2003 (or earlier), with 11 sites with at least one major ion and trace metals analysis. The construction information and length of data record for each site is summarised in Appendix A (Table A-1) and is an excellent long term data set for a project at the Gateway application stage. The monitoring was also conducted over a period of dry climate followed by a wetter period, which means it has captured the response of the groundwater system to these relatively long term cycles (see Section 2.2 for further climate data).

Six monitoring bores (within the network of 18) also monitor shallow alluvium close to or in the creek beds of Sandy Creek North, Coal Creek and Sandy Creek South. Inference can be drawn from these six bores when the creeks may have water in them (and possible flow), refer to Section 2.3 for further information of Creek flow.

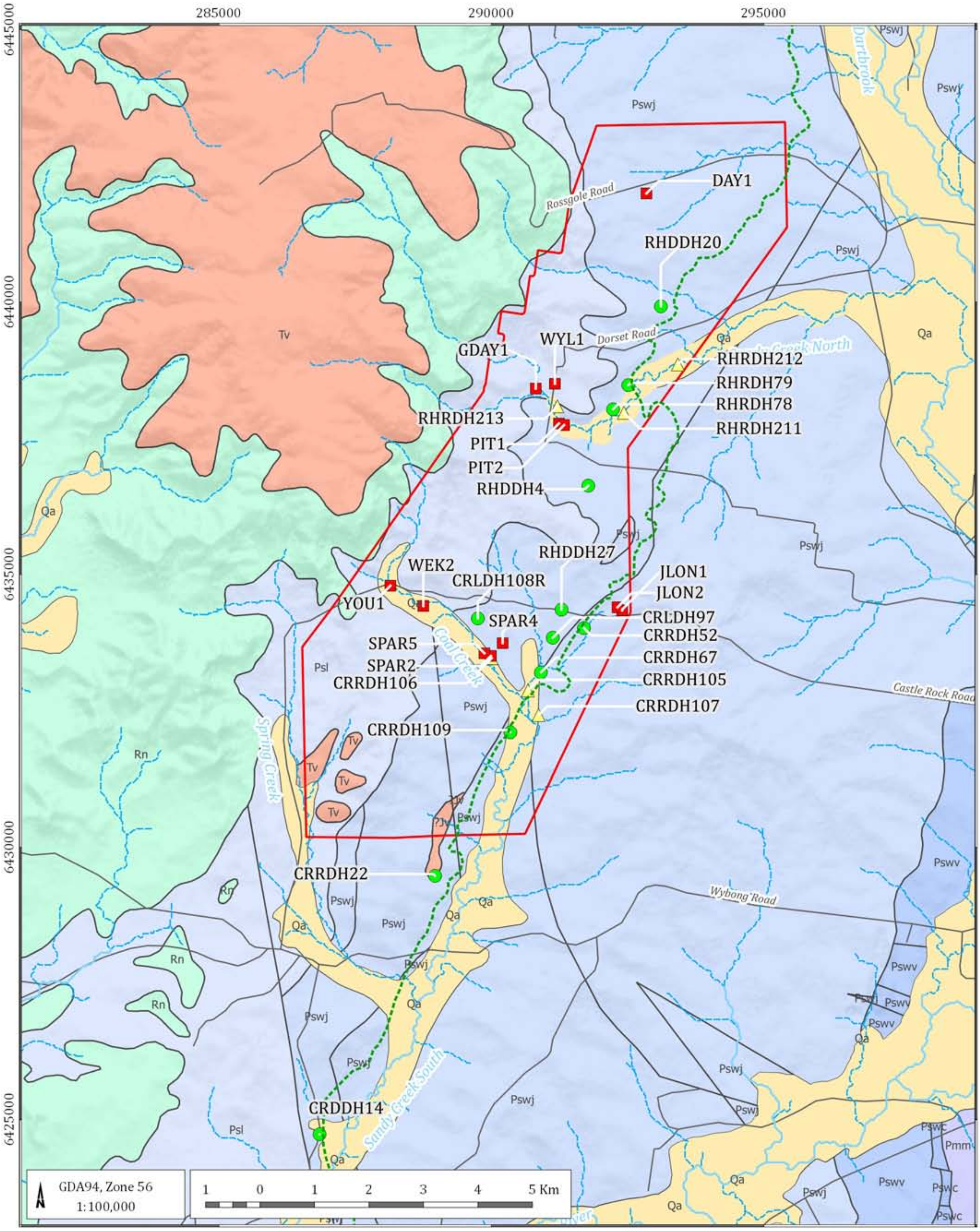
A literature search was carried out to find any other available/useful groundwater level data representing the environment around the Study Area. A series of private landholder bores, some with significant length of groundwater level records was sourced from the NSW Office of Water (NOW) PINNEENA groundwater database. Groundwater level data were also sourced from four shallow bores monitored at Dartbrook mine (Anglo American 2013). Appendix A (Table A-2) summarises the available data for these bores and Figure 3.3 shows their location in the context of the Project monitoring.

Additional groundwater level data have been recorded during MCC exploration drilling, with over 300 individual groundwater levels recorded either through 'dipping' or estimated from the responses on geophysical logs. The water levels in holes open to multiple coal seams are a composite water pressure and are less useful than shallower exploration holes to east of the project area, which were generally drilled only to Blakefield Seam. A total of 45 open hole water levels was selected from the exploration data set from near the Blakefield Seam near sub-crop.

Groundwater level and quality data is used throughout the remaining sections of this report to conceptualise, discuss baseline conditions and support numerical model development.

3.4.2 *Surface water data*

Surface water quality is monitored at 15 sites in and around the PAA. Figure 3.4 shows the position of these sites. Two additional sites in the headwaters of Spring Creek were also visited by AGE during June 2014. Appendix A (Table A-3) summarises positional data and describes each site and its flow characteristics. Flow measurements are not collected during sampling and there are no permanent flow/ stage gauges on any streams within the Study Area.



LEGEND

- Blakefield subcrop
- Groundwater monitoring
- Groundwater monitoring - surface water
- Production bores
- Project Assessment Area
- Main streams
- Minor ephemeral streams
- Road major
- Road

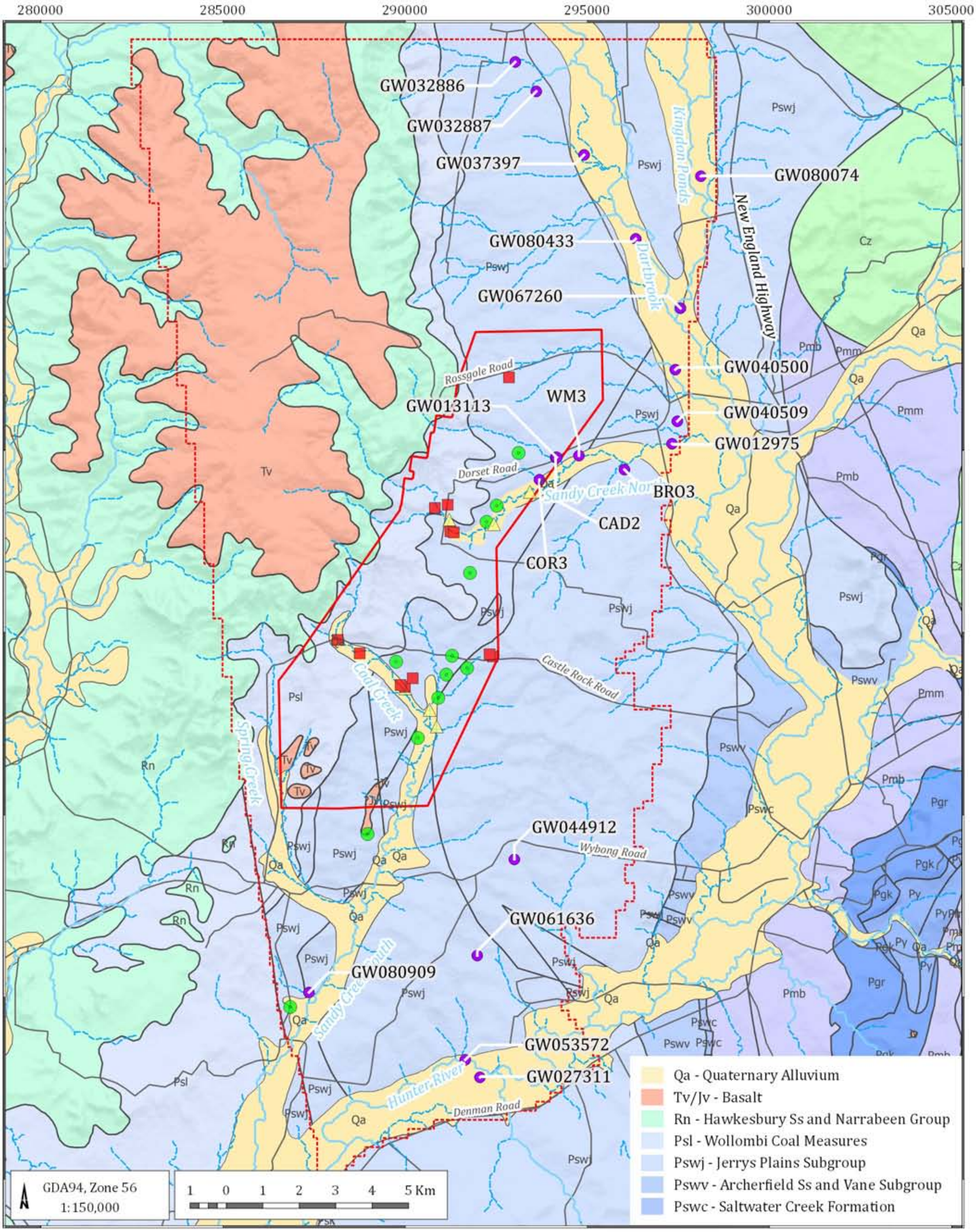
- Qa - Quaternary Alluvium
- Tv/Jv - Basalt
- Rn - Hawkesbury Ss and Narrabeen Group
- Psl - Wollombi Coal Measures
- Pswj - Jerrys Plains Subgroup
- Pswv - Archerfield Ss and Vane Subgroup
- Pswc - Saltwater Creek Formation

West Muswellbrook (G1676)

Groundwater monitoring locations - MCC sites within the vicinity of PAA

DATE 10/11/2014

FIGURE No: **3.2**



LEGEND

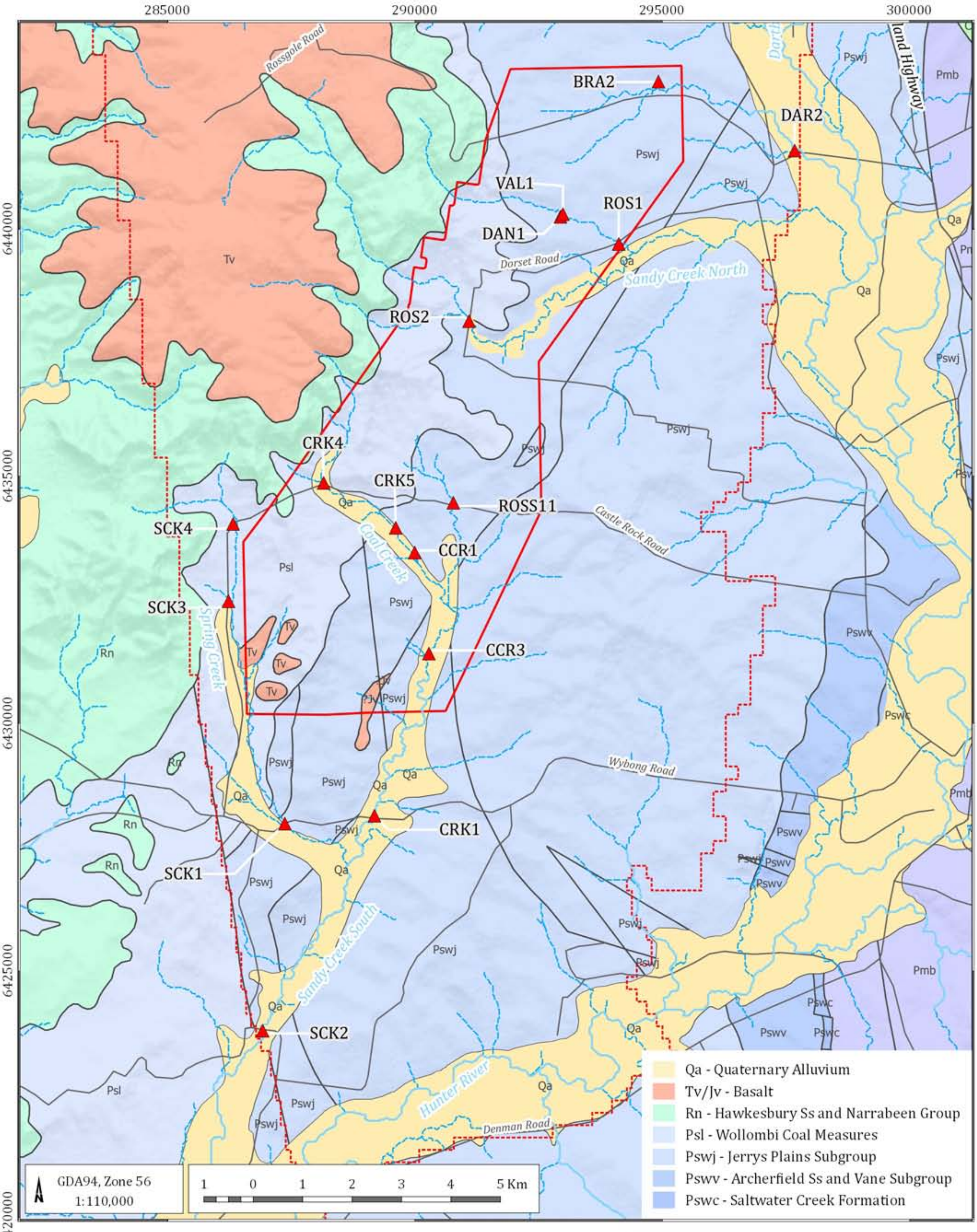
- PINNEENA groundwater bores
- Groundwater monitoring
- Groundwater monitoring - surface water level
- Production bores
- Project Assessment Area
- Study Area
- Main streams
- Minor ephemeral streams
- Road major
- Road minor

West Muswellbrook (G1676)

Groundwater monitoring location - Study area

DATE 10/11/2014

FIGURE No: **3.3**



LEGEND

- Surface water quality June 2014 survey
- Main streams
- Minor ephemeral streams
- Project Assessment Area
- Study Area
- Road major
- Road

West Muswellbrook (G1676)

Surface water monitoring locations
Project Area

DATE 10/11/2014

FIGURE No: **3.4**

3.5 Recharge

Percolation of diffuse rainfall through the unsaturated zone is expected to be the dominant recharge process to groundwater bearing strata within the Study Area, with leakage through the beds of streams and rivers likely to be a lesser contributor. Sections 3.5.1 and 3.5.2 below discuss these recharge processes in more detail.

3.5.1 *Rainfall recharge*

Rainfall recharge (or deep drainage) occurs during wet climatic periods when the soil cover reaches field capacity (zero soil moisture deficit). Water that leaks from beneath the soil zone may infiltrate to the water table (recharge), or may flow laterally within the unsaturated zone, discharging to surface before reaching the water table (interflow). Regional scale groundwater studies are interested in estimating recharge to the water table, a requirement for developing a numerical model of the groundwater system.

The climate summary (Section 2.2) shows that both annually and monthly for the majority of the available 100 year record that evapotranspiration (EVT) exceeds rainfall. This indicates that rainfall recharge is limited to periods of above average rainfall intensity and longevity. Our previous experience calibrating models in the Upper Hunter Valley indicates the amount of recharge that reaches the water table is only a small proportion of the annual rainfall. Recharge to alluvial sediments in the upper Hunter is expected to be between 1% to 5% of annual rainfall and nearly always less than 10%. Recharge to Permian coal seams (at subcrop below regolith) is at least one order of magnitude less than alluvium. Recharge to lower permeability interburden sediments is expected to be lower again than that of the coal seams.

A soil moisture balance (SMB) recharge model was used to estimate recharge to the groundwater system. The model uses daily rainfall and climate records (described in Section 2.2) for both Aberdeen representing the Project Area, and Rossgole representing the top of the escarpment to the west. The SMB model represents a simplistic soil moisture bucket which runs a cumulative soil moisture calculation. The model calculates deep drainage rates when the soil store is filled by persistent rainfall. The SMB tool includes a lag effect to distribute extensive rainfall events over subsequent days.

The SMB model was initially run to investigate recharge processes in alluvium along Sandy Creek North and South. Section 2.3 describes the six shallow alluvial monitoring bores located along these creek systems. The automated groundwater level readings (twice daily) from a selection of these sites provided ideal data to test and "calibrate" the SMB recharge model. The objective was to estimate volumes of recharge occurring when water levels in the monitoring bores spiked following rainfall events. The period 2004 to 2014 was selected for analysis, as this period overlaps the majority of the available monitoring data for the Study Area (see Section 3.4). The estimated recharge rates were checked on an annual basis to ensure they remained within the bounds discussed above.

Figure 3.5 shows results from the SMB model plotted against Sandy Creek (North and South) groundwater level data. The green line at the base of the graph shows the moving soil moisture bucket with effective recharge shown as orange (and red) lines. Generally, as is suggested by climate data, soil moisture is below field capacity (green line remains negative) with only excessive and prolonged rainfall events resulting in drainage through soils and recharge to the groundwater system. The recharge on any individual day was also capped at 18 mm/day (capped effective recharge) to account for run-off during intensive daily rainfall events. Figure 3.5 shows the estimated recharge events and groundwater levels are generally correlated, with rapid increases in some (but not all) groundwater levels. A good example is the major recharge event in mid-2007 which occurred following a long dry period.

The SMB recharge model was also run with the Rossgole SILO data from the top of the escarpment and produced slightly more recharge events compared with the data shown in Figure 3.5. This is due to more rainfall and less evapotranspiration (EVT) on top of the escarpment compared to the valley floor around the PAA (See Section 2.2 for more climate detail).

3.5.2 *River recharge*

Stream leakage is a second potential source of recharge to both the alluvium and Permian coal measures within the Project Area. During periods when stream stage is higher in elevation than the adjoining aquifer system groundwater levels there will be stream leakage (aquifer recharge from the stream/river). Elevated stream stage in Sandy Creek North and Sandy Creek South (including tributaries) may occur at periods when rainfall recharge occurs but may also occur when there is no rainfall recharge.

The numerical model described in Section 0 below was used to investigate stream leakage within the context of the wider water balance.

3.6 Discharge

The main aquifer discharge mechanisms in the system are EVT and groundwater seepage to water courses as baseflow. Other less significant discharge sources are water seeping from springs at the base of the Triassic Sandstone and groundwater pumped from private bores.

The headwater reaches of Sandy Creek North, Coal Creek and Spring Creek receive baseflow from the base of the Triassic Sandstone and the colluvium at the base of the escarpment. As the tributaries drain east across the lower slopes of the Wollombi Coal Measures, the volume of baseflow appears to reduce. Sandy Creek North and Coal Creek are largely ephemeral with limited baseflow. In contrast, the perennial reaches of Sandy Creek South and Spring Creek have a more reliable baseflow component.

Figure 3.4 shows the sections of Sandy Creek South that appear to have perennial flow. Section 3.8 examines baseflow further by comparing stream and groundwater quality data.

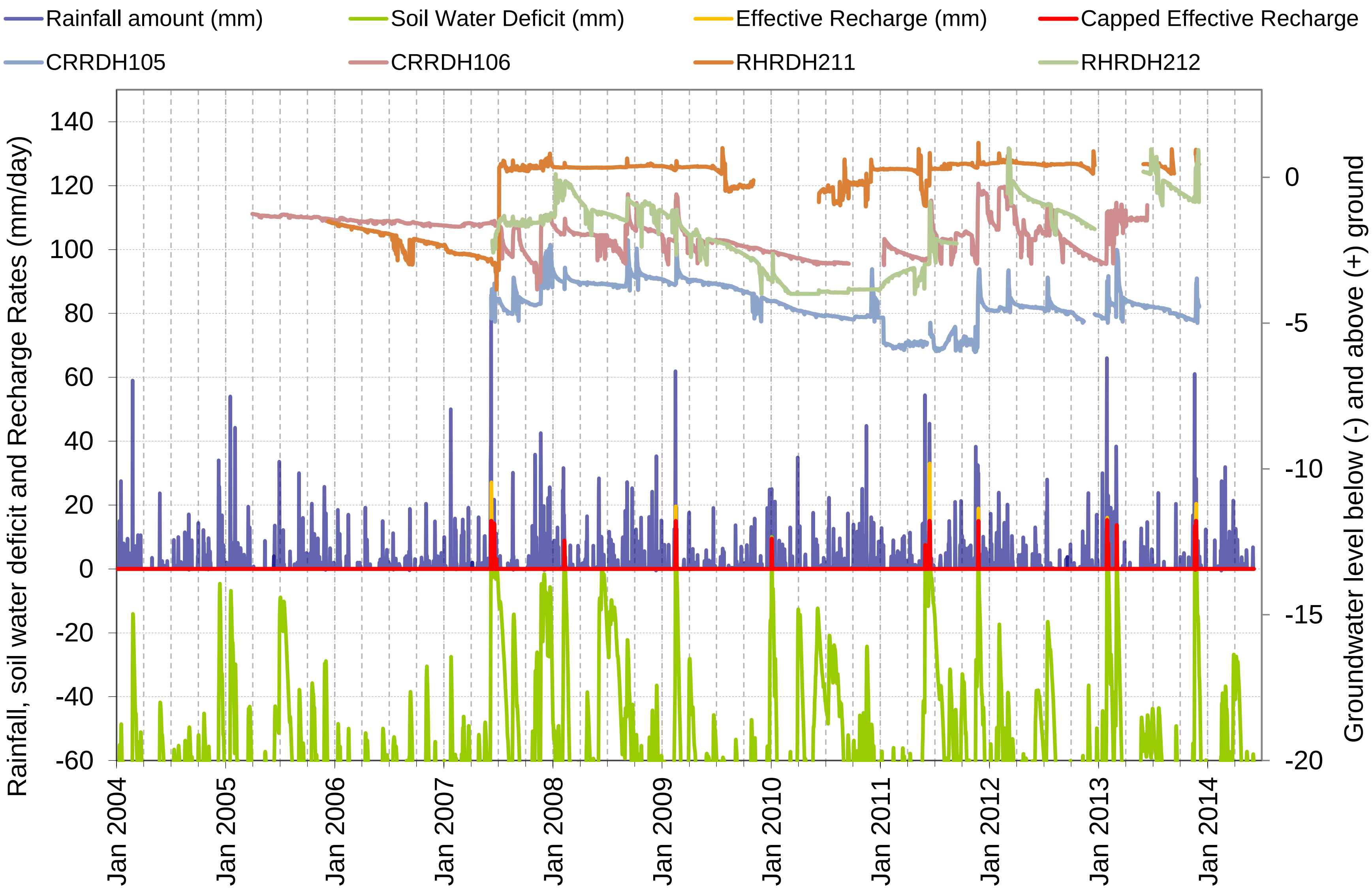


Figure 3.5 Calculated daily recharge Sandy Creek North and South

3.7 Groundwater levels and hydraulic gradients

Groundwater levels and gradients were investigated by preparing a series of bore hydrographs and groundwater level contour maps.

Figure 3.6 shows the available long term groundwater level data for four bores east of the project area:

- Bore CAD2 installed within Sandy Creek North alluvium;
- Bore COR3 installed within regolith next to Sandy Creek north; and
- Bores GW040509 and GW040566 installed within Dartbrook alluvium.

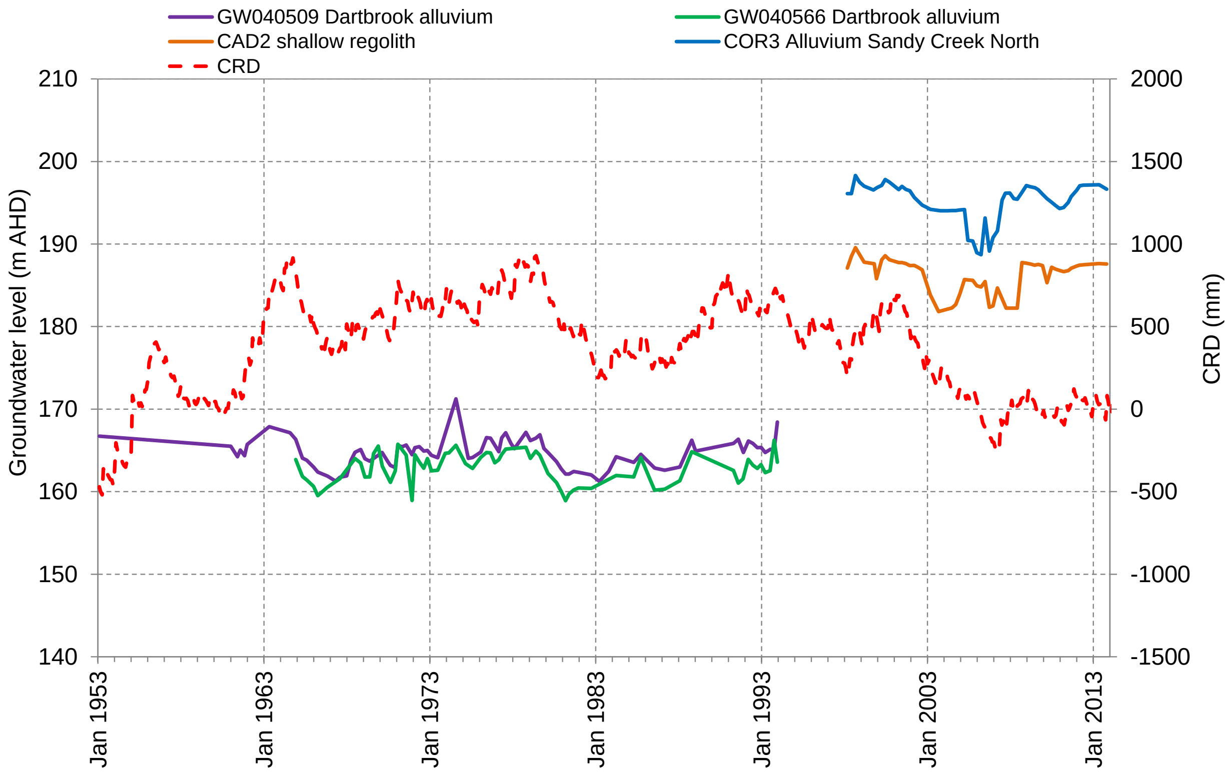


Figure 3.6 Groundwater level hydrographs – long term trends

The hydrographs show that groundwater levels fluctuate in a pattern correlating with the CRD. No other influences, e.g. significant drawdowns associated with cumulative mining impacts, apart from climatic conditions, are evident in the long term water level records representing the Study Area.

Figure 3.7 and Figure 3.8 show groundwater levels within the Permian and alluvium for both the Sandy Creek North and Sandy Creek South / Coal Creek areas.

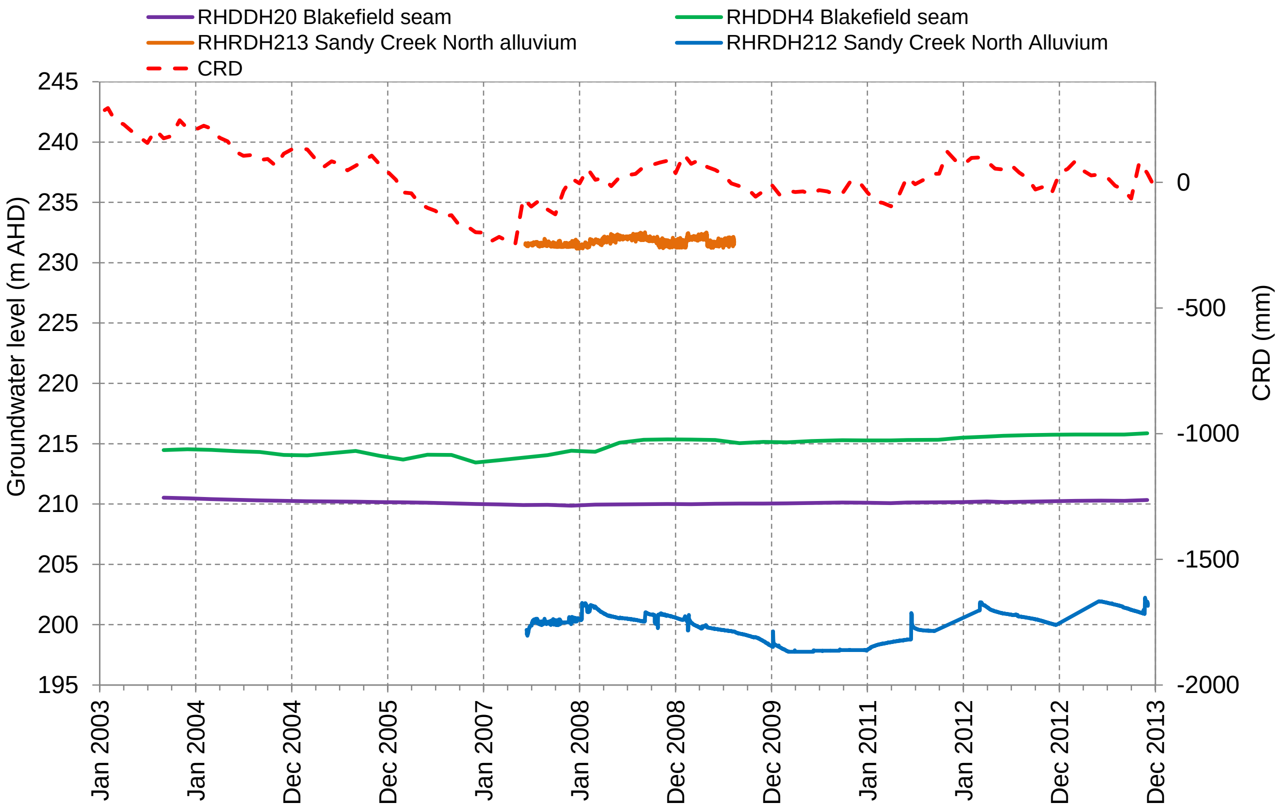


Figure 3.7 Alluvial and Permian groundwater levels – Sandy Creek North

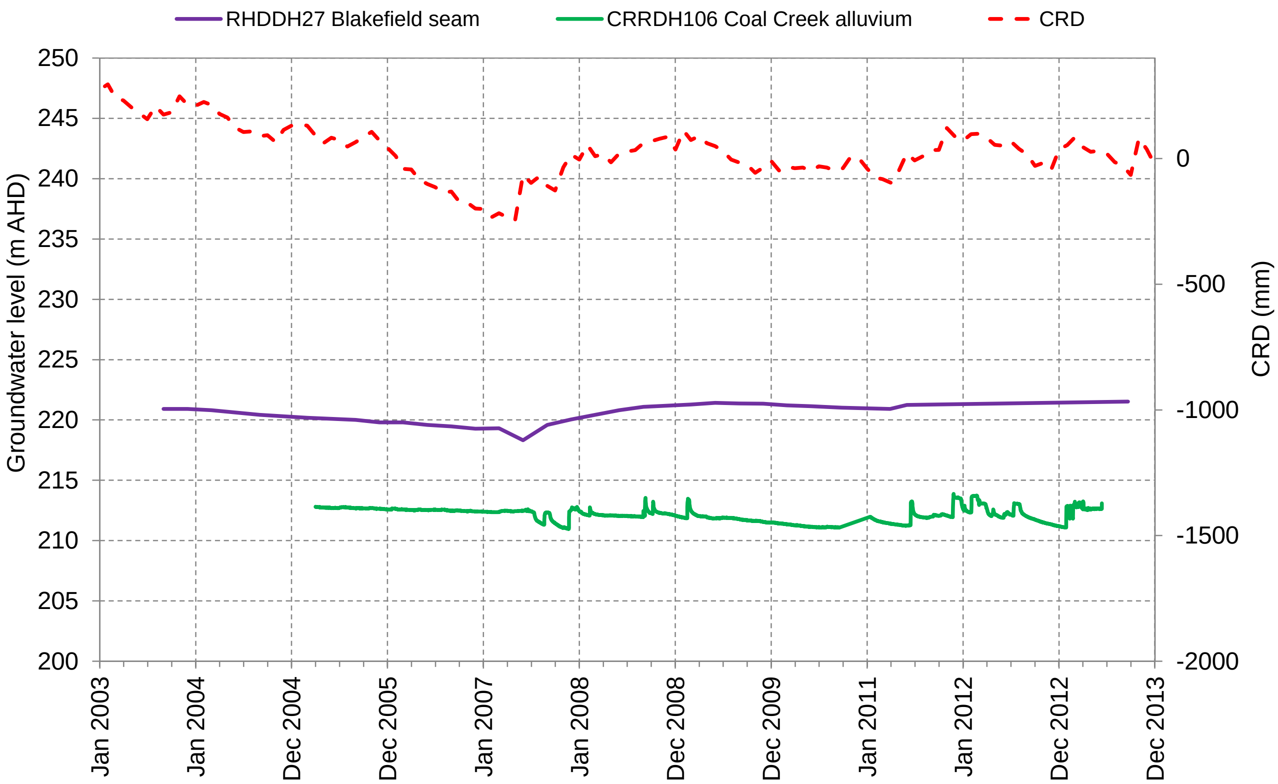


Figure 3.8 Alluvial and Permian groundwater levels – Coal Creek / Sandy Creek South

The Permian graphs are based on groundwater levels measured quarterly, whereas the alluvium data are recorded daily by electronic data loggers. Consequently, significantly more detail is seen in the water level data from alluvium, which capture small spikes in groundwater levels following rainfall events. The hydrographs indicate:

- Permian groundwater levels measured in RHDDH20 show very limited fluctuation through the record, suggesting limited recharge and poor hydraulic connection with the alluvium; and
- Permian groundwater levels in RHDDH4 and RHDDH27 show more influence from rainfall events rising in response to above average rainfall in 2007.

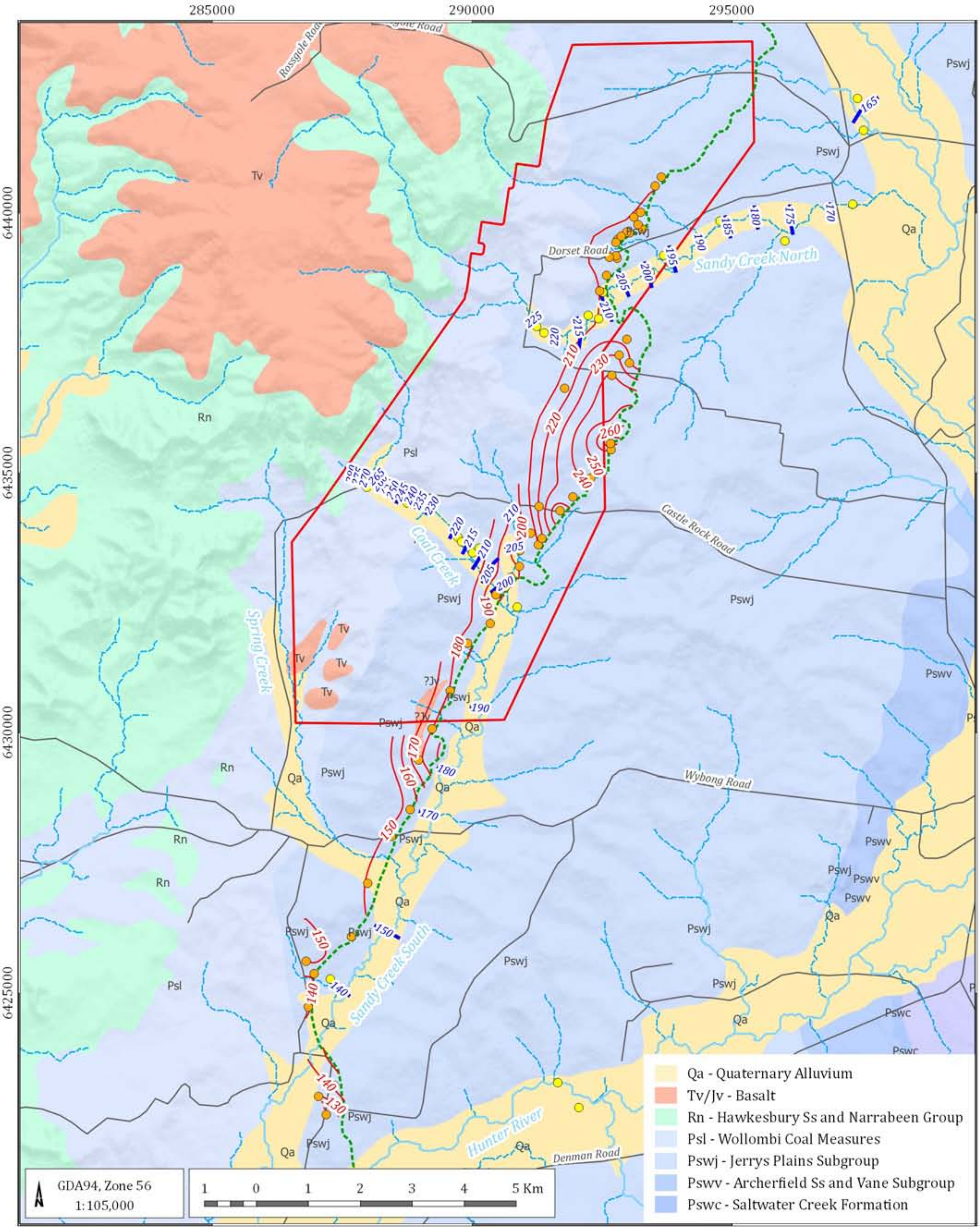
In general the magnitude of groundwater level fluctuations is more pronounced within the alluvium, but this response is retarded within the underlying Permian with increasing distance from alluvial sources. The measured groundwater levels (see Figure 3.7 and Figure 3.8) within the PAA show no evidence of groundwater decline impacts from mining in the region, rather climatic conditions controlling groundwater levels.

No nested monitoring sites or vibrating wire piezometers are constructed within the Study Area, meaning vertical hydraulic gradients cannot be measured. To analyse hydraulic gradients and groundwater flow between strata, a "snapshot" of water level data from the Permian and alluvium was compiled and contoured. This required combining measurements of groundwater levels in monitoring bores and open exploration hole water levels (see Section 3.4.1).

Figure 3.9 overlays the interpreted groundwater level contours for both alluvium and the Blakefield seam, and shows the data points used to create the contours.

Figure 3.9 indicates the water table within the Sandy Creek North, Coal Creek and Sandy Creek South alluvium follows topography downstream, flattening beyond the confluence of Coal Creek and Sandy Creek South. In contrast, the contoured potentiometric surface for the Blakefield seam shows a hydraulic gradient reflecting the dip of the coal seam from east to west, although the limited distribution of water level data from the Blakefield seam west of the sub-crop is limited.

Groundwater levels between the Permian and alluvium converge along the Blakefield seam outcrop at both Sandy Creek North and South, suggesting the coal seams are discharge zones where they pass under the creeks. West from the sub-crop area of the Blakefield seam there may be downward hydraulic gradient from the alluvium to the Permian. As recommended in section 8, further monitoring sites should be installed down dip of the coal seam outcrop during the DA stage to better map the potentiometric surface and hydraulic gradients within the Permian sequence.



LEGEND

- Blakefield seam groundwater level data point
- Alluvium groundwater level data point
- Alluvium groundwater level contours (mAHD)
- Blakefield seam groundwater level contours (mAHD)
- Blakefield subcrop
- Project Assessment Area
- Main streams
- Minor ephemeral streams
- Road major
- Road

West Muswellbrook (G1676)

Groundwater levels 2000 to 2004 - alluvium and Blakfield seam

DATE 10/11/2014

FIGURE No: **3.9**

3.8 Groundwater-surface water interaction

Within the Study Area, no stream stage / flow monitoring sites are located on either Sandy Creek North or South. MCC has installed six shallow piezometers either within the alluvial stream bed or directly next to it along Sandy Creek North and Sandy Creek south since 2004 (see Section 2.3 for background to these sites). Figure 2.4 shows the position of the sites. Automatic pressure transducers record water level in these bores twice daily and return information on when groundwater levels within shallow alluvium are below and above the river bed. With no dedicated stream gauges the data from these six sites are a valuable surrogate to actual stream stage gauges.

Figure 3.10 shows two monitoring sites (RHRDH213 and RHRDH211) along Sandy Creek North and one site (CRRDH105) along Sandy Creek South showing periods when the stream may flow, i.e. water level above ground, and other periods when the stream may be dry i.e. water level below ground. As these sites measure stream bed alluvial groundwater level they represent sustained periods of stream stage, and possible flow, reflected by elevated groundwater levels.

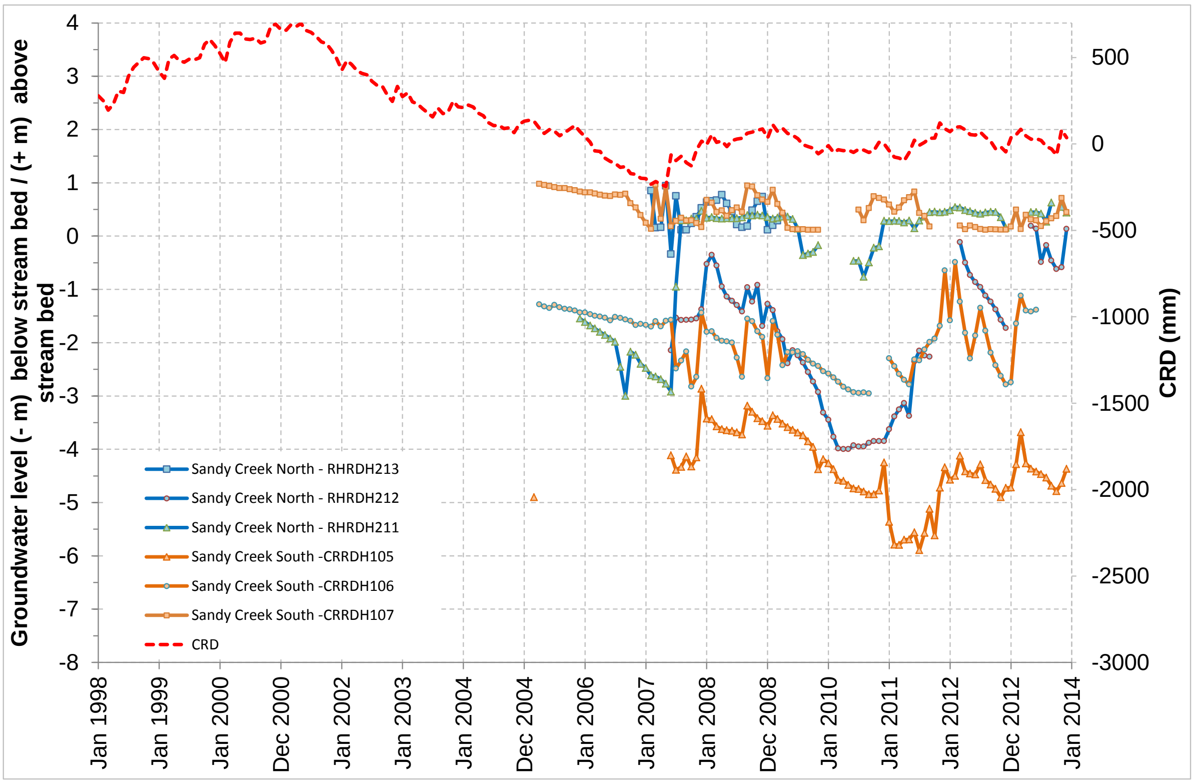


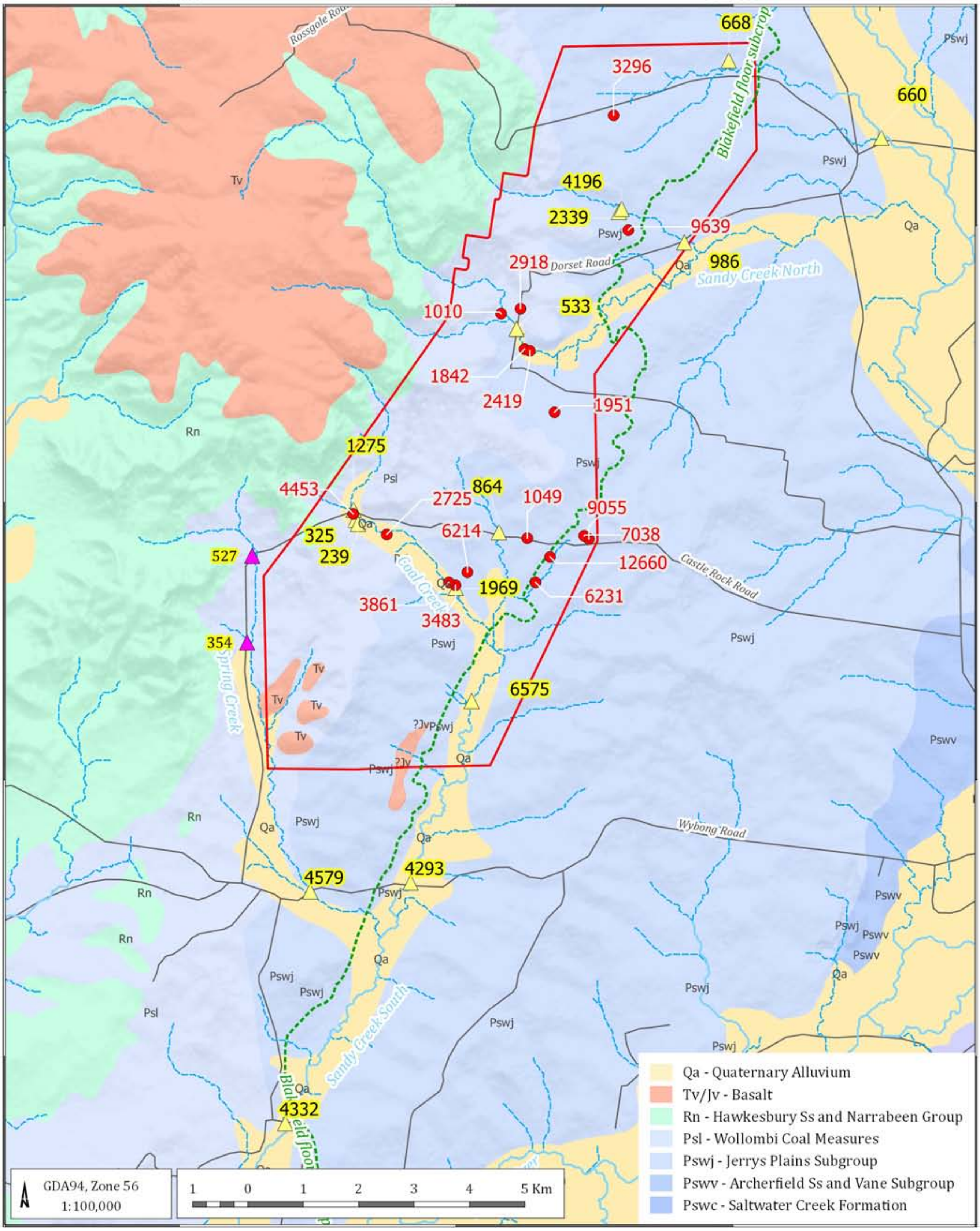
Figure 3.10 Shallow Sandy Creek groundwater level recorders

3.9 Groundwater quality

Appendix A summarises the available surface and groundwater quality data available for the Study Area. In total, 58 water quality analyses are available for the Study Area over the period 2011 to 2013, comprising 28 surface water and 30 groundwater samples. The samples have been analysed for a suite of major ions, metals and nutrients. This is supported by quarterly field measurements at all the sites. Field based data records extend back at some sites to 2003. Table 3-3 compares the water quality data to guidelines for the quality of stock, domestic and irrigation waters. Sections 3.9.1 and 3.9.2 below discuss the groundwater and surface water quality.

3.9.1 *Salinity and pH*

Over 450 groundwater and 350 surface water electrical conductivity (EC) and pH measurements are available for the network. Table 3-2 shows minimum, mean and maximum statistics for each site.



LEGEND

- Average EC groundwater sites uS/cm
- Average EC surface water sites uS/cm
- Salinity single survey June 2014 uS/cm
- Blakefield subcrop
- Project Assessment Area
- Main streams
- Minor ephemeral streams
- Road Major
- Road

West Muswellbrook (G1676)

Surface and groundwater EC

DATE 10/11/2014

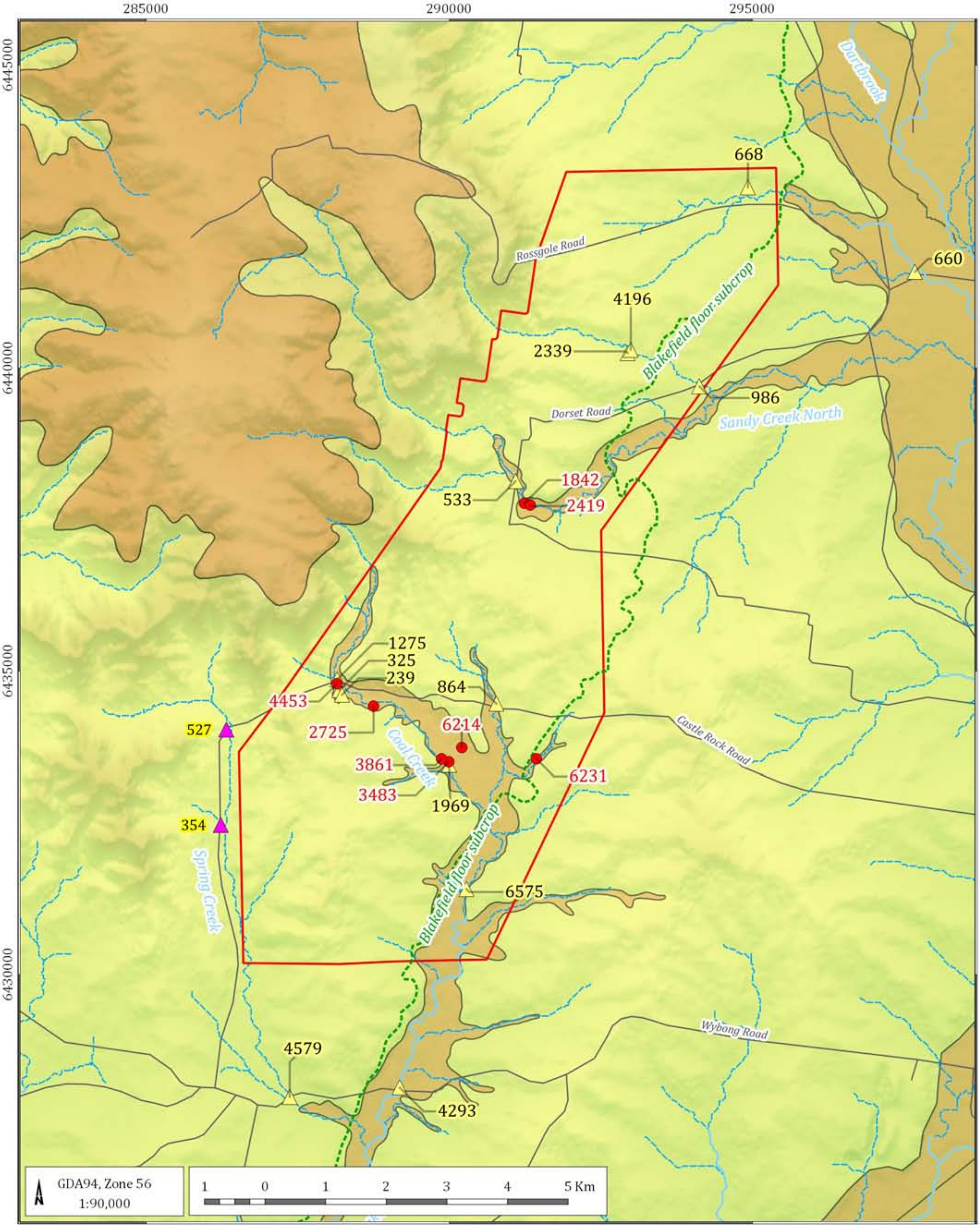
FIGURE No: **3.11**

Table 3-2 shows the average EC for each site against mapped highly productive aquifers.

Table 3-2 Surface and groundwater average EC

	Surface water -SW	pH			EC (µS/cm)		
ID	Groundwater - GW	Min	Mean	Max	Min	Mean	Max
CCR1	SW	7.7	8.5	9.3	712	1969	2625
CCR3	SW	8.2	8.6	9.2	1027	6575	10700
CCR4	SW	7.0	7.6	8.4	115	1406	4360
CRK1	SW	7.2	8.0	8.7	600	4293	7840
CRK4 (HUT4)	SW	6.0	7.6	8.6	116	1275	1990
DAR2	SW	6.5	8.2	9.0	112	660	1140
ROS1	SW	6.7	7.5	8.1	315	986	1674
ROS11	SW	7.0	7.5	7.9	199	864	1205
ROS2	SW	6.2	7.4	8.1	86	533	1065
SCK1	SW	7.3	8.0	8.7	819	4579	8970
SCK2	SW	7.1	7.9	8.6	661	4332	11000
BRA2	SW	6.4	7.6	8.9	106	668	14750
DAN1	SW	6.3	8.3	9.9	332	2339	14440
HUT1	SW	6.9	7.6	8.7	150	325	518
HUT2	SW	7.0	7.4	7.7	108	239	341
HUT3	SW	6.3	7.4	8.5	183	256	308
VAL1	SW	7.6	8.8	10.0	2490	4196	8420
SPAR3	GW – Highly Productive PAA	6.8	7.8	8.7	2715	6231	10120
DAY1	GW – Less Productive PAA	7.2	8.6	9.9	340	3296	13000
RDDH20	GW – Less Productive PAA	6.7	7.0	7.9	2149	9639	12240
RDDH27	GW – Less Productive PAA	7.1	7.6	8.5	946	1049	1510
RDDH4	GW – Less Productive PAA	6.6	7.4	8.2	765	1951	3780
JLON1	GW – Less Productive PAA	7.7	9.0	10.1	6395	9055	22000
JLON2	GW – Less Productive PAA	7.4	7.7	8.8	4870	7038	8860
PIT1	GW - Highly Productive PAA	6.7	7.2	8.1	740	1842	5530
PIT2	GW - Highly Productive PAA	6.9	7.2	8.3	713	2419	7390
CRDH52	GW – Less Productive PAA	6.9	7.2	8.4	11400	12660	15440
SPAR2	GW - Highly Productive PAA	6.4	7.5	8.4	194	3483	7470

	Surface water -SW	pH			EC (µS/cm)		
ID	Groundwater - GW	Min	Mean	Max	Min	Mean	Max
SPAR4	GW - Highly Productive PAA	7.1	8.1	9.7	1743	6214	9310
SPAR5	GW - Highly Productive PAA	6.6	7.3	8.3	409	3861	6865
WEK2	GW - Highly Productive PAA	7.0	7.2	7.9	2375	2725	3270
WYL1	GW – Less Productive PAA	7.2	7.4	7.6	423	2918	9800
YOU1	GW - Highly Productive PAA	6.9	7.8	8.8	1681	4453	5870
GDAY1	GW – Less Productive PAA	6.9	7.3	7.8	835	1010	1412



LEGEND

Groundwater productivity

- Highly
- Less
- Project Assessment Area
- Average EC groundwater sites within highly productive alluvium uS/cm
- Average EC surface water sites uS/cm
- Salinity single survey June 2014 uS/cm
- Blakefield subcrop
- Main streams
- Minor ephemeral streams
- Road

West Muswellbrook (G1676)

Surface and groundwater average EC against mapped highly productive aquifers

AGE GROUNDWATER & ENVIRONMENTAL

DATE 9/10/2014

FIGURE No: **3.12**

The data shows the salinity of the surface water samples varies considerably within and between sampling sites. There is no record of surface water flows during each sampling round, but rainfall runoff is a logical reason why the salinity is lower during some sampling events. Rainfall events that result in runoff from the Triassic sandstone escarpment would reduce stream salinity, and during drier periods salinity would increase due to increased proportions of groundwater baseflow and evaporation.

Figure 3.11 shows a generally increasing salinity from the westerly headwaters to those downstream sample sites in the creeks. Salinity increases substantially along Sandy Creek South where groundwater levels within the Permian strata are close to the alluvial levels.

The salinity of groundwater ranges from slightly saline to brackish.

Figure 3.12 shows a large proportion of the groundwater monitoring sites yield samples with a salinity greater than 1,500 mg/L (≈ 1,900 µS/cm), which is the bench mark below which the AIP considers aquifers highly productive (along with a yield of >5L/sec).

3.9.2 *Major Ions and trace metals*

Figure 3.13 and Figure 3.14 show major ion data for surface water and groundwater sites plotted on Piper and Extended Durov diagrams.

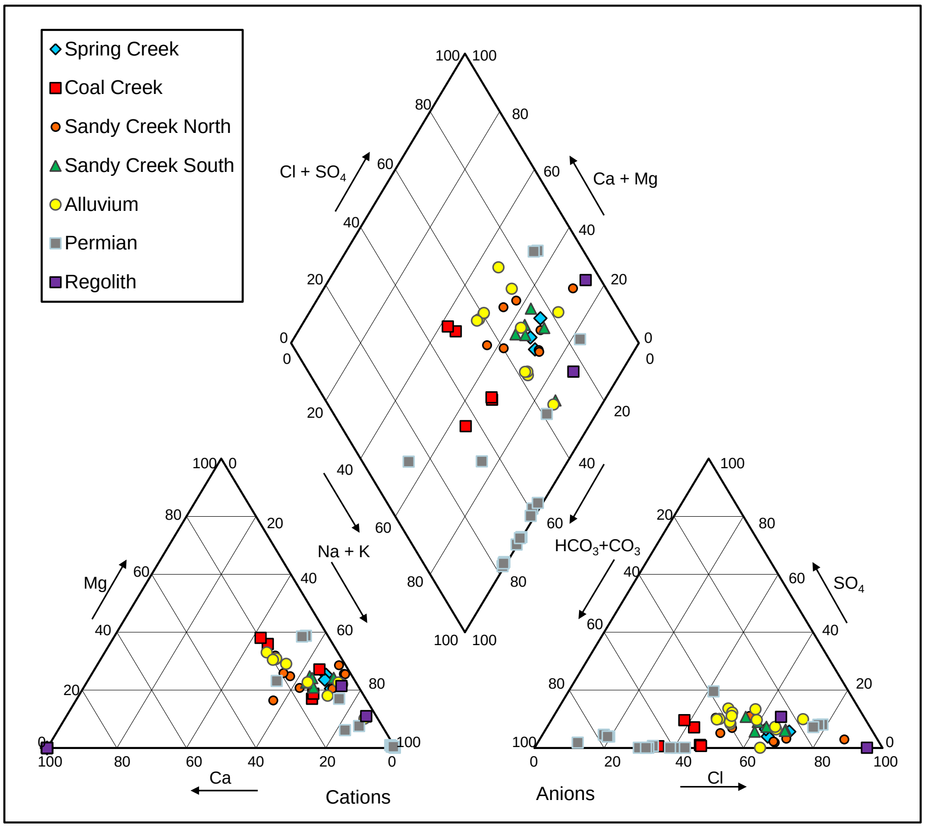


Figure 3.13 Piper diagram - surface water and groundwater

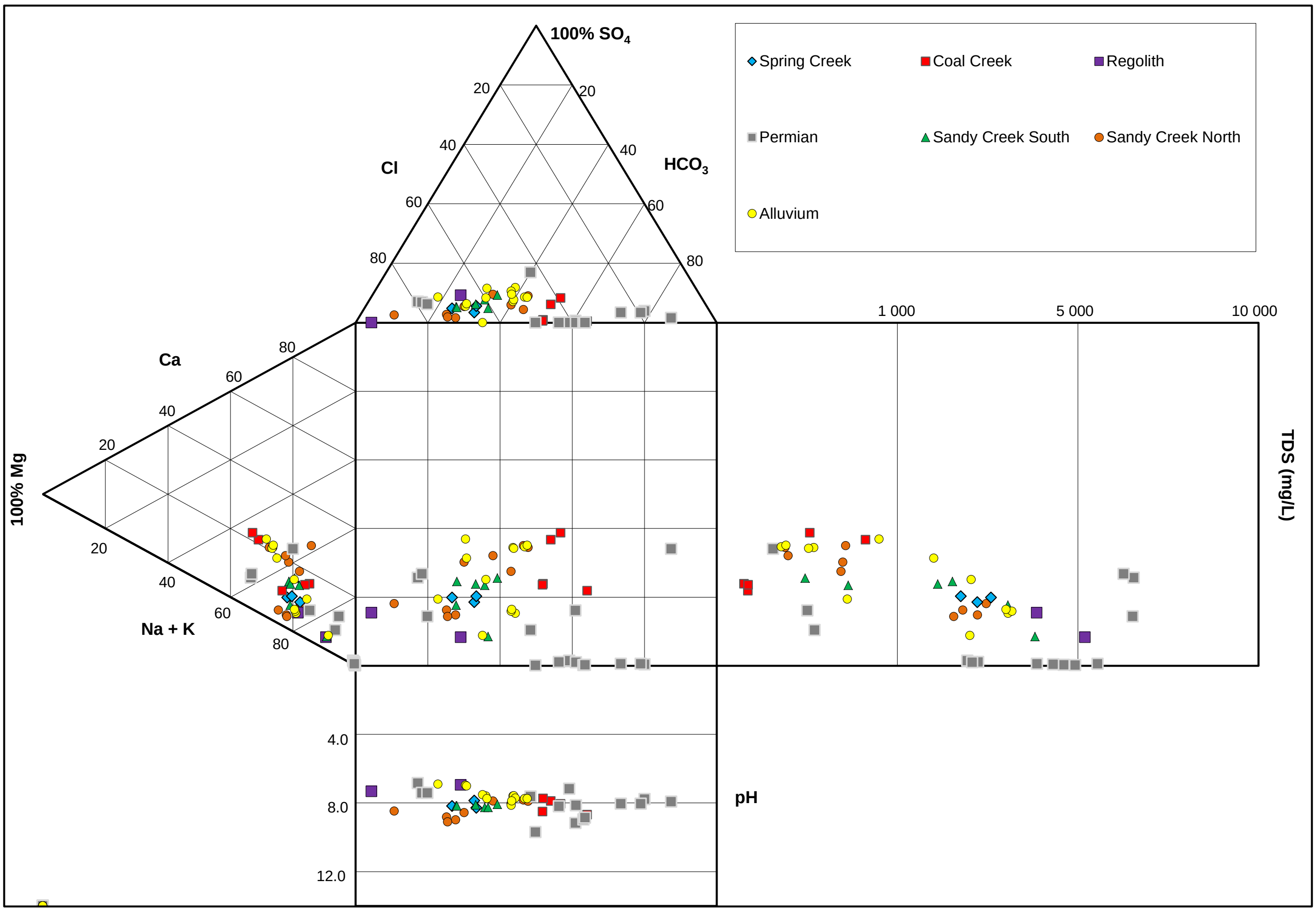


Figure 3.14 Durov diagram – surface water and groundwater

The Piper diagram shows samples from alluvium, Sandy Creek South and Sandy Creek North clustered together, indicating a similar chemistry and source. Coal Creek samples plot slightly away from this cluster due to greater proportions of alkalinity, magnesium and calcium potentially indicating a recharge source from Triassic sandstone runoff. Generally the Permian samples are grouped on their own due to reduced proportions of chloride and higher alkalinity. All samples show limited sulphate.

The Extended Durov diagram expands on what can be seen in the clustering in the Piper diagram by introducing EC and pH to the plot. Figure 3.14 supports what was discussed previously, that waters tend to increase in salinity downstream from the base of the Triassic sandstone escarpment. To the west these lower salinity waters tend to have higher alkalinity, calcium and magnesium ratios, presumed sourced from interaction with the sandstones. As you move downstream within the surface and groundwater systems, magnesium and calcium ratios reduce, and sodium and chloride ratios increase. These changes in major ion ratios, combined with increases in salinity are presumably a result of surface water and alluvial groundwater interacting with coal seam groundwater.

An objective of this report is to identify how groundwater is used within the Study Area. To support this assessment average water quality (for each site) has been compared the ANZECC (2000) guidelines for stock and irrigation and the NHMRC (2011) guideline for drinking water (Table 3-3). Table 3-3 highlights samples that have concentrations exceeding guidelines for these uses.

Table 3-3 Water quality comparison to ANZECC guidelines

Parameter	Units	LOR[a]	ANZECC GUIDELINES		NHMRC																													
Sample Location						**CRK1**	**CRK4**	**DAR2**	ROS1	ROS11	ROS2	SCK1	SCK2	BRA2	DAN1	HUT1	HUT2	HUT3	VAL1	SPAR3	DAY1	RHDDH20	RHDDH27	RHDDH4	JLON1	JLON2	PIT1	PIT2	CRRDH52	SPAR2	SPAR4	SPAR5	YOU1	GDAY1
Lab Number			**Irrigation Water**	**Stock Water**	**Drinking Water**																													
Date Sampled																																		
Lithology																																		
Sampling Date																																		
Field pH	pH units		-	-	-																													
Field Electivcal Conductivity (EC)	µS/cm		-	-	-																													
Depth to Groundwater	m bTOC		-	-	-																													
Physical Parameters																																		
pH	pH Units	0.1	**6.0 - 8.5**	-	**6.5 - 8.5[b]**	8.1	8.0	8.2	8.0	7.8	7.9	8.2	8.1	7.7	**8.5**	**8.7**	7.7	**8.5**	**8.8**	8.3	8.4	7.2	7.6	7.8	**9.2**	8.0	7.4	7.4	7.0	7.6	7.3	7.5	7.9	7.3
Electrical conductivity	µS/cm	1	-	-	-	3840	1110	687	1190	1200	623	2659	2425	261	2002	206	108	183	3600	6950	2717	10733	962	3640	11773	7023	1056	1134	11400	3540	7370	3970	5100	1003
Sodium Absorption Ration (SAR)	-	0.01	-	-	-																													
Total Dissolved Solids (grav) @180°C	mg/L	1.00	-	**3000 - 13000***	**600[b]**	**2193.30**	**671.00**	369.00	**690**	**716**	380	**1426**	**1325**	276	**1109**	174	152	175	**1953**	**3810**	**1541**	**6447**	542	**2087**	**7080**	**4580**	599	**635**	**5200**	**2050**	**3860**	**2010**	**3087**	**643**
Total Suspended Solids	mg/L		-	-	-				<5	6	<5					30	18	24		<5			28						30	10	54	105		
Total Hardness as CaCO3	mg/L	1.00	-	-	**200[b]**				**226**	**261**	156					32	16	29		**463**			70						**752**	**655**	**866**	**249**		
Hydroxide Alkalinity as CaCO3	mg/L	1.00	-	-	-																													
Carbonate Alkalinity as CaCO3	mg/L	1.00	-	-	-				<1	<1	<1					<1	<1	<1		<1			<1						<1	<1	<1	<1	0	0
Bicarbonate Alkalinity as CaCO3	mg/L	1.00	-	-	-				242	263	128					61	26	41		1090			183						1290	548	143	651	1200	147
Total Alkalinity as CaCO3	mg/L	1.00	-	-	-																													
Major Ions																																		
Sulfate as SO4 - Turbidimetric	mg/L	1	-	**1000 - 2000**	**500 / 250[b]**	95.3	45.5	12.5	40	29	30	88.3	76.5	7.2	34	0.5	0.5	0.5	44.7	173	59.7	**433.7**	89	0.5	2	163.7	40.3	45.7	**558**	162	0.5	0.5	**311**	56.5
Chloride	mg/L	1	**40**	-	**250[b]**	894	171.5	88	231	216	100	589.7	582.5	17.3	443	24	17	27	**915.3**	**1380**	**500**	**3193.3**	**140**	**542.3**	**1381**	**547.7**	**223.7**	**235.3**	**2520**	**734**	**2200**	**851**	**938.3**	**226**
Fluoride	mg/L	0.1	**1.0**	**2**	**1.5**				0.3	0.4	0.2					0.5	0.4	0.5		**1.2**			**1.4**						0.9	0.5	<0.1	0.8		
Calcium	mg/L	1	-	**1000**	-	63.7	45	43	41	65	23	40.3	60	14	27.3	3	3	5	29.3	42	24	160	13	6.3	2.7	4.7	42.3	41	62	99	63	27	51.3	29
Magnesium	mg/L	1	-	-	-	113	52.5	36.5	30	24	24	72.3	74	6.3	60	6	2	4	105	87	38.7	371.7	9	3	2	3.7	41.3	41.3	145	99	172	44	148	10.5
Sodium	mg/L	1	-	-	**180[b]**	631.7	118.5		168	154	69	399	360	14.3	291	20	11	23	**564.7**	**1300**	**492.7**	**1400**	**184**	**860.3**	**2653.3**	**1713.3**	**117.3**	134.7	**2140**	**521**	**1110**	**690**	**911**	154
Potassium	mg/L	1	-	-	-	6.7	2	2	5	7	3	4.7	6	22.3	19.3	12	7	7	26.3	22	22	25	17	3.7	11.3	7	3	3	30	4	25	34	7.3	4
Carbonate	mg/L		-	-	-	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	26.5	0.3	0.3	0.3	49.2	0.3	9.2	0.3	0.3	3.4	870.4	87.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Bicarbonate	mg/L		-	-	-	644.2	369.1	269.6	295.2	320.9	156.2	415.2	405	104.9	288.3	74.4	31.7	50	327	1329.8	603.5	1028.5	223.3	1333.9	3310.3	3696.6	225.7	235.5	1573.8	668.6	174.5	794.2	1200.1	147
Nutrients																																		
Ammonia as N	mg/L	0.01	-	-	**0.5[b]**				0.02	<0.01	<0.01					0.04	0.02	0.04		**7.92**			0.02						8.56	0.02	**9.05**	**49.1**		
Nitrate as N	mg/L	0.01	-	-	**50**				0.02	<0.01	<0.01					<0.01	<0.01	0.02		0.07			0.9						0.63	0.4	0.11	<0.01		
Dissolved Metals																																		
Arsenic	mg/L	0.001	-	-	-				<0.001	<0.001	<0.001					0.006	0.003	0.004		0.001			0.003						0.004	<0.001	0.001	0.002		
Barium	mg/L	0.001	-	-	-				0.086	0.234	0.033					0.086	0.086	0.074		0.157			0.092						0.133	0.204	0.327	1.09		
Boron	mg/L	0.05	-	-	-				0.08	0.05	<0.05					<0.05	<0.05	0.06		0.14			0.08						0.3	0.06	0.05	0.08		
Cadmium	mg/L	0.0001	-	-	-				<0.0001	<0.0001	<0.0001					<0.0001	<0.0001	<0.0001		<0.0001			<0.0001						0.0002	<0.0001	<0.0001	<0.0001		
Chromium	mg/L	0.001	-	-	-				<0.001	<0.001	<0.001					<0.001	<0.001	0.001		0.001			0.003						0.005	<0.001	<0.001	<0.001		
Copper	mg/L	0.001	-	-	-				<0.001	<0.001	<0.001					<0.001	0.047	<0.001		<0.001			0.008						0.014	0.032	0.002	0.009		
Iron	mg/L	0.05	-	-	-	0.03	0.06	0.03	0.05	0.24	0.06	0.06	0.05	0.14	0.04	0.71	0.87	0.84	0.04	0.73	0.3	0.53	0.03	0.4	0.06	0.09	0.03	0.03	0.35	0.03	5.71	7.53	0.03	0.25
Lead	mg/L	0.001	-	-	-				<0.001	<0.001	<0.001					<0.001	0.002	0.002		<0.001			0.011						0.014	<0.001	<0.001	<0.001		
Manganese	mg/L	0.001	-	-	-				0.035	0.37	0.04					0.097	0.061	0.064		0.572			0.107						0.221	0.01	0.698	0.254		
Mercury	mg/L	1.001	-	-	-				<0.0001	<0.0001	<0.0001					<0.0001	<0.0001	<0.0001		<0.0001			<0.0001						<0.0001	<0.0001	<0.0001	<0.0001		
Nickel	mg/L	0.001	-	-	-				0.002	0.003	<0.001					0.002	0.003	0.004		0.003			0.008						0.005	0.001	<0.001	0.001		
Selenium	mg/L	0.01	-	-	-				<0.01	<0.01	<0.01					<0.01	<0.01	<0.01		<0.01			<0.01						<0.01	<0.01	<0.01	<0.01		
Zinc	mg/L	0.005	-	-	-				<0.005	0.018	<0.005					0.005	0.014	0.01		0.114			0.16						0.22	0.317	0.018	0.064		
Total Metals																																		
Iron	mg/L	0.05	**0.2**	-	**0.3 [b]**				**0.22**	**0.45**	**0.21**					**1.77**	**3.43**	**4.02**		**0.94**			**2.03**						**4.26**	0.18	**15.3**	**24.6**		
Other																																		
Oil and grease	mg/L		-	-	-				<5	<5	<5					<5	<5	<5		<5			<5						<5	<5	<5	<5		

Notes:

a.	Limit of reporting
b.	Aesthetic guidelines for Drinking Water
mbTOC	metres below top of casing
0.7	Detected concentration above ANZECC (2000) Long Term Irrigation purposes
0.024	Detected concentration above ANZECC (2000) Stock purposes
0.024	Detected concentration above NHMRC (2011) Drinking Water Guidelines
*	maximum concentration at which good condition might be expected, with 13,000 mg/L for sheep, 5,000 mg/L for beef cattle, 4,000 mg/L for dairy cattle, 6,000 mg/L for horses and 3,000 mg/L for pigs and poultry.
-	No value

Table 3-3 shows:

- a large portion of both the groundwater and surface water samples are not suitable for human consumption due to elevated salinity, hardness, chloride, sodium and iron;
- four groundwater sites are not suitable for irrigation due to high chloride concentrations;
- six groundwater and one surface water site are too saline for stock; and
- three groundwater and one surface water site report high concentrations of ammonia, potentially due to the dominant landuse in the catchment being cattle grazing.

3.10 Bore census

A census of private bores was conducted to determine the reliance of the local landholders on groundwater resources. The bore census was conducted in two stages. The first stage was a desktop review of the government water bore database and data held by MCC. During the second stage bores identified as potentially being impacted by mining activities within the Study Area were visited to obtain groundwater data (refer Figure 3.15).

The review of available data sources (GeoTerra 2003, GeoTerra 2006, AGE 2008) and publicly available database (PINEENA 2013) found 320 privately owned bores within the greater Project Area, of which 62 bores are located within the PAA. 172 bores are within highly productive groundwater within the wider Study Area with the majority of these to the east associate with Dartbrook. 31 bores are within highly productive alluvium within the PAA.

The bore census excluded some bores within the PAA that would be removed by a future mine, concentrating on bores surrounding the mine footprint that could be potentially impacted by mining activities proposed within the PAA. The bore census focussed on visiting and surveying bores north of the pits (south of Rossgole Rd), between the pits (Sandy Creek North area) and on the western (Castle Rock Rd) and southern edge of pits. The elevation of the bore casing was surveyed using differential GPS (DGPS), and the construction, equipment, use and where possible, water quality recorded.

Table 3-4 summarises the properties visited. In total 37 bores were visited on 27 properties. Four visited bores were found destroyed (backfilled), 8 bores could not be located at previously recorded locations (Table 3-5). Appendix B contains all available information recorded during the bore census.

The bore census indicated stock watering is the dominant use of groundwater resources within the Study Area and surrounding region. Groundwater is used for domestic purposes, mainly along Spring Creek, but this is a less common use than for stock. Landholders predominantly source groundwater from alluvium, and to a lesser extent from shallow regolith or coal seams.

Table 3-4 Properties visited during the census

Lot	Plan	Landholder	Ownership	PAA*)
15	DP750931	FA Wheatley and Son Pty Limited	private	in
28	DP750931	Wilcrow Pty Limited	private	in
37	DP750915	Anne Michelle Pratt	private	in
324	DP829973	Robert Geoffrey Gowing	private	in
16	DP750931	Wilcrow Pty Limited	private	in
3	DP998239	Coal & Allied Operations Pty Ltd	mine	in
2	DP136249	Graeme Carl Sparre	private	in
5	DP1000366	Robert Geoffrey Gowing	private	in
177	DP750951	n/a	private	in
101	DP750951	Muswellbrook Coal Company	mine	in
4	DP556410	Dawn Molly Agnes Carey	private	out
212	DP634465	Ian Vincent and Colleen Anne Ingold	private	out
16	DP731123	Scott Heywood Jennar	private	out
16	DP830934	Trevor George Woods and Karen Muriel Bates	private	in
11	DP830934	Peter Brian Watts	private	in
2	DP33881	Rossgole Pastoral Company Pty Limited	private	in
32	DP748710	Muswellbrook Coal, Colin William Hutchinson	mine	in
13	DP830934	John Howard	private	in
1	DP625029	Walter John and Gwen Elizabeth Pitman	private	in
1	DP838220	John Lawrence and Diane Gai Day, and Rodney William	private	in
4	DP21335	Graeme Carl Sparre	private	in
1	DP416437	Bruce Anthony Day	private	in
4	DP584230	John Edward and Johanna Lambertina Lonergan	private	in
178	DP750951	Darryl Len Caddey and Phillip Caddey	private	in
2	DP625029	Lawrence Edward and Sandra Robyn Holdsworth	private	in
101	DP1124883	Anthony Denis Lonergan	private	in
101	DP1157712	Maree Esther Daniels	private	in

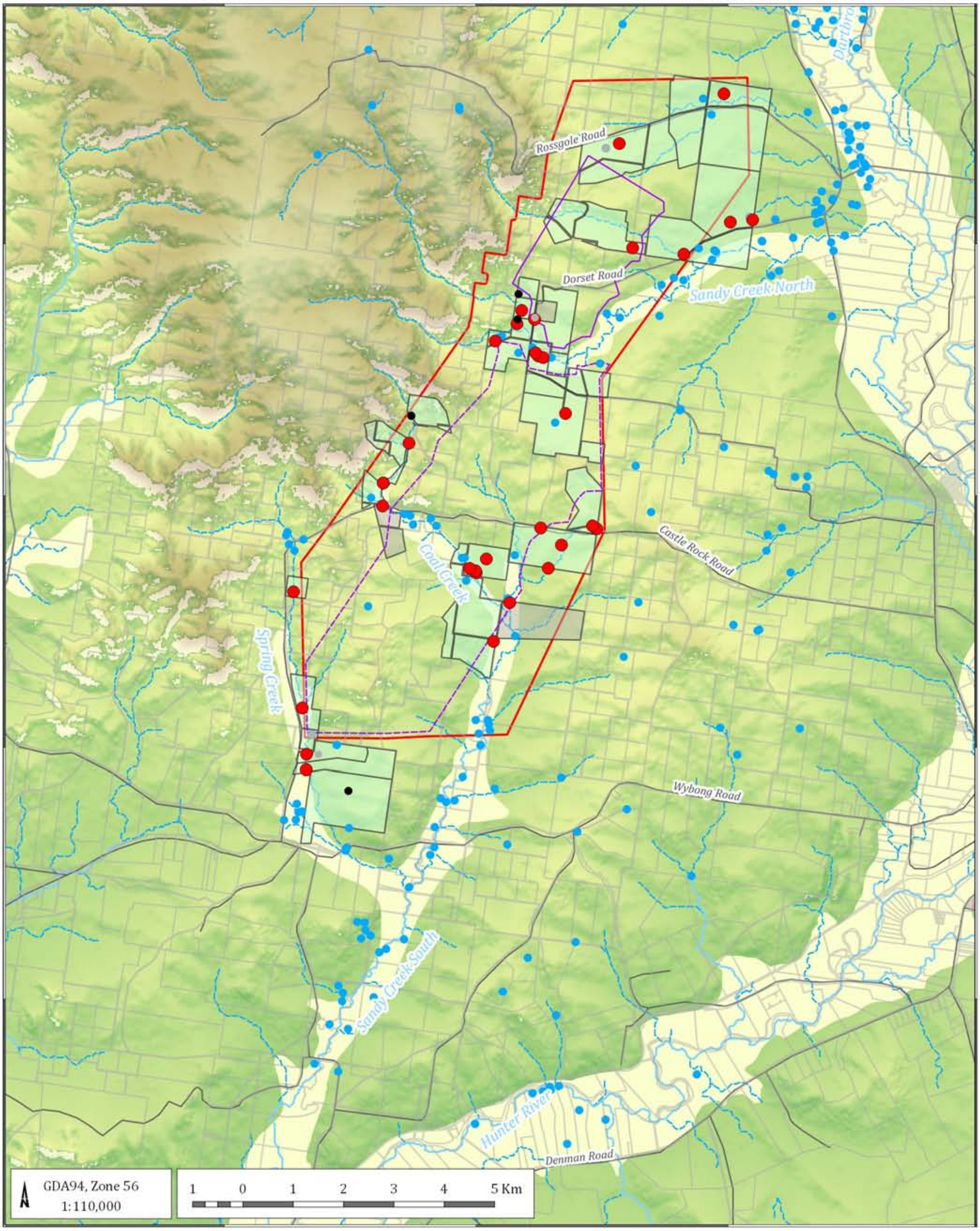
Note: **) Column indicates properties fully or partially within the PAA (in) and properties outside of the PAA (out)*

Table 3-5 Bores visited during the census

Bore ID	Alt. ID	Easting	Northing	Elevation	Comment	Lot	Plan	PAA*)
BRA2		294928.48	6442978.85	197.70	found	2	DP33881	in
CAD2	MARYVALE, GW078984	294131.81	6439790.20	200.08	found	178	DP750951	in
CRRDH105		290674.30	6432864.43	203.95	found	3	DP998239	in
CRRDH106		290009.14	6433457.19	213.00	found	4	DP21335	in
CRRDH109		290352.46	6432094.78	200.60	found	4	DP21335	in
CRRDH52	RDH52	291701.57	6434009.73	237.61	found	2	DP136249	in
DAY1		292850.35	6441989.50	245.99	found	1	DP416437	in
DOR01	JDAY1	290386.43	6438064.94	251.54	found	1	DP838220	in
GDAY1		290818.30	6438405.69	237.64	found	15	DP750931	in
GOW01		286554.37	6430771.16	197.61	found	5	DP1000366	out
GOW02		286380.37	6433080.71	235.26	found	37	DP750915	out
GW025626		288164.43	6435243.41	262.06	found	11	DP830934	in
GW025631		288674.69	6436034.70	284.89	found	13	DP830934	in
GW079025		295498.49	6440472.93	182.03	found	177	DP750951	out
GW079026		295055.83	6440426.75	189.56	found	177	DP750951	out
ING01		286632.36	6429549.48	186.79	found	212	DP634465	out
JEN01		286639.92	6429854.81	190.29	found	16	DP731123	out
JLON1	GW033725	292403.50	6434331.87	259.20	found	4	DP584230	in
JLON2	GW023652	292318.84	6434390.91	252.07	found	4	DP584230	in
PIT1		291243.59	6437765.25	230.08	found	1	DP625029	in
PIT2		291337.60	6437735.42	229.63	found	2	DP625029	in
RHDDH20	DDH20	293115.37	6439916.10	240.30	found	101	DP1157712	in
RHDDH27	DDH27	291291.04	6434348.03	244.04	found	2	DP136249	in
RHDDH4	DDH4	291782.68	6436624.36	257.16	found	101	DP1124883	in
ROS01		291188.98	6437829.99	230.27	found	2	DP625029	in
SPAR2		289994.50	6433497.99	217.38	found	4	DP21335	in
SPAR3		291439.68	6433548.47	220.61	found	2	DP136249	in
SPAR4	GW024561, GW061636	290210.33	6433732.92	215.17	found	4	DP21335	in
SPAR5	GW032890	289875.92	6433546.68	217.14	found	4	DP21335	in
WAT02		288162.37	6435240.01	261.01	found	11	DP830934	in
WILCROW01		290912.93	6438672.69	243.86	found	16	DP750931	in
WYL1	GW013009	291169.47	6438494.78	243.83	found	101	DP750951	in
YOU1		288149.59	6434786.27	250.42	found	32	DP748710	in

Bore ID	Alt. ID	Easting	Northing	Elevation	Comment	Lot	Plan	PAA*)
GROXD4		287470.80	6429132.22	218.20	destroyed	4	DP556410	out
GW023103	TUR3	290850.93	6438997.39	247.05	destroyed	28	DP750931	in
GW200256		288720.21	6436578.93	310.98	destroyed	16	DP830934	in
WH02		290832.14	6438493.76	238.28	destroyed	15	DP750931	in
CRK5		286871.16	6429851.63		not found	16	DP731123	out
GW012971		295433.61	6440527.66		not found	177	DP750951	out
GW012972		295041.83	6440458.13		not found	177	DP750951	out
GW013113		294164.09	6439793.29		not found	178	DP750951	in
GW023065		286737.76	6430241.37		not found	324	DP829973	in
GW053572		291175.82	6438530.47		not found	101	DP750951	in
GW080733		294129.07	6439784.32		not found	178	DP750951	in
ROS8		292584.79	6441895.36		not found	1	DP416437	in

Note: **) Column indicates bores within the PAA (in) and bores outside of the PAA (out)*



LEGEND

Bore census

- Found - destroyed
- Not found
- Found
- Private production bore

Census property visited

- Mine property
- Private property

- Project Assessment Area
- North Pit
- South Pit
- Road
- Main streams
- Minor ephemeral streams
- Alluvium

West Muswellbrook (G1676)

Bore census

DATE 9/10/2014

FIGURE No: **3.15**

3.11 Highly productive groundwater

Mapping of highly productive and less productive groundwater systems is available as GIS database from NOW (NOW 2013b). Figure 1.3 shows the available mapping of the aquifers for the PAA and wider Project Area. There is currently no meta-data available for this supplied mapping, although comparison to published geological maps suggests that more detailed Quaternary alluvium mapping has been used in productivity mapping than is available in the public domain. The defined area of alluvium for Sandy Creek north and south does appear to represent the local quaternary environment better than the published geology images (Hunter Coalfield Regional 1:100,000 Geology Map).

Figure 3.12 shows average groundwater EC for mapped highly productive alluvium and surface water records overlaid on the aquifer productivity mapping. The average alluvial groundwater EC records for Sandy Creek North, Sandy Creek and Coal Creek show EC levels greater than the 1,500 mg/L (≈ 1,900 µS/cm) guidelines limit within the AIP. Based on EC data alone the alluvial systems within the PAA should be reclassified as less productive groundwater sources. Sandy Creek South surface water within the PAA is partially saline with average EC of 6,575 µS/cm.

The Hawkesbury Sandstone, located west of the PAA, and the main alluvial sequences associated with Dart Brook and the Hunter River, to the east, have been mapped as being highly productive groundwater sources. Sandy Creek North and Sandy Creek South are located east and south of the PAA respectively are also considered highly productive groundwater sources. The highly productive alluvium of Sandy Creek North and Sandy Creek South drain to the alluvium of Dart Brook and the Hunter River respectively.

The AIP also defines highly productive aquifers as having a yield of greater than 5 L/s. No yield information is available for bores located in the mapped alluvium within the PAA. Based on the bore census a qualitative assessment suggests the long term yield from most bores in alluvium within the PAA is less than 5 L/s. This is supported by the observation that a large proportion of bores appear to be shallow large diameter wells where low aquifer yield is overcome and water supply is reached over short supply periods through well storage. Bore/well step drawdown pumping tests would be required to confirm this low formation yield hypothesis.

Available baseline data (based on both groundwater salinity and aquifer yield) indicates that the mapped highly productive groundwater zones within the PAA do not meet the AIP guideline limits for highly productive groundwater and should be reclassified as less productive groundwater sources. For this study, the existing mapping and classification has been used. However, it is recommended that further field pumping tests be carried out to define the alluvial aquifer yield within the PAA to confirm both yield and EC do not meet the AIP guideline limits.

4. Numerical modelling

A numerical groundwater flow model was developed to assess the influence of the Project on the groundwater regime. The model simulated the behaviour of the entire groundwater system within the Study Area prior to and during proposed mining. The pre-mining period was used to calibrate the model using measured rainfall, streamflow and groundwater levels. Once calibrated the model simulated the influence of mining on the mapped highly productive groundwater regime including the:

- volume of groundwater seepage from the highly productive aquifers to pits;
- drawdown both within and outside the PAA in:
    - unconfined and unconsolidated highly productive alluvium;
    - highly productive Triassic sandstones to the west; and
    - private landholder bores within highly productive alluvium;
- changes to baseflow of Sandy Creek North, Sandy Creek South, Spring Creek and Hunter River; and
- changes to recharge of the highly productive alluvial water system.

All predicted water-take and water level drawdowns were calculated by comparing two model scenarios, firstly one with the proposed 30 years of mining in place and one without. The impact and changes due to mining were then derived by comparing the differences in water levels and water budgets between the two runs.

Appendix C details the methodology used to build (Appendix C, Section 1.2) and calibrate (Appendix C, Section 1.3) the numerical model and presents detailed description of results of the modelling (Appendix C, Section 1.4).

In general, the model predictions of heads and drawdowns are better for highly productive alluvium than the Permian layers and Triassic sandstone. The predictions of piezometric head within Permian coal seams are more reliable towards the subcrop than down dip, due to the paucity of data in the area west towards the escarpment. Heads in the Triassic sandstone have been qualitatively calibrated using available bore construction information, not actual head data. Any groundwater level measurements from the highly productive Triassic sandstone would improve the understanding of the interconnectivity within the hydraulic system and contribute towards the improvement of the model predictions. Further improvement of the model predictions can be achieved by incorporation of structural elements (faulting, folds) and intrusives (dykes) into the model, however their role within the groundwater flow system (conduits vs. barriers) needs to be better understood.

The reliability of inflow predictions could be improved by gauging the surface streams, which would provide more solid baseflow calibration targets, and by undertaking pumping tests in selected bores in highly productive alluvium. Recharge and discharge through the stream beds would also be improved by field measurement of vertical hydraulic conductivity of the stream beds.

4.1 Cumulative impacts

Section 2.6 discusses the existing approved mining activities surrounding the PAA. There are no existing (or former) mines in the local vicinity of the PAA extracting from the proposed Project targets seams. To the east, Dartbrook, Bengalla and Mt. Pleasant Mines all extracted (or are approved to extract) coal seams stratigraphically lower (Warkworth Seam and below) than the proposed Project targets seams (Blakefield and above). There are numerous interburden layers that will retard depressurisation and prevent cumulative hydraulic impacts between the operations. The Mangoola Coal Mine is hydraulically separated from the Study Area by the Mt. Ogilvie Fault.

Published EIS documentation (groundwater technical studies) for the adjoining mines - Bengalla (AGE 2013), Mangoola (MER 2006) and Dartbrook (MER 2000) - were consulted to investigate if predicted drawdowns would extend as far as the coal seams to be mined as part of the Project. All studies show that no predicted drawdown would reach the coal seams to be mined in the PAA. Anglo American (2013) also shows that there is recovery of drawdowns surrounding the Dartbrook underground mine.

Based on the available data, it is considered the zone of depressurisation generated by the adjoining mining activities will not merge with localised drawdown from the Project. Based on the above conclusions the adjoining mining activities were not included in the numerical model. However, it is recommended that any modelling for a future DA stage include the surrounding mines to confirm the conclusion that cumulative impacts will not be significant.

5. Gateway Process Guideline requirements

The transient numerical groundwater modelling, baseline data and conceptualisation were used to address the requirements of the AIP and Gateway Process Guidelines (outlined in Table 5-1).

Table 5-1 Guideline: Highly Productive Aquifers criteria

Criteria	Section addressing this point
Estimates of all quantities of water that are likely to be taken from any water source on an annual basis during and following cessation of the activity.	See Section 5.1
A strategy for obtaining appropriate water licence/s for maximum predicted annual take.	See Section 5.2
Establishment of baseline groundwater conditions including groundwater depth, quality and flow based on sampling of all existing bores in the area, any existing monitoring bores and any new monitoring bores that may be required under an authorisation issued under the Mining Act 1992 or the Petroleum (Onshore) Act 1991.	See Sections 2 to Section 3.11 and Section 5.3
A strategy for complying with any water access rules applying to relevant categories of water access licences, as specified in relevant water sharing plans.	See Section 5.2
Estimates of potential water level, quality and pressure drawdown impacts on nearby water users who are exercising their right to take water under a basic landholder right.	See Section 5.4
Estimates of potential water level, quality and pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources.	See Section 5.1 and Section 5.4
Estimates of potential water level, quality and pressure drawdown impacts on groundwater dependent ecosystems.	See Section 5.5
Estimates of potential for increased saline and contaminated water inflows to aquifers and highly connected river systems.	See Section 5.6
Estimates of the potential to cause or enhance hydraulic connection between aquifers.	See Section 5.7
Estimates of the potential for river bank instability, or high wall instability or failure to occur.	See Section 5.8

Each sub-section below summarises results from the baseline assessment and predictive modelling to address the requirements of the Gateway Process Guidelines. In addition, the requirements of the NSW AIP for minimal impact considerations for aquifer interference activities are also addressed (NOW 2012).

Table 5-2 summarises the AIP considerations.

Table 5-2 Minimal impact considerations for aquifer interference activities – Highly productive aquifers

Source	Water Table	Section addressing this point	Comment
1. Alluvial Water Sources These considerations apply to all highly productive alluvial groundwater sources	1. Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan"(2) variations, 40m from any: (a) high priority groundwater dependent ecosystem; or	See Section 5.5	No GDEs present within drawdown in highly productive aquifers.
	(b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan; or		
	A maximum of a 2m decline cumulatively at any water supply work.	See Section 5.4	Drawdowns greater 2m at water supply works in highly productive aquifers calculated.
	2. If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: (a) high priority groundwater dependent ecosystem; Or	See Section 5.5	No GDEs present within drawdown in highly productive aquifers.
	(b) high priority culturally significant site;		
	listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than 2m decline cumulatively at any water supply work then make good provisions should apply.	See Section 5.4	Drawdowns greater 2m at water supply works in highly productive aquifers calculated.
1. Alluvial Water Sources These considerations apply to all highly productive alluvial groundwater sources	1. A cumulative pressure head decline of not more than 40% of the "post-water sharing plan"(2) pressure head above the base of the water source to a maximum of a 2m decline, at any water supply work.	See Section 5.4	Pressure head decline calculated for highly productive aquifers and water supply works.
	2. If the predicted pressure head decline is greater than requirement 1. above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	See Section 5.4	Pressure head decline calculated for highly productive aquifers and water supply works.
1. Alluvial Water Sources These considerations apply to all highly productive alluvial groundwater sources	1. (a) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity; and	See Section 5.6	
	(b) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. Redesign of a highly connected surface water source that is defined as a "reliable water supply" is not an appropriate mitigation measure to meet considerations 1.(a) and 1.(b) above.	See Section 5.6	

Source	Water Table	Section addressing this point	Comment
	(c) No mining activity to be below the natural ground surface within 200m laterally from the top of high bank or 100m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a "reliable water supply".		
	(d) Not more than 10% cumulatively of the three dimensional extent of the alluvial material in this water source to be excavated by mining activities beyond 200m laterally from the top of high bank and 100m vertically beneath a highly connected surface water source that is defined as a "reliable water supply".		
	2. If condition 1.(a) is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.		
	If condition 1.(c) or (d) are not met, then appropriate studies are required to demonstrate to the Minister's satisfaction that: - there will be negligible river bank or high wall instability risks; - during the activity's operation and post-closure, levee banks.		

5.1 Estimates of water take

The Gateway Process Guidelines requires "*estimates of all quantities of water that are likely to be taken from any water source on an annual basis during and following cessation of the activity.*"

The model predicts the groundwater seepage rate to the proposed mine peaks at 188 ML/year with a long term average for the life of mining from the Permian of 97 ML/year. This water-take being sourced from both the less productive Permian coal seam strata and leakage from highly productive alluvium.

The predictive model indicates that once mining commences, the Permian strata depressurises and within the zone of influence, flow from the Permian to the highly productive alluvium of Sandy Creek North and Sandy Creek South reduces. This is due to changes in pressure gradients between the alluvium and Permian that reduces upward flow, and potentially results in downward flow adjacent to the mining areas. The loss of water from the alluvial system depends on the proximity of the mine to the creeks. Obviously, when mining is more distant, the losses are lower than when mining moves in closer proximity

Table 5-3 shows loss of seepage of Permian groundwater into each highly productive alluvial system due to depressurisation in the Study Area. It should be noted only a small proportion of Spring Creek is mapped as highly productive.

Table 5-3 Loss of seepage into highly productive alluvium

Alluvial Zone	Max (ML/year)
Sandy Creek North	66.1
Coal Creek	158.8
Sandy Creek South	12.8
Spring Creek	59.6
Cumulative *)	224.9

Note: **) that all max values reported for each individual alluvial system do not occur at the same time, hence the maximum for all does not equal the sum of individual maximum values.*

The maximum results shown in Table 5-3 are conservative estimates and are the maximum annual value at any year during mining. A peak annual total of approximately 225 ML/year is calculated to be taken from highly productive groundwater (alluvium) during mining. As can be seen in the table, the mining of a section of Coal Creek causes the largest predicted water-take during mining.
There was no calculated loss of the highly productive groundwater within the Triassic sandstone escarpment to the west of the site.

The Project proposes to backfill all but a single final void in the South Pit. Groundwater levels are expected to recover within the north and south pit areas and a pit lake will form in the void left in the south pit. The rate of water level recovery in the south pit area is expected to be to a lesser extent than for the north pit.

As water levels are expected to recover to some extent, from the maximum drawdown during mining, the mean long term water-take from highly productive groundwater will be less than the estimated mean total during mining of approximately 225 ML/year.

Baseflow changes are predicted to be the same or less than the predicted water-take from alluvium.

The initial calculated water take volumes for highly productive groundwater are thought worst case and are based on the current calibrated model and mining planning information.

5.2 Water licensing

The Gateway Process Guidelines require:

- *"a strategy for obtaining appropriate water licence/s for maximum predicted annual take"*
- *"a strategy for complying with any water access rules applying to relevant categories of water access licences, as specified in relevant water sharing plans"*

Calculated water takes from highly productive alluvium groundwater sources within and adjacent to the PAA will require water licences from the Hunter River Alluvial water source (HRAWS). This water source has been fully allocated through the Water Sharing Plan for the Hunter Regulated River Water Source. It is anticipated that the proponent will acquire some proportion of the required water-take through future land acquisition. The proponent will commit to securing any water allocations or licences from existing users to meet the predicted water take, prior to commencement of development.

As well as calculating the water-take from highly productive aquifers as required by the AIP, the predictive model also reported water-take from the less productive Permian groundwater strata (188 ML/year at peak). Water-take from the Permian strata is currently allocated under the Water Act 1912. The proponent currently holds water licences for existing operations and will investigate the potential for a permanent transfer of the volumetric entitlement attached to those licences. The proponent will also assess whether a new licence is needed to account for the predicted water-take from the Permian sequence at the DA stage.

5.3 Baseline conditions

The Gateway Process Guidelines require "*establishment of baseline groundwater conditions including groundwater depth, quality and flow based on sampling of all existing bores in the area, any existing monitoring bores and any new monitoring bores that may be required under an authorisation issued under the Mining Act 1992 or the Petroleum (Onshore) Act 1991.*"

Section 3 describes the baseline groundwater conditions and interconnectivity between groundwater and surface waters.

The alluvium associated with Sandy Creek North, Sandy Creek South and Coal Creek within and adjacent to the PAA is mapped by the NOW as highly productive groundwater source. The Triassic sandstone escarpment to the west of the PAA is also mapped as highly productive. The Permian coal measures are mapped as less productive groundwater bearing strata.

Baseline groundwater conditions were established by visiting the Study Area, conducting a bore census and reviewing geological and hydrogeological data collected by MCC. The bore census focussed on the area potentially impacted by the proposed mining activities. Whilst it was not possible to visit all private bores, as land access was not always granted, the census did establish the level of reliance on groundwater resources in the Study Area.

MCC have also been monitoring water levels and quality in a network of monitoring bores at 12 private landholder bores within alluvial aquifers, which provided excellent long term baseline data. At some sites, ten years of baseline data is available. This is well in excess of the two year minimum defined in the AIP. The baseline monitoring also covers periods of both drought, and above average rainfall, which allows the influence of a full climatic cycle on the groundwater regime to be observed. Notwithstanding this, some improvements to the spatial distribution of the monitoring network during the DA stage have been identified and are outlined in Section 8.

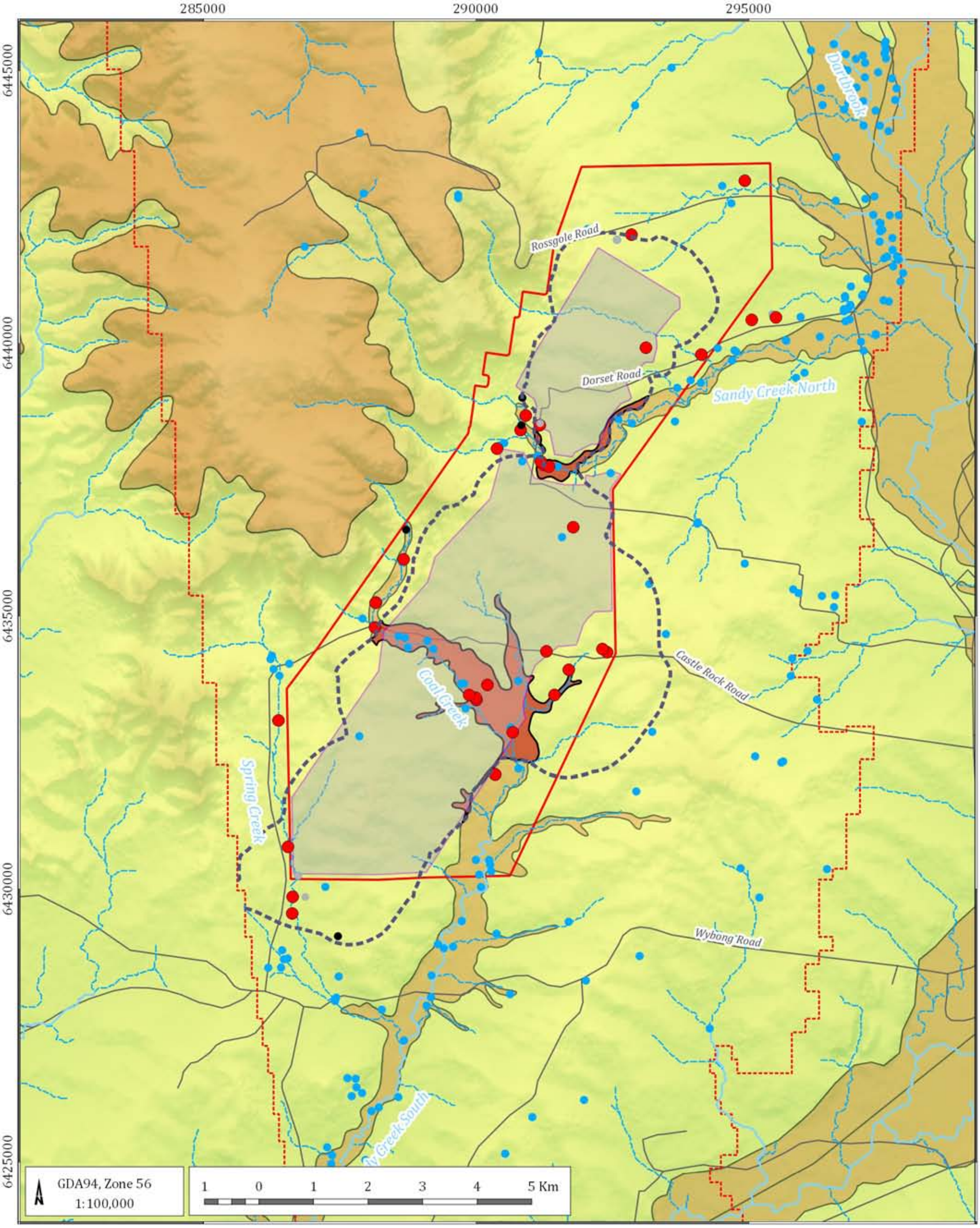
Baseline data does indicate (based on average EC data) that the mapped highly productive alluvium may have salinity levels above the 1,500 mg/L threshold. Conceptualisation indicates that the lower reaches of Sandy Creek North and South alluvium interact with underlying coal seams, resulting in elevated EC readings in both groundwater and surface water in excess of 3,000 to 4,000 µS/cm. For the basis of this report, these aquifers have been considered as highly productive; however, as further field data on groundwater salinity and aquifer yield is collected, the aquifers may be reclassified as less productive. In contrast, the downstream alluvium associated with Dart Brook and the Hunter River are highly productive aquifers with low salinity and high yield from basal gravel sequences within the alluvium.

5.4 Water level drawdowns on nearby users

The Gateway Process Guidelines require "*estimates of potential water level, quality and pressure drawdown impacts on nearby water users who are exercising their right to take water under a basic landholder right.*"

The bore census identified that the majority of the private bore owners within the PAA take groundwater from either the shallow alluvium or regolith, which is the shallowest and most economic water to access. Figure 5.1 shows the limit of the modelling predicted 2 m drawdown in the unconfined, highly productive alluvium, and adjoining less productive shallow regolith / Permian strata. The figure shows the maximum drawdown extent for the entire mine period, at any individual mine year the effect will be smaller than this maximum extent. There are two areas of highly productive alluvium that show a decline in water level greater than 2 m (shown in red polygons in Figure 5.1).

Table 5-4 shows 19 bores within highly productive alluvium that are predicted to have drawdowns greater than 2.0 m. 12 of these bores are situated along Coal Creek and are proposed to be removed by mining. The maximum drawdown at the seven remaining bores is predicated to between 2.0 m to 5.9 m.



LEGEND

Groundwater productivity
- Highly
- Less
- Highly productive alluvium within 2m or greater drawdown
- 2m drawdown extent - alluvium/regolith
- Project Assessment Area
- Project Area
- Main streams
- Minor ephemeral streams
- Road

Bore census
- Found - destroyed
- Not found
- Found
- Private production bore
- South Pit
- North Pit

West Muswellbrook (G1676)

Groundwater system maximum drawdown and nearby bore users

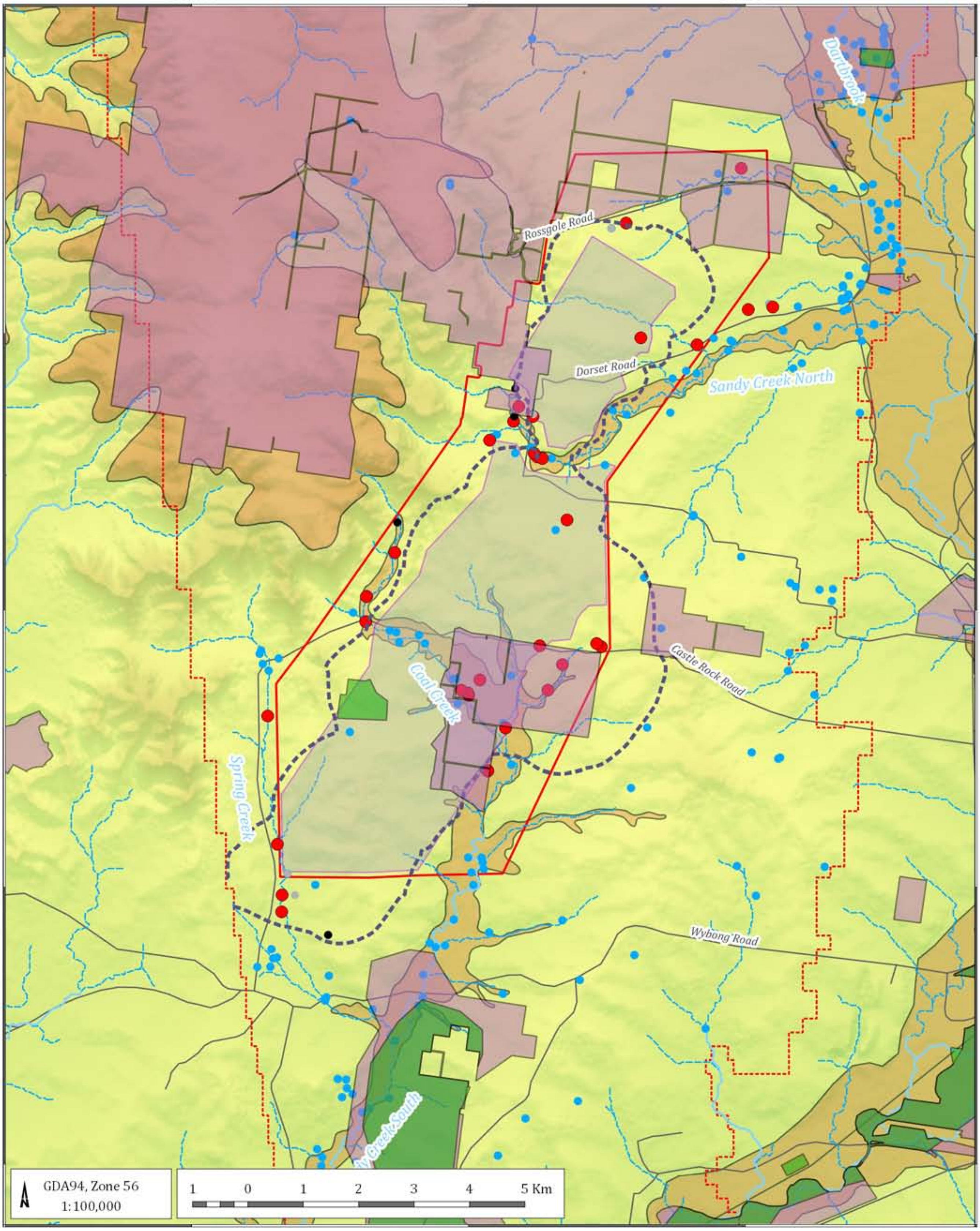
DATE 9/10/2014

FIGURE No: **5.1**

Table 5-4 Predicted maximum drawdown in bore within highly productive alluvium

Bore	Easting	Northing	Model layer	Area	Max drawdown (m)	Max drawdown time	Will be mined
GW016279	288584.1	6434625.0	1	Coal Ck	13.3	17 years, 5 months	yes
GW022292	289217.7	6434391.7	1	Coal Ck	16.7	18 years, 11 months	yes
GW024558	289109.7	6434543.5	2	Coal Ck	17.7	17 years, 7 months	yes
GW025631	288674.7	6436034.7	2	Coal Ck	1.6	16 years, 1 month	no
GW032889	290775.4	6433807.7	1	Coal Ck	11	17 years, 7 months	yes
GW038412	291506.7	6437736.1	2	Sandy Crk North	2.6	9 years, 1 month	no
GW052617	289781.1	6433756.3	1	Coal Ck	14.1	19 years, 11 months	yes
GW078457X	289728.7	6433755.2	1	Coal Ck	14.1	19 years, 11 months	yes
GW200257	290635.5	6432950.7	1	Coal Ck	9.7	20 years, 12 months	yes
PIT1	291243.6	6437765.2	1	Sandy Ck North	1.7	8 years, 12 months	no
PIT2	291337.6	6437735.4	1	Sandy Ck North	2.0	8 years, 12 months	no
ROS01	291189.0	6437830.0	1	Sandy Ck North	1.8	8 years, 12 months	no
SPAR1	291428.6	6433506.5	2	Coal Ck	5.9	21 years, 3 months	no
SPAR2	289994.5	6433498.0	1	Coal Ck	18.6	19 years, 11 months	yes
SPAR3	291439.7	6433548.5	2	Coal Ck	5.8	21 years, 4 months	no
SPAR4	290210.3	6433732.9	2	Coal Ck	15.5	19 years, 1 month	yes
SPAR5	289875.9	6433546.7	1	Coal Ck	16.0	19 years, 11 months	yes
WEK2	288753.6	6434415.6	1	Coal Ck	16.9	18 years, 7 months	yes
WEK3	288701.4	6434592.8	1	Coal Ck	18.6	17 years, 8 months	yes

Figure 5.2 additionally shows the predicted 2 m drawdown against mapped CIC layers for viticulture and equine agriculture. There is one area outside the mine footprint and within the modelled 2 m drawdown extent for highly productive alluvium aquifers. This area is east of the confluence of Coal Creek and Sandy Creek South. The area is currently mapped as equine CIC.



LEGEND

- 2m drawdown extent - alluvium/regolith

Bore census

- Found - destroyed
- Not found
- Found
- Private production bore
- South Pit
- North Pit

Groundwater productivity

- Highly
- Less

- SAL Equine
- SAL Viticulture
- Project Assessment Area
- Project Area
- Main streams
- Minor ephemeral streams
- Road

West Muswellbrook (G1676)

Groundwater system maximum drawdown, nearby bore users and CICs

DATE 9/10/2014

FIGURE No: 5.2

Appendix C provides more detail on the private bores predicted to be impacted including:

- Table C18 presents the maximum decline in groundwater levels in bores predicted to be impacted;
- Figures C25 to C29 show drawdown contours; and
- Figure C30 provides predicted groundwater levels hydrographs for bores with drawdown predicted to exceed 2 m that will be not mined out.

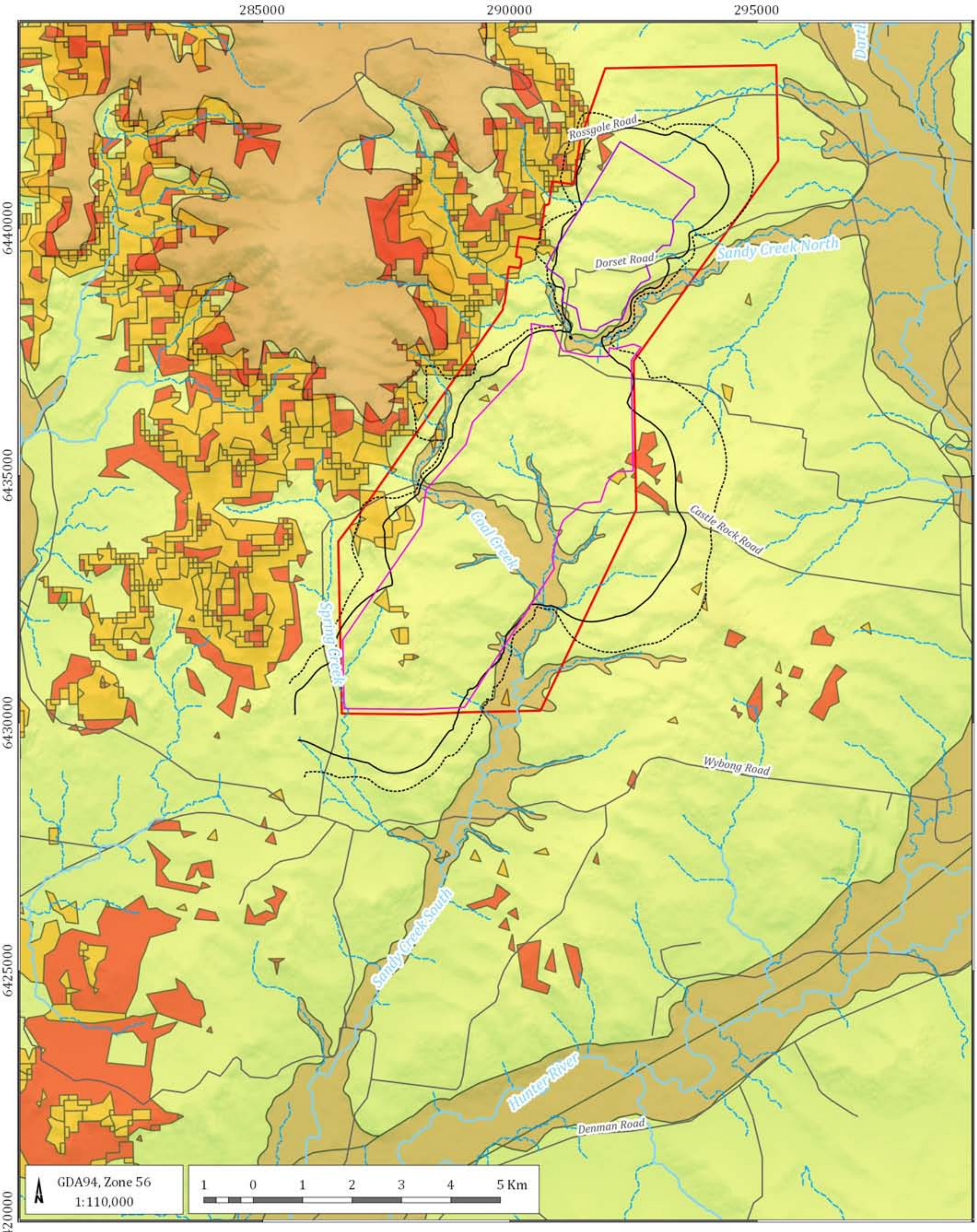
5.5 Groundwater dependent ecosystems (GDEs)

The Gateway Process Guidelines require "*estimates of potential water level, quality and pressure drawdown impacts on groundwater dependent ecosystems."*

Parsons Brinckerhoff (2013) published a biodiversity survey of the PAA. Although the report does not specifically consider GDEs it does consider species, populations and communities of conservation concern likely to occur within the PAA. Matters of National Environmental Significance, relating to biodiversity were discussed in relation to the EPBC Act. The study identified zones of mostly native vegetation such as ironbark, stringy bark, red gum, white box and rough-barked apple-forest oak.

The Atlas of Groundwater Dependant Ecosystems (BOM, 2012) identifies zones of high, moderate and low potential for groundwater interaction. Most of the identified zones are located at the foot-slopes of the Triassic sandstone escarpment where colluvium sediments are expected to have accumulated. Figure 5.3 shows the BOM mapped GDEs surrounding the PAA and this figure also shows predicted maximum extent of 1m and 2m drawdown from the water table aquifer.

The available information suggests limited or no GDEs and no wetlands are present within the 1m drawdown extent of highly productive groundwater. During detailed design it is proposed to conduct targeted GDE assessment to confirm the initial assessment.



LEGEND

Groundwater productivity*

- Highly
- Less
- 1 - High potential for GW interaction
- 2 - Moderate potential for GW interaction
- 3 - Low potential for GW interaction
- 1m drawdown extent - alluvium/regolith
- 2m drawdown extent - alluvium/regolith
- Project Assessment Area
- North Pit
- South Pit
- Main streams
- Minor ephemeral streams
- Road

West Muswellbrook (G1676)

Potential GDEs within the zone of depressurisation

DATE 8/10/2014

FIGURE No: **5.3**

Ref: BOM (2012): GDE Atlas (V 1.0), Commonwealth of Australia, Bureau of Meteorology. On-line source: http://www.bom.gov.au/water/gde/, email: groundwater@bom.gov.au *

5.6 Salinity changes

The Gateway Process Guidelines require "*estimates of potential for increased saline and contaminated water inflows to aquifers and highly connected river systems.*"

Sections of Sandy Creek North, Coal Creek, Sandy Creek South and Spring Creek are potentially 'highly connected' with underlying groundwater. Drawdown induced during mining will reduce the rates of discharge from the Permian coal measures to alluvium and in turn to local streams. The available baseline data indicates groundwater in the Permian is the most saline in the system. Any reduction in groundwater seepage to the alluvium during mining would therefore not increase stream salinity.

Once the mining operations cease, dewatering of the open pit will not be required and a slow recovery in groundwater levels in the area is expected over time. A void will remain in the southern area of the southern pit. Groundwater and rainfall inflows will slowly fill the void forming a lake and eventually reaching an average stable water level which will be influenced by the balance of inflows from groundwater and surface runoff and losses from evaporation. Although not specifically modelled, it is common in the Upper Hunter for pit lakes to form below the regional water table, forming sinks in the local groundwater environment. In such a case, there would be a low likelihood of transfer of saline water from any pit lake to the surrounding environment.

At the cessation of mining, there will be a relatively high groundwater gradient between the open void and the coal seam aquifers which will result in relatively rapid inflows; however, as a lake begins to form in the void, the gradient is reduced and the rate of groundwater inflow will slow. Eventually, a state of 'quasi' equilibrium will occur where inputs are balanced by outputs. Recovery of groundwater levels in the surrounding alluvial and coal seam systems will be dependent on rainfall. Years of below average rainfall will extend the recovery period and wet years will reduce stabilisation time. Groundwater levels will not fully recover to pre-mining levels, if average evaporation losses exceed rainfall and runoff inflow, which will result in a permanent cone of depression in the pit area. Post closure monitoring will assist in assessing the permanence of a cone of depression and if mitigation measures are needed.

The north pit is proposed to be completely backfilled and may recover close to, or even above the original groundwater level pre-mining. Further post closure modelling will be completed as part of the detailed design phase of the DA and final landforms design will include measures to reduce groundwater seepage from previously mined areas, if this is considered problematic.

In addition to groundwater flow modelling, coal seam and interburden rock samples are currently undergoing long-term kinetic leach tests. Initial water extract results indicate that spoil material will be fairly benign from an acid generating point of view and the salinity of the leachate will be similar to the levels within the current groundwater environment (RGS 2014).

The potential water quality in the final void has not been assessed; however, concentration of salts in the final void lake by evaporation and continual groundwater inflow is expected to result in a brackish to saline water quality developing over time. The void lake will likely become a permanent discharge zone for groundwater if open water evaporation exceeds rainfall and runoff and is not expected to affect water quality in the surrounding aquifers. The groundwater regime is expected to recover to close to pre-mining conditions. The waste rock piles also have the potential to effect water quality, however as noted previously the acid generating potential of the waste rock is deemed to be very low (RGS 2014).

The average baseline EC downstream of the PAA in Sandy Creek South is brackish, with the average ranging at the three downstream sites between 4293 µS/cm to 6575 µS/cm. There is currently no data available downstream of the PAA for Sandy Creek North as it is ephemeral. But the data for Sandy Creek South does indicate high salt content in the natural drainage suggesting a significant proportion of baseflow is sourced from coal seams.

The available data indicates the baseline groundwaters and surface water across the PAA are not fresh. Early indications are that the spoils are relatively benign in terms of acidity and salinity and therefore with appropriate onsite water management there appears at this early stage a low likelihood of problematic changes in salinity in either highly productive groundwater or interconnected surface water.

5.7 Enhanced hydraulic connections

The Gateway Process Guidelines requires "*estimates of the potential to cause or enhance hydraulic connection between aquifers.*"

Underground mining is not proposed and therefore fracturing creating hydraulic connections between aquifers will not occur.

Mining is proposed to pass through the Coal Creek alluvium, and there is potential this will enhance hydraulic connection between the alluvium and the coal measure post mining. TheDA and detailed design phases will need to investigate the need for engineering solutions if the hydraulic interconnection is shown to be problematic.

The mine plan has been designed to remain 150 m from the edge of the other neighbouring alluvium associated with Sandy Creek South, Sandy Creek North and Spring Creek to ensure that interconnection to the alluvial system is minimised as far as possible.

5.8 River bank instability

The Gateway Process Guidelines require "*estimates of the potential for river bank instability, or high wall instability or failure to occur.*"

As noted above, the mine plan has been designed to remain 150 m from the edge of the alluvium of Sandy Creek South, Sandy Creek North and Spring Creek so no impacts on river bank stability are anticipated. There is the potential river bank instability where mining progresses through sections of Coal Creek alluvium. Engineering solutions will need to be investigated during the DA and detailed design project phases to address this.

5.9 Minimal impacts considerations specified in the AIP

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

The modelling indicates potential for drawdown in a number of private bores to exceed the Level 1 minimal impact considerations. Further studies will be undertaken during the DA phase to improve the accuracy of the model predictions. If predictions are confirmed by future monitoring data, the proponent will consider purchasing the land or entering into a 'make good agreement' with landowners.

6. Conclusions

The proponent recognised from an early stage the importance of obtaining baseline data and characterising the groundwater regime in the PAA and surrounds. The proponent has integrated the collection of hydrogeological data into exploration drilling campaigns and now have over ten years of available data.

Data collected as part of routine quarterly monitoring, commenced in 2003, has been used in this assessment. This routine monitoring consists of the measurement and recording of field water quality parameters at 18 surface water monitoring locations; and groundwater levels and field water quality parameters at 30 groundwater monitoring locations. Most of the monitored sites are located within the PAA, all of them are within the Study Area.

In total, 58 suites of water quality analyses for major ions, metals and nutrients are available for the Study Area over the period between 2011 and 2013 (28 surface water and 30 groundwater samples). The oldest bores have a data set that spans more than ten years, with the majority of the bores having between five and seven years of data. This quantity of data satisfies the requirement of the AIP to have a minimum two years of baseline data.

The installation of shallow alluvial bores that monitor alluvial groundwater level has allowed analysis of groundwater-surface water interaction in the ephemeral and perennial stream reaches under different climate conditions. The available data record of 2004-2014 spans periods of drought and above average rainfall which has allowed the response of the groundwater system to these extremes to be observed.

A selection of local landholder water bores have been monitored within the Study Area since a pre-feasibility study was conducted in 2008. This dataset has been augmented using the 2013 version of the PINNEENA database and a field bore census of key properties. This evolving knowledge base of landholder bores combined with ongoing water sampling provides a good understanding of the reliance of the region on groundwater resources. Groundwater use within the catchment is dominated by shallow bores, predominantly installed within the alluvium for stock supply. There are lesser amounts of bores used for domestic supply and limited use for irrigation.

Groundwater quality in both alluvium and the Permian coal measures is slightly saline to brackish. The alluvial systems can be largely grouped into two areas, firstly west of the Study Area where the alluvial groundwater level appears elevated above the Permian (downward gradient) and secondly downstream in the drainage systems where the alluvium and Permian groundwater levels are similar. This promotes less saline groundwater and surface waters in the headwater reaches of the drainage systems with increases in salinity downstream in all systems. Despite this fact, waters are generally brackish to saline throughout the system and only a small number of sites or individual samples are below 1,500 mg/L value (the limit for highly productive aquifers in the AIP).

Mapping sourced from NOW shows that the alluvial systems of Sandy Creek North, Sandy Creek South and Spring Creek are considered highly productive groundwater zones under the AIP. Although available information and conceptualisation (based on both groundwater EC and aquifer yield) suggests that the mapped highly productive groundwater sources within the PAA would be more appropriately classified as less productive. For the purposes of this assessment the current mapping and classification of highly productive groundwater zones has been used. It is recommended that further field pumping tests be carried out to define the alluvial aquifer yield within the PAA and ascertain that both yield and EC are outside the AIP guidelines limits.

The Triassic Sandstones to west and alluvium associated with Dartbrook and the Hunter River are also classed as highly productive.

The data collected from the field investigation allowed the development of a conceptual model and simple groundwater model to assess the impact of the proposed mining on the highly productive groundwater sources. The predictive modelling indicated that the mining within the Study Areahas the potential to lower groundwater levels within highly productive Sandy Creek North alluvium and the upper reaches of Sandy Creek South alluvium. An area of Coal Creek alluvium will be removed by mining. No drawdown impact is predicted for highly productive Triassic sandstone groundwater to the west and also for highly productive alluvium associated with Dartbrook and the Hunter River.

The model predicts 19 bores within highly productive alluvium will be impacted by drawdown greater than 2 m. Twelve of these bores are situated along Coal Creek and are proposed to be removed by mining. The maximum drawdown at the seven remaining bores is predicted to between 2.0 to 5.9 m.

The groundwater model predicts that during mining, the groundwater-take from highly productive alluvium will peak at 225 ML/yr and 188 ML/yr from less productive Permian water sources. These initial estimates of calculated water-take from alluvium include groundwater lost due to mining of Coal Creek alluvium. Reduction in baseflow to local streams has also been calculated to be less than 225 ML/year, although this volume is accounted for within the calculated water-take from alluvium.

Calculated water takes from highly productive alluvium groundwater sources within and adjacent to the PAA will require water licences from the Hunter River Alluvial water source (HRAWS). This water source has been fully allocated through the Water Sharing Plan for the Hunter Regulated River Water Source. It is anticipated that the proponent will acquire some proportion of the required water-take through future land acquisition. The proponent will commit to securing any water allocations or licences from existing users to meet the predicted water take, prior to commencement of development.

As well as calculating the water-take from highly productive aquifers as required by the AIP, the predictive model also reported water-take from the less productive Permian groundwater strata (188 ML/year at peak). Water-take from the Permian strata is currently allocated under the Water Act 1912. The proponent currently holds water licences for existing operations and will investigate the potential for a permanent transfer of the volumetric entitlement attached to those licences. The proponent will also assess whether a new licence is needed to account for the predicted water-take from the Permian sequence at the DA stage.

The brackish to saline groundwater and surface water, suggests the natural alluvial groundwater/surface water system has a significant connection to the underlying coal seams. Preliminary rock leaching tests show low acid-forming potential and leachate of similar salinity to the natural system. Post mining, a pit lake will form in the final void at the southern extent of the south pit, forming a sink in the local environment. This sink (while inducing a long term post closure take) will also reduce the potential for saline water to move into the wider environment. The current design for the north pit post closure is to completely backfill the pit. The water levels in this final void may reach pre-mining levels, or above post closure. During the detailed design stage of the project integration of refined post closure plans, further geochemistry analysis and refined modelling will be used to mitigate changes in surface water salinity post closure.

In summary, this document addresses the requirements of the Gateway Process Guidelines and AIP.

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7. Recommendations

The study identified that the Project has the potential to reduce yields in bores proximal to mining areas and flows within highly productive alluvial aquifers and connected streams. Further assessment is planned to better understand the groundwater regime, extent of highly productive groundwater sources and improve the predictive capability of the groundwater model.. The subsequent sections outline areas requiring further assessment prior to the submission of a DA.

7.1 Field investigations

Additional groundwater monitoring bores are recommended to in-fill gaps in the current network, which is clustered around the alluvium of Sandy Creek North and Coal Creek, and close to the sub-crop. Currently, no nested bore sites are available to investigate hydraulic gradients and no groundwater level data is available at depth within coal seams in the western side of the project area.

It is also proposed to gather groundwater level and groundwater quality data from selected private landholder bores that are within the highly productive Triassic Sandstone escarpment to the west of the PAA.

Surface water groundwater interaction has already been shown to be an important part of this study. From a groundwater perspective, a consideration should be given to installing dedicated stream flow gauges on major stream reaches.

7.2 Numerical modelling

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

- calibrating the model to transient water level records collected from the current and any newly installed monitoring bores and/or pressure measurements from newly installed VWP installations ;
- representing the measured stage heights in the creek systems in the model;
- updating the geological surfaces with any updated exploration data;
- introducing structural features within the model build and calibration (dykes, coal fired rock, and faults);
- integration of detailed mine plans into the predictive simulation and simulating progressive backfilling of mine areas with higher permeability spoil;
- analysing the uncertainty of the predictions to model parameters;
- increasing the model confidence class from Level 1 to Level 2 as described in the Australian Groundwater Modelling Guidelines (Barnett et al, 2012); and
- having the model peer reviewed.

The model will require further calibration within the bounds of the field data using both manual and automated parameter estimation software (PEST). Field observations from the monitoring bores and stream gauges should be used in the calibration, which will reduce the non-uniqueness of the solution. Transient calibration should utilise the data collected at the site including rainfall, recharge, groundwater levels and stream levels. The sensitivity of the model calibration and predictions should be fully assessed, so that the uncertainty of the predictions are understood.

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