Chapter 17

Groundwater

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17. GROUNDWATER

17.1 Introduction

This chapter identifies the environmental values associated with groundwater, assesses the impacts on groundwater from the project and recommends mitigation measures for impacts. The chapter is based on an Environmental Impacts Assessment Groundwater Aspects technical report prepared by Rob Lait Associates Pty. Ltd. (RLA) (2012) (see **Appendix 18**) and addresses the requirements of the project's Terms of Reference (ToR).

17.2 Legislative Framework and Guidance

The project approvals chapter (**Chapter 3**) details Legislation, Regulations and Policy of relevance to the protection of groundwater values. Information of particular relevance to the groundwater assessment is as follows:

- The Water Resource (Burdekin Basin) Plan of 2007 applies only to surface water. There is currently no legislation or other water resource plan that refers to groundwater in the Belyando-Suttor section of the Burdekin Basin (which contains the project area).
- The groundwater component of this EIS is not considered to be directly relevant to any future Water Resource Plan for the Belyando-Suttor section of the Burdekin River catchment as the following applies for the project area:
  - There is very little groundwater of any significance.
  - The aquifers are in limited hydraulic connectivity and/or have low hydraulic conductivity.
  - The natural groundwater quality is poor.
  - There is no groundwater - surface water interaction.
  - There are no GDE's which can be impacted by mining (see **Chapter 20** for stygofauna assessment).
- The groundwater associated with the project has no relevance to the Great Artesian Basin (GAB) Water Resource Plan as the project area is more than 200 km to the east of the closest section of the GAB.
- The purposes of the Environment Protection (Water) Policy 2009 (EPP (Water)) are to identify environmental values and management goals; state water quality guidelines and water quality objectives to enhance or protect the environmental values; provide a framework for making consistent, equitable and informed decisions; and monitor and report on the condition of Queensland waters.

17.3 Methodology of Assessment

This assessment has sought to identify the groundwater resources for the project area to inform the process of impact assessment and development of mitigation measures if required. The overall assessment methodology is summarized as follows:

- a desk top study of geology maps, public bore records and previous assessments undertaken, including assessment of exploration bore data (from boreholes installed by the proponent)
- preparation of a program of monitoring bores to provide site specific information including hydraulic conductivity testing
- reporting and review of the information obtained from the monitoring program
- determination of the likely impacts of the project on the groundwater resources in the project area
- preparation of a strategy for management and monitoring of impacts on the groundwater resources in the project area.

Underground mining is not being considered as part of the project (detail regarding the removal of underground mining as part of the project is provided in **Chapter 1, Section 1.12**. Accordingly the potential issue of subsidence associated with underground mining is no longer relevant to the project. However a qualitative engineering review was undertaken by the proponent to ascertain if any other project aspects pose potential subsidence risks, including, open cut mining, water infrastructure, MIA, CHPP and linear infrastructure. No subsidence related impacts are expected to arise as a result of the project; therefore, there will be no ground water related impacts associated with subsidence from the project.

17.3.1 Desktop Study

The desktop study was designed to provide information relating to the regional geology, hydrogeology, current groundwater uses (such as the identification of existing water bore extraction licenses, primary industries using the groundwater resource, characterization of the local drinking water supply, existing industrial use of groundwater) and the relationship of groundwater with the local ecosystems. This information was used to determine the value, and likely impacts of the project on the groundwater resource and where applicable, in the development of the mitigation design.

The study comprised a review of publically available information and datasets and existing reporting relevant to the proposed project.

Of particular note, the desktop study included the following key information sources:

- review of the Department of Natural Resources and Mines (DNRM) groundwater database for details regarding privately owned groundwater facilities
- review of existing coal exploration drilling programmes undertaken by the proponent in a 7 km by 4 km area in the southern section of the project area, where the operational activities will be focussed in the first 15 years of the mine life and where the largest pit dewatering programs will occur.

17.3.2 Field Investigations

The proponent has installed a suite of 11 dedicated groundwater bores to characterise the hydrogeology of the project area. The detailed methodologies and results from these investigations are included in **Appendix 18**.

17.4 Environmental Values

The EPP (Water) describes environmental values to be enhanced and protected. These are listed in **Table 17-1** and their relevance to project groundwater is described.

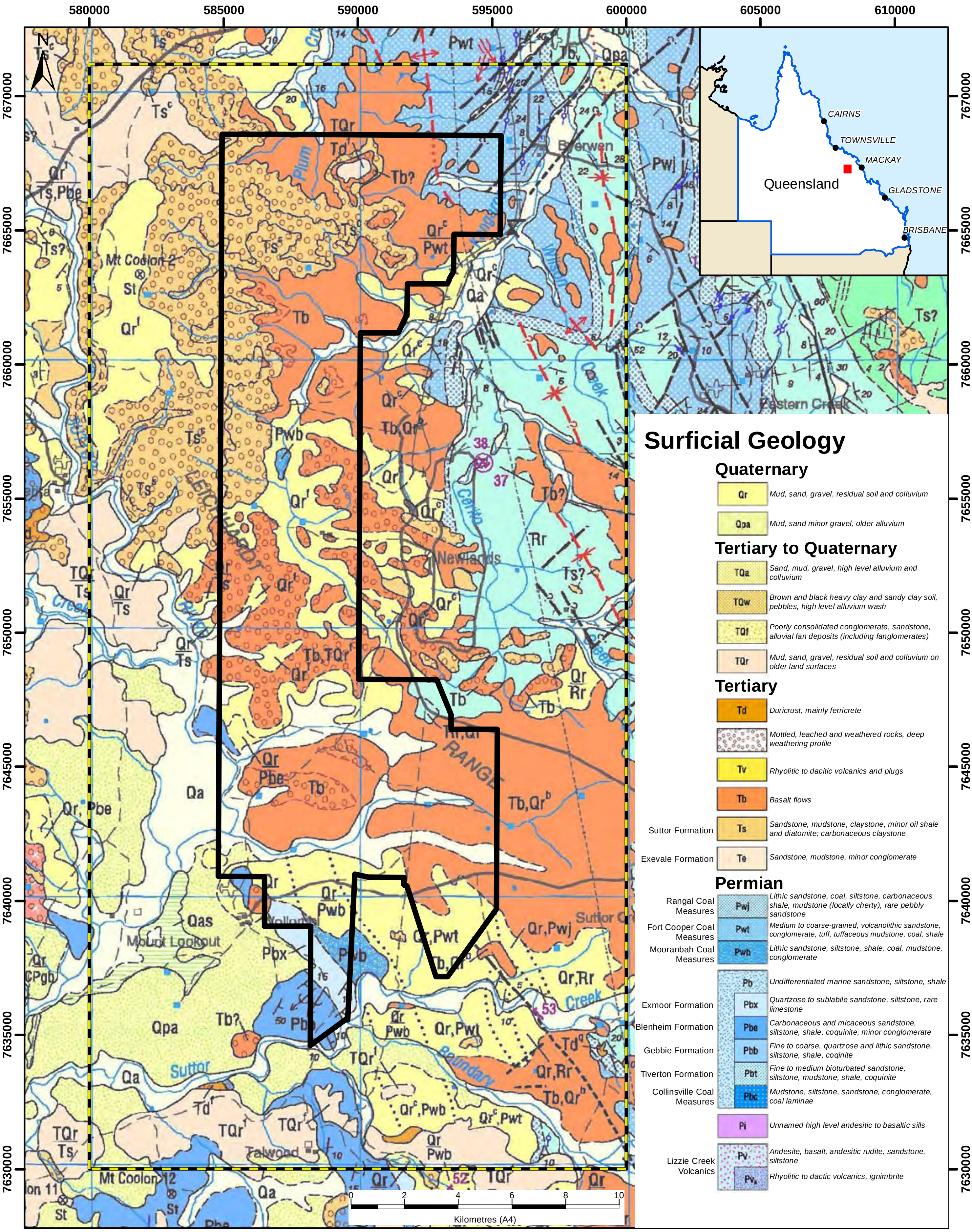
Table 17-1 Environmental Values for Groundwater from the EPP (Water)

EPP (Water) environmental value	Relevance to project groundwater
The biological integrity of an aquatic ecosystem	Aquatic ecosystems that are potentially associated with groundwater include those that support stygofauna and groundwater dependent ecosystems (GDEs). Stygofauna are described in Chapter 20 and GDEs are described in **Section 17.4.4** and **Section 17.5.3**
Suitability of the water for producing aquatic foods for human consumption	The groundwater that may be impacted by the project is not used to produce aquatic foods for human consumption.
Suitability of the water for aquaculture	The groundwater that may be impacted by the project is not suitable for aquaculture.
Suitability of the water for agricultural purposes.	Groundwater use for agriculture is limited to water for livestock, as described in **Section 17.4.3**.
Suitability of the water for recreation or aesthetic purposes	The groundwater that may be impacted by the project is not suitable for recreation or aesthetic purposes.
Suitability of the water as drinking water	The groundwater that may be impacted by the project is not known to be used as a drinking water supply due to its poor quality, as described in **Section 17.4.14**.
Suitability of the water for industrial purposes	The groundwater that may be impacted by the project may be suitable for industrial purposes, however, other than coal mining, there are no known industrial users of groundwater.
The cultural and spiritual values of the water	The groundwater that may be impacted by the project is not kwon to have any cultural and spiritual values.

17.4.1 Geology

The geology of the project study area is provided in detail in **Chapter 13**.

Figure 17-1 shows the surficial geology of the project study area.



Legend

Project Area

Study Area

Surficial Geology

Figure 17-1

Byerwen Coal Project

Date: 29/01/2013

Author: samuel.ferguson

Map Scale: 1:185,000

Revision: R1

Coordinate System: GDA 1994 MGA Zone 55

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Table 17-2 shows the stratigraphy of the project area.

Table 17-2 Stratigraphy of the Project Area

Age	Unit		Lithology	Topography
Quaternary			Silt, sand, clay soil.	Occurs on floodplains of major watercourses and as outwash fan deposits.
Tertiary	Suttor Formation		Sandstone and conglomerate, locally silicified.	Breakaways; table-top mesas.
	Tertiary Basalt		Olivine basalt, fresh and vesicular in places.	Slightly elevated lands.
	Sand below Basalt		Unconsolidated sand and minor gravel; lag deposits from formerly exposed topography.	Not exposed at surface.
Triassic	Moolayember Formation		Micaceous and lithic sandstone and siltstone.	Recessive; flat areas on Clematis Group tablelands.
	Clematis Group		Medium–coarse quartz sandstone & pebble conglomerate.	Tablelands; steep scarps.
	Rewan Group		Green lithic sandstone; red, brown and green mottled mudstone.	Recessive.
Late Permian	Bowen Basin	Blackwater Group Includes: **Rangal Coal Measures** Fort Cooper Coal Measures **Moranbah Coal Measures**	Coal; grey, brown, green sandstone; siltstone; shale; chert; minor conglomerate; fossils.	Generally recessive, subdued.
Early Permian		Back Creek Group Includes: Exmoor Formation	Grey to purple fine sandstone & siltstone; local coarse sandstone; grey carbonaceous shale; cocquinite lenses; fossils.	Generally recessive sandstone ridges.
		Lizzie Creek Volcanics	Andesite; subordinate rhyolite and shale.	Not exposed in project area. Regarded as basement for the hydrogeological regime.

The Permian sedimentary strata around the project area are generally conformable but are largely obscured by younger Tertiary and Quaternary cover.

No large-scale regional faults have been mapped in the project area however these may be obscured by Tertiary and Quaternary cover. Small-scale local faulting is common causing vertical and lateral disruption of the coal seams. Economic coal seams in the area occur in the Rangal, Fort Cooper and Moranbah Coal Measures of the Blackwater Group, which are all of Permian age. The Blackwater Group is comprised of labile sandstone, siltstone, mudstone and thick sequences of interbedded coal and carbonaceous shale.

All of above mentioned Permian geological units contain a proportion of sandstone. Sandstone is traditionally regarded as a groundwater hosting lithology. No distinction between the sandstone contained in the separate Permian units is made for the purposes of this report and they are all similar regardless of the geological unit within which they are incorporated.

The Permian sequence is overlain by green-grey siltstone and lithic sandstone of the Rewan Group of Triassic age. There is only a small area of the Rewan Group on the project area - just to the north of dedicated groundwater monitoring bore BYGW03.

Extensive sediments and sedimentary rocks of Early–Mid Tertiary age include fluvial and lacustrine sediments—notably sandstone, siltstone, mudstone and claystone of the Suttor Formation, up to 60m thick, especially in the northwestern part of the project area, consisting predominantly of indurated mudstone.

Tertiary Basalt flows dominate the central section of the project area in a more or less north - south trending belt that corresponds to the Leichhardt Range. These are shown on **Figure 17-1**. Basalt erupting on the east side of a palaeo-valley may have diverted the palaeo-drainage westwards. Remnant basalt flows locally underlie the Redcliffe Tableland, and also underlie the Leichhardt and Denham Ranges. The lower basalt is relatively fresh, but the upper basalts are deeply weathered and ferruginised. Fresh basalt forms heavy black clay soils; weathered basalt forms dark red loam, commonly with an ironstone ‘gravel’ of ferruginised mud. The basalt flows are constrained by the Suttor River to the west and Cerito Creek to the east in the project area.

Residual sand and fine-grained gravel of Tertiary age are encountered in some boreholes on the project area. These are laterally discontinuous and appear to occur as 'shoestrings' (analogous to present-day braided stream deposits). It is interpreted that they are 'bedsand deposits' that occur in the beds of streams that traversed the landscape prior to the eruption of the basalt. These sediments are not exposed at the surface.

Residual soils including blanketing sands, loams and clays cover much of the area. Preferential induration of old valley floor material now stands up locally as inverted relief. Silcretes up to 10m thick, nodular ferricretes and clay-indurated duricrusts also occur.

Deep weathering is responsible for the strongly mottled and bleached profiles of the basalts and the Suttor Formation.

Of the geological units listed in **Figure 17-1**, the following are hydrogeologically relevant to the project:

- Tertiary Sand beneath Basalt Flows
- Suttor Formation
- Rangal Coal Measures
- Fort Cooper Coal Measures
- Exmoor Formation.

17.4.2 Hydrogeology

17.4.2.1 Groundwater Investigation Bores

As there was little or no groundwater information available from either private groundwater facilities or previous groundwater investigations over the project area, the proponent installed a suite of 11 dedicated groundwater bores to characterise the hydrogeology of the project area, the locations of which are shown in **Figure 17-2**. These 11 bores also comprise the dedicated groundwater monitoring bore suite for the project (see **Appendix 18**).

Table 17-3 shows details of total borehole depth, standing water levels (SWL), airlift yield (ALY), field electrical conductivity and hydrostratigraphy details from the bores. Airlift Yields of >5 L/s are generally considered to be significant and in **Table 17-3** are noted in bold

Table 17-3 Standing Water Levels, Airlift Yield and Field Water Quality in Byerwen Groundwater Investigation Bore Suite

Bore_ID	*Total depth (TD) (m)*	First water intercept (m)	Perforated Interval (m from - m to)	Standing water level (m btoc)*	Airlift Yield (L/s)	Electrical Conductivity (µS/cm)	Hydrostratigraphic Unit
BYGW01	59.5	59.0	47.5-59.5	11.24	0.8	1,870	Rangal Coal Measures
BYGW02	59.5	46.0	47.5-53.5	33.77	0.4	11,050	Fort Cooper Coal Measures
BYGW03	67.0	56.0	56-62	36.58	0.8	2,720	Fort Cooper Coal Measures
BYGW04	119.0	66.0	95-107	78.53	0.1	8,410	Fort Cooper Coal Measures
BYGW05	105.0		99-105; 81-93	94.70	0.0	No water intersected	Exmoor Formation
BYGW06	120.0	45.0	103-115	55.89	0.1	7,580	Rangal Coal Measures
BYGW07A	68.5	26.0	65-69	21.18	**10.0**	2,020	Tertiary Sand below Basalt
BYGW07B	52.0	27.0	46-52	22.86	0.3	4,400	Basalt
BYGW08	66.0	59.0	56.5-65.5	43.37	0.1	20,200	Basalt
BYGW09	97.0	88.0	91-97	71.51	4.0	1,560	Moranbah Coal Measures
BYGW10	52.0	35.0	40-52	43.02	0.1	5,970	Rangal Coal Measures

Note: * = metres below top of casing

The geological and construction logs for the dedicated groundwater monitoring bores are presented in **Appendix 18**.

A number of significant preliminary conclusions can be drawn from the data in **Table 17-3**:

- The depth at which groundwater was first encountered in the basalt and the Tertiary sand below the basalt, is relatively shallow.
- The ALY supplies from the various coal measures intersected are so low as to be almost insignificant.
- The SWL in all of the groundwater monitoring bores is higher than the depth at which the groundwater was intersected during drilling of the well, indicating that the hydrostratigraphic units in which wells are screened comprise confined aquifers.
- Unconsolidated Quaternary sediments consisting predominantly of sand and gravel are associated with the Suttor River, to the west and southwest, and Kangaroo Creek to the north and northeast. This geological unit is also colloquially referred to as 'alluvium' and this chapter uses both terms for discussion purposes. These sediments appear to be only a thin veneer (nominally <2 m thick), if present at all. Two of the dedicated groundwater monitoring bores (BYGW04 and BYGW08) were located to assess the thickness of the alluvium, as some alluvium was shown to cross the southern part of the project area; however, neither BYGW04 nor BYGW08 intersected any alluvium.

17.4.3 Location, Type and Status of Private Groundwater Facilities

A search of records held in the DNRM groundwater database details privately owned groundwater facilities in the project study area. The search identified eight privately owned existing groundwater facilities as well as nine abandoned and destroyed bores within the project study area, as shown on **Figure 17-2.**

Bores RN 60458, RN 60459, RN 100092 and RN 100274 were originally mining exploration holes that are now shown as 'existing' in the groundwater database. There is no record of pumping equipment for these four bores.

Table 17-4 summarises the data available for the existing bores.

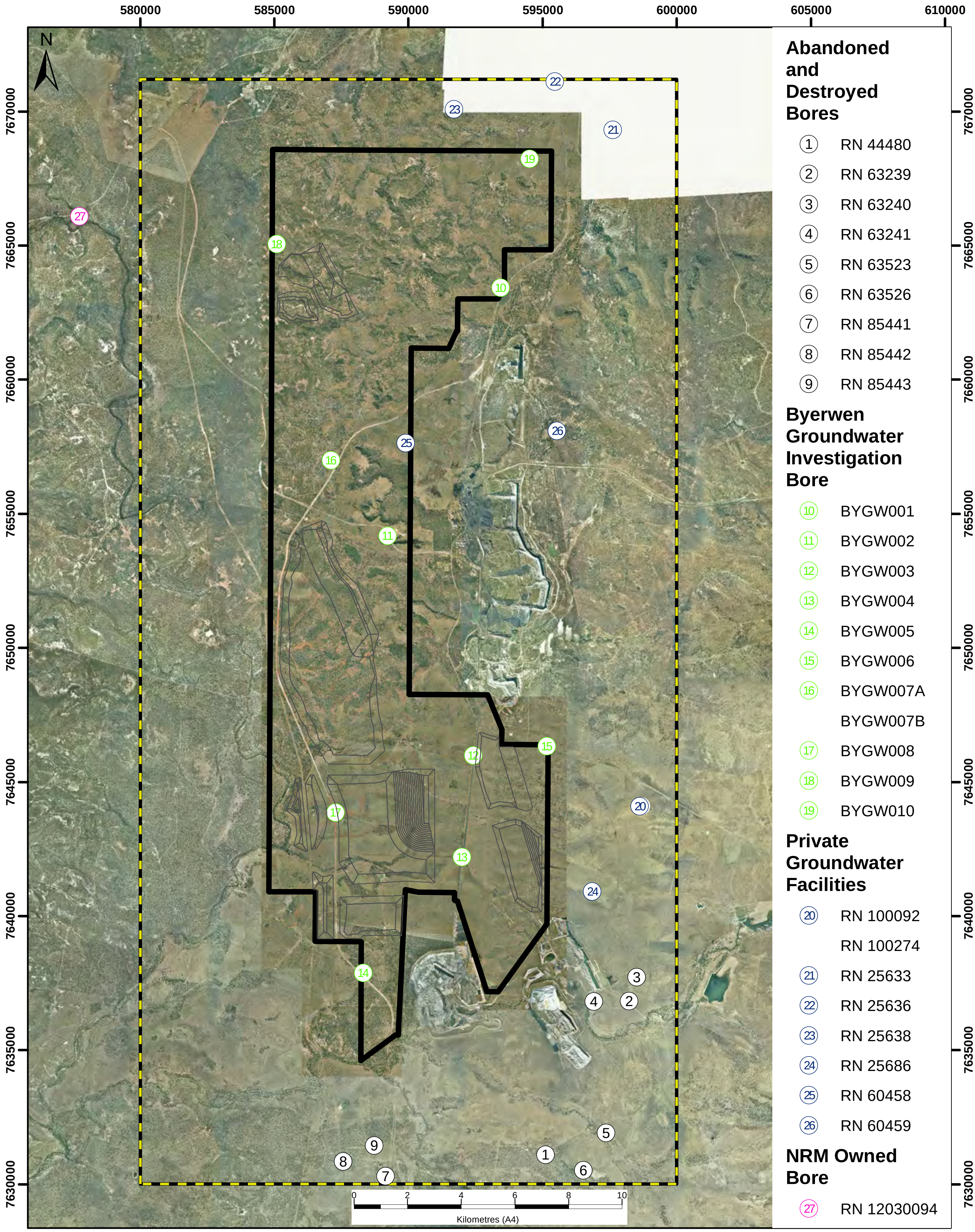
Table 17-4 Summary of DNRM Groundwater Data for Existing Private Groundwater Facilities

Facility Registered Number	Property or Holding	Bore Name	Easting MGA94	Northing MGA94	Cased Depth (m)	Reported Discharge (L/s)	Pumping Equipment)
RN 25633	Weetalaba	Rockhole	597618	7669314	18.3	1.25	Windmill
RN 25636	Weetalaba	3-ways	595464	7671126	37.2	0.88	Windmill
RN 25638	Weetalaba	Millers Well	591706	7670079	16.4	0.5	Windmill
RN 25686	Not stated	Not recorded	596844	7640920	6.4	0.32	Windmill
RN 60458	Byerwen	AGC26	589906	7657632	56	2.1	-
RN 60459	Byerwen	AGC35	595533	7658096	45	1.5	-
RN 100092	Not stated	MGC Suttor Creek No 2	598620	7644095	No strata log, no casing information	Not reported	-

Facility Registered Number	Property or Holding	Bore Name	Easting MGA94	Northing MGA94	Cased Depth (m)	Reported Discharge (L/s)	Pumping Equipment)
RN 100274	Not stated	MGC Suttor Creek No 4	598678	7644094	No strata log, no casing information	Not reported	-

17.4.3.1 Pumping Parameters, Drawdown and Recharge

Apart from the discharge data shown in **Table 17-4**, there are no records of pumping rates, drawdown and recharge measurements from any of the private groundwater facilities in the DNRM groundwater database. As the bores are mostly used for stock watering, they are equipped with either windmills or low discharge diesel-powered pumps. Bores of this type with this sort of equipment, pump at low discharge rates which generally results in less drawdown. The recorded discharges for the bores are considered low.



Legend

- Project Area
- Study Area
- Waste Rock Dumps and Pits

Private Groundwater Facilities, and Dedicated Groundwater Monitoring Bores	QCOAL GROUP
Figure 17-2	**Byerwen Coal Project**
Date: *5/02/2013*	**Author:** Shahram.Nasiri
	Map Scale: 1:185,000
Revision: R1	**Coordinate System:** GDA 1994 MGA Zone 55
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17.4.3.2 Seasonal Groundwater Level Variations in Private Groundwater Facilities

There are no records in the DNRM groundwater database of seasonal groundwater level measurements from any of the private groundwater facilities identified above, with which to assess seasonal groundwater level variation.

However, DNRM owns a groundwater monitoring bore (RN 12030094) (see **Figure 17-2**) on the east bank of the Suttor River (immediately south of where it intersects the Bowen Development Road), about 8 km to the west of the project area (at Easting 577734, Northing 7666087 MGA94 datum).

RN 12030094 bore is 72.3 m deep and is screened from 70.3 to 72.3 m depth. The bore monitors sand and claystone of the Suttor Formation (and is therefore analogous with some of the wells located on the project area). The groundwater quality in the bore is very poor with a total dissolved solid content of 6,200 mg/L.

This bore was monitored for groundwater level on a regular basis from 1975 to 1986 and those records give insight into the seasonal variations that may be expected in the groundwater monitoring bores on the project area. **Figure 17-3** shows the trend in seasonal variation in the groundwater level in RN 12030094.

Based on **Figure 17-3**, the seasonal variation in groundwater level in the project bores can be expected to be small, as the measured groundwater levels appear to fluctuate by no more than 0.6m; a maximum range of fluctuation could be assumed to be two metres.

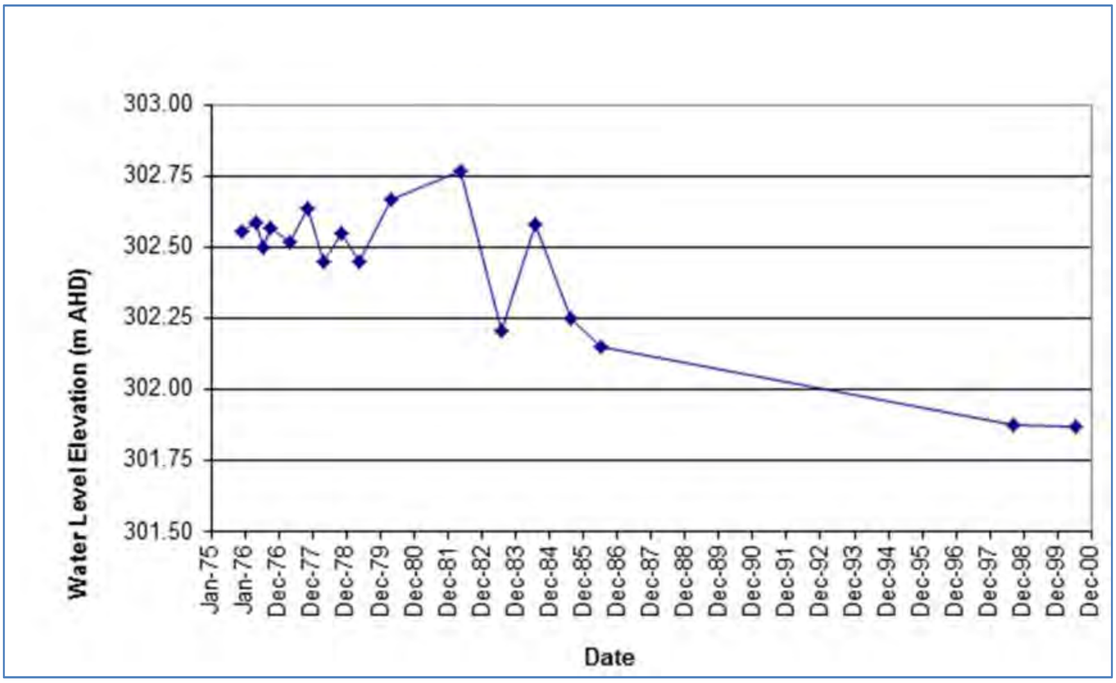


Figure 17-3 ***Seasonal Groundwater Level Variation in DNRM groundwater monitoring bore RN 12030094.***

17.4.3.3 Unregistered Private Groundwater Facilities

There are no known unregistered bores within the search area.

17.4.3.4 Groundwater Quality in Private Groundwater Facilities

The only available information on groundwater quality in private groundwater facilities is a groundwater chemical analysis from RN 25686 from 1965. This facility is only 6.4 m deep and extracts groundwater from the basalt. The groundwater chemistry information for this facility is shown in **Table 17-5**.

Table 17-5 Groundwater Analysis from RN 25686

Groundwater Quality Parameter	Unit	Observed Value
Conductivity	µS/cm	1,550
pH	pH units	8
Hardness	mg/L	5,758
Alkalinity	mg/L	7,845
Total Ions	mg/L	19,050.3
Total Solids	mg/L	14,187.55
Na	mg/L	3,632.2
Ca	mg/L	514.8
Mg	mg/L	1,086.8
HCO_3	mg/L	9,566.7
Cl	mg/L	3,832.4
F	mg/L	2.7
SO_4	mg/L	414.7

17.4.4 Springs

No springs, seeps or swamps are known within the project study area and there is no groundwater - surface water interaction between the aquifer sequences beneath the project area and the watercourses that traverse the project area. Project mining activities will have no impact on river baseflow.

17.4.5 Groundwater Information from Exploration Bores

The proponent has undertaken extensive coal exploration drilling programs in a 7 km by 4 km area in the southern section of the project area (where the largest pits are planned and the where the initial 15 years of operations will occur), to the west of BYGW04 and to the north of BYGW05. Many of the exploration bores encountered groundwater. A total of 207 exploration bores were drilled in this area. Of these 198 recorded a standing water level (SWL) and 69 recorded both a SWL and an ALY. In many instances it was necessary to install pre-collar casing to preclude hole caving so that drilling to target depth could be achieved.

The data from the mineral exploration bores provides information on the occurrence of groundwater in the stratigraphic units in the study area.

17.4.5.1 Basalt and Tertiary Sand below the Basalt

Data from mineral exploration bores that intersected groundwater in basalt or basalt and basalt sand is included in **Appendix 18**. In summary it is shown that:

- There is a wide range in the SWL in exploration boreholes in the basalt and in the Tertiary sand below the basalt.
- The ALYs from individual bores in the basalt and in the Tertiary sand below the basalt range from 0 L/s to 12.5 L/s, with an exceptional ALY of 100 L/s being estimated in BY073 (the method of estimation is not recorded).

This information indicates that the aquifer/s in the basalt and in the Tertiary sand below the basalt are not hydraulically continuous.

17.4.5.2 Coal Seams

Data from mineral exploration bores that intersected groundwater in coal seams is included in **Appendix 18**. In summary it is shown that:

- There is a wide range in the SWL in the exploration boreholes in the coal seams.
- The ALYs from individual bores in the coal seam aquifers are lower than those from the basalt aquifers with an exceptional ALY of 8.75 L/s being reported in BY125.

17.4.5.3 Other Lithologies

Data from bores that intersected groundwater in other lithological units is included in **Appendix 18**. In summary it is shown that:

- There is little groundwater of any significance in mudstone or siltstone and that the only significant groundwater is associated with sandstone.
- The larger ALYs in the sandstone are very localised, suggesting that fracture (secondary) porosity and not intergranular (primary) porosity is the dominant mechanism for groundwater accumulation and flow.

17.4.6 Hydraulic Conductivity Testing Program

Falling head permeability tests were conducted on all of the dedicated groundwater monitoring bores and on exploration bore BY073. The data from the tests were analysed using the Bouwer and Rice analytical method.

Table 17-6 shows the hydraulic conductivity of the perforated zones within each dedicated groundwater monitoring bore.

Table 17-6 Calculated Permeability Values

Bore_ID	Perforated Interval (m)	Lithologies tested	Hydrostratigraphic unit	Permeability (m/s)	Permeability (m/d)
BYGW01	47.5-59.5	Sandstone and interbedded coal	Rangal Coal Measures	6.48E-07	0.0560
BYGW02	47.5-53.5	Coal	Fort Cooper Coal Measures	4.63E-07	0.0401
BYGW03	56-62	Sandstone	Fort Cooper Coal Measures	1.16E-06	0.1006
BYGW04	95-107	Sandstone and interbedded coal	Fort Cooper Coal Measures	2.02E-09	0.0002
BYGW05	99-105; 81-93	Sandstone	Exmoor Formation	4.32E-10	0.0000
BYGW06	103-115	Sandstone and interbedded coal	Rangal Coal Measures	9.88E-09	0.0009
BYGW07A	65-69	Sand below Basalt	Tertiary Sand below Basalt	1.67E-05	1.4407
BYGW07B	46-52	Basalt	Basalt	2.17E-07	0.0187
BYGW08	56.5-65.5	Basalt	Basalt	8.85E-07	0.0765
BYGW09	91-97	Sandstone	Moranbah Coal Measures	2.03E-07	0.0176
BYGW10	40-52	Sandstone and interbedded coal	Rangal Coal Measures	1.58E-08	0.0014
BY073*	Open hole 97 - 265	Sandstone and interbedded coal	Not interpreted	1.48E-07	0.0128

* Note that the results from BY073 represent the gross permeability of the open hole from 97 to 265 m depth.

Table 17-6 shows that the hydraulic conductivity values for all lithologies tested are relatively low (10^{-7} to 10^{-10} m/s) with the only exceptions being the Tertiary sand below the basalt in BYGW07A and the sandstone in BYGW03. These are regarded as exceptional as to what can be generally be expected.

The variations in calculated hydraulic conductivity explain the wide variations in ALY obtained by both the groundwater monitoring bores and the mineral exploration bores, and reinforce the conclusion that fracture porosity, not primary porosity, is the dominant mechanism for groundwater accumulation and flow.

17.4.7 Aquifers

Aquifers beneath the project area occur in a number of stratigraphic units as discussed below.

17.4.7.1 Alluvium

The Suttor River is the major drainage west of the project area. The Suttor rises in the Leichhardt Range—underlain by mudstone and claystone of the Tertiary Suttor Formation. Little alluvial development of any significance has occurred along the Suttor above its confluence with Diamond Creek downstream of the project area.

Two of the dedicated groundwater monitoring bores (BYGW04 and BYGW08) are located to assess the thickness of the alluvium as alluvium was shown to cross the southern part of the project area (where the largest pits are planned and the where the initial 15 years of operations will occur). Neither BYGW04 nor BYGW08 intersected any alluvium.

None of the remaining groundwater monitoring bores intersected any alluvial sequence. Therefore, the alluvium is not regarded as an aquifer on the project area.

17.4.7.2 Suttor Formation

The Suttor Formation is dominated by clay and claystone. It is noted as a poor aquifer owing to low yields due to a predominantly clayey lithology and poor groundwater quality. Recharge through this stratigraphic unit to the underlying sequences is expected to be slow. Any aquifers in this formation would be unconfined or semi-confined.

17.4.7.3 Basalt

A northwest-trending line of Tertiary basalt outcrops possibly marks the position of an ancestral tributary of the Bowen River. The yields from the basalt are low to moderate and no reports of significant vesicles occur. Fracture porosity is the dominant mechanism for groundwater storage and flow in the basalt. Any aquifers in this formation would be unconfined or semi-confined.

17.4.7.4 Tertiary Sand below the Basalt

The Tertiary sand aquifer at the base of the basalt is lensoid and discontinuous but locally high yielding. This aquifer is not used for stock water probably due to the random nature of occurrence of the basal sands, with landholders tending to rely more heavily on dams and piped water. Any aquifers in this formation would be confined.

17.4.7.5 Coal Seams

Potentially higher yielding aquifers occur in sandstone within the Bowen Basin coal measure sequence. The Fort Cooper Coal Measures, for example, contain extensive medium- to coarse-grained sandstone and conglomerate beds. The aquifers within the sandstone are discontinuous which shows that fracture porosity is the dominant mechanism for groundwater storage and flow in the sandstone.

Because many coal measure sandstones were deposited in a brackish water environment and/or have a clay-rich matrix, the groundwater quality in the coal seams is generally very poor and may be unsuitable for stock. The waters are sodium chloride type with a high total dissolved salt (TDS) content. The sulphate content is also high.

Any aquifers in this formation would be confined.

17.4.7.6 Basement (Lizzie Creek Volcanics)

Aquifers within the Lizzie Creek Volcanics are not reported. It is noted that they would be too deep to be accessible by pastoralists. Generally andesitic and rhyolitic sequences contain poor aquifers. Basement aquifers are not regarded as significant for the purposes of groundwater impact assessment and are not considered further. Any aquifers in this formation would be confined.

17.4.8 Aquifer Importance

An assessment of the relative importance of the aquifers was undertaken. The aquifer units are listed in order of significance, from highest (1) to lowest (6), based on the criteria used in **Table 17-7**. It should be noted that these criteria were developed by RLA (refer **Appendix 18**) based on significant Bowen Basin hydrological experience for the purpose off this report to assist in better understanding of the hydrogeological regime.

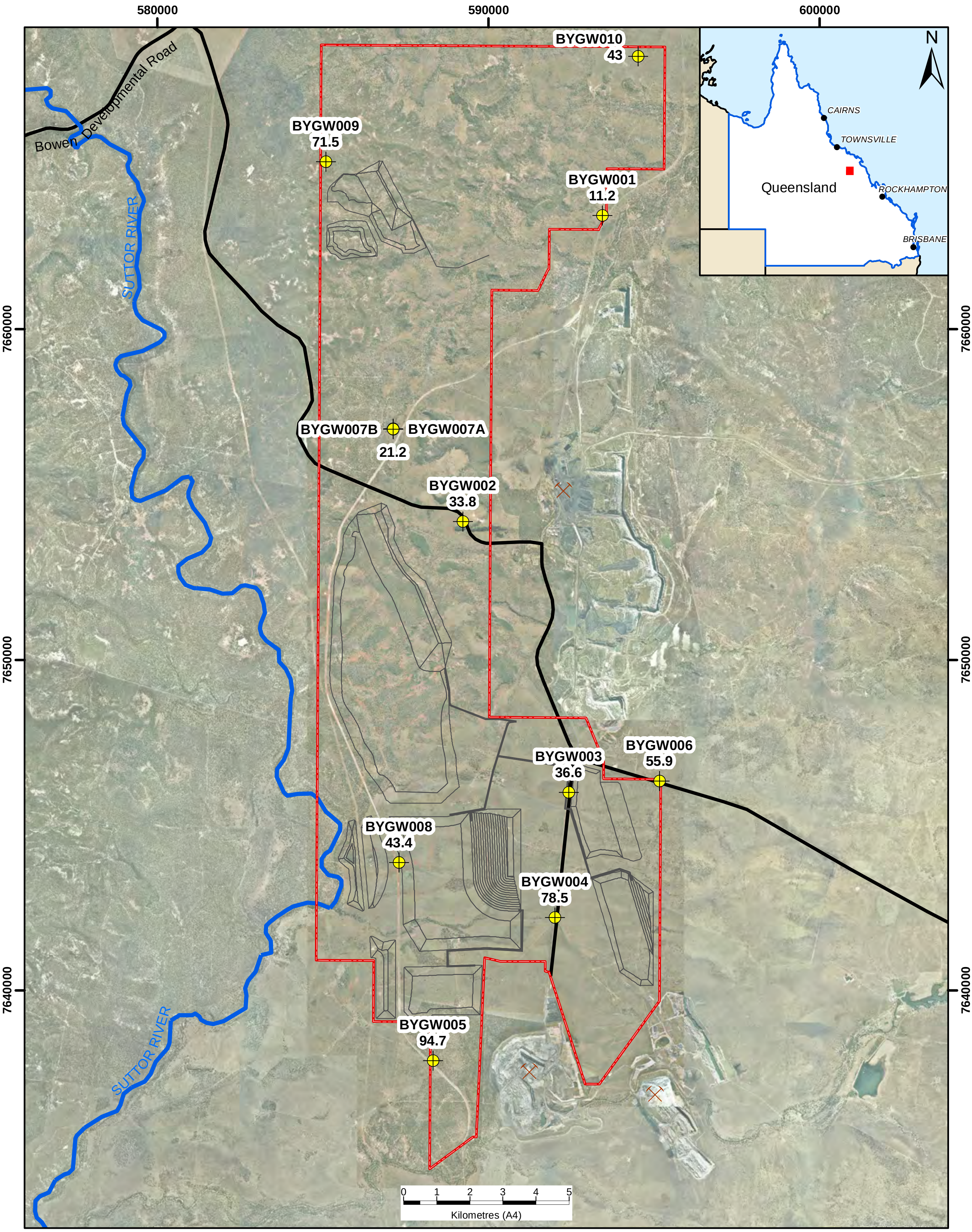
Table 17-7 Aquifer Units and Significance

Aquifer Unit	Significance	Criterion 1: Yield	Criterion 2: Permeability	Criterion 3: Hydraulic Continuity	Criterion 4: Groundwater Quality
Tertiary Sand below Basalt	1	High	High	Discontinuous, probably lensoid.	Brackish
Coal Seam Aquifers (mainly Sandstone)	2	Low to Moderate	Low	Discontinuous	Very Poor
Basalt	3	Low	Moderate	Discontinuous	Poor
Suttor Formation	4	Low	Low	Discontinuous	Very Poor
Alluvium	5	No significant alluvial sequences are evident in the project area.			
Basement	6	No groundwater occurrence or use form the Lizzie Creek Volcanics is known or has been reported in the study area.			

17.4.9 Depth to Water Table

The thickness of the interval of the hydrostratigraphic unit being assessed corresponds to the perforated interval of the groundwater monitoring bores and is presented in **Table 17-3** along with the related measured depth to SWL for those units.

Figure 17-4 shows the SWLs in the dedicated groundwater monitoring bores.



Legend

- Project Area
- Waste Rock Dumps and Pits
- Groundwater Monitoring Bore
- Existing Mine Site
- Suttor River
- Formed Roads

Standing Water Level in Groundwater Monitoring Bores	
Figure 17-4	Byerwen Coal Project
Date: 29/01/2013	Author: samuel.ferguson Map Scale: 1:150,000
Revision: R1	Coordinate System: GDA 1994 MGA Zone 55
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Figure 17-4 shows that the SWL (metres below ground level) is relatively shallow beneath the basalt and much deeper where there is no basalt cover. This suggests that the basalt is a storage mechanism for groundwater and that groundwater within the Tertiary sequences is perched above the underlying Permian sequences.

Both the SWLs and thickness of aquifers show wide ranges, reinforcing that there is little hydraulic continuity in the aquifers beneath the project area. If the Tertiary and Permian aquifers were in hydraulic connection a relatively uniform depth SWL would be expected.

17.4.10 Aquifer Connectivity

There are no alluvial aquifers of any significance in the project area.

Tertiary sequence aquifers do not appear to be in hydraulic connectivity with the deeper Permian sequence aquifers.

The aquifers within the sandstones contained in the Permian coal seams are discontinuous. Therefore the hydraulic connectivity within the coal seam aquifers will be at best very limited (as evidenced by the low hydraulic conductivity values derived from the testing program).

There are no aquifers of significance in the basement.

In summary, the following apply:

- Hydraulic connection between alluvium and Tertiary aquifers does not exist as there are no alluvial aquifers.
- Hydraulic connection between the Tertiary basalt and sand aquifers with the underlying Permian sequence does not exist as the groundwater in the basalt and sand aquifers is perched well above the Permian aquifers.
- Hydraulic connection between Permian coal seam aquifers is considered to be limited.
- Hydraulic connection between Permian coal seam aquifers and the underlying basement probably does not exist as basement lithologies are regarded as impermeable.
- Hydraulic connection between the Suttor Formation and the underlying Permian sequences is very limited based on the available data.

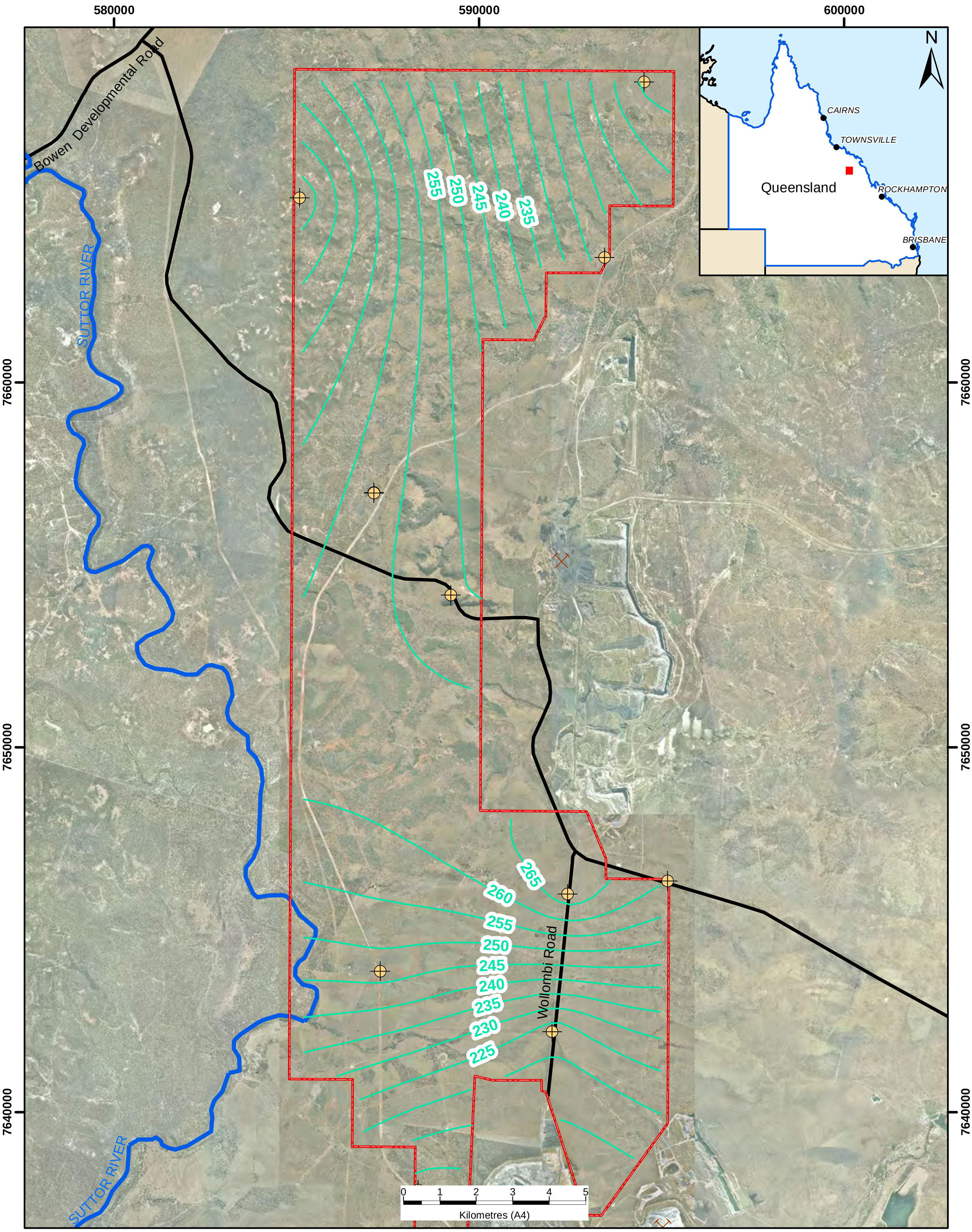
17.4.11 Groundwater Flow Directions

It is considered reasonable to assess the regional potentiometric surface for the Permian sequences based on the groundwater level elevations from the aquifers within the coal seams beneath the project area. This assumes that there is at least limited hydraulic connectivity between the coal seam aquifers.

Contouring of the groundwater elevation can therefore only provide an indication of groundwater flow directions within the Permian sequences beneath the project area.

Figure 17-5 shows a contour map of groundwater elevation in October 2011. These contours exclude the groundwater level data from the Tertiary aquifer sequences, which are not connected.

The contours suggest that groundwater flow in the Permian sequences is both to the north east and to the south with a groundwater divide (mounding) between BYGW02 and BYGW03.It is noted that this groundwater divide correlates to the boundary between surface water drainage sub-catchments which straddle the site (see **Chapter 15**); namely the Rosella Creek sub-catchment to the north and the Upper Suttor River sub-catchment to the south.



Legend

- Project Area
- Groundwater Monitoring Bore
- Groundwater Elevation Contours
- Existing Mine Site
- Formed Road

Groundwater Elevation Contours Permian Aquifer Sequences, October 2011		QCOAL GROUP
Figure 17-5	**Byerwen Coal Project**	environmental and licensing professionals pty ltd
Date: *5/02/2013*	**Author:** Shahram.Nasiri	
	Map Scale: 1:136,281	
Revision: R1	**Coordinate System:** GDA 1994 MGA Zone 55	
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17.4.12 Groundwater – Surface Water Interactions

Data from DNRM observation bore RN 12030094 (see **Figure 17-3**) indicate that there is little or no hydraulic connection between the Suttor Formation aquifers and the Suttor River. The groundwater level in this bore is generally well below the depth of incision of the river bed.

The data from the groundwater monitoring bores and mineral exploration bores shows that the SWL beneath the project area ranges from about 20 to 80 m below ground level (bgl). None of the drainage features that traverse the project area are incised to any more than about 5 m. Furthermore there is no alluvial development of any significance.

BYGW04 intersected its first significant groundwater at 102 m bgl and the SWL in this bore is over 70 m bgl. Similarly BYGW08 intersected its first significant groundwater at 66 m bgl and the SWL in this bore is over 40 m bgl. The strata from surface to 37 m bgl in BYGW08 consists of mottled clay, which must be regarded as a significant aquitard, especially as the SWL in this bore is below that depth. This is significant evidence that the aquifers within the project area are not hydraulically connected to the Suttor River or any of the major watercourses.

It is concluded that there is little or no groundwater - surface water interaction across the project area, as the SWLs are deep and there is generally a significant thickness of low permeability material or aquitards above any aquifers that are encountered.

17.4.13 Groundwater Recharge

Recharge of the Tertiary aquifers occurs by direct infiltration of rainfall. As the Tertiary and Permian sequences are not hydraulically connected the Tertiary aquifers do not contribute recharge to the Permian aquifers.

Recharge to the coal measure sandstone aquifers, also occurs via direct (but slow) infiltration of rainfall. The majority of the recharge to the Permian coal sequence aquifers probably derives from slow infiltration through the predominantly clayey Suttor Formation.

There is no recharge from the alluvium to the Permian sequence aquifers as there are no significant alluvial aquifers on the project area. In other areas in the Bowen Basin it has been estimated that only about 3% of incident rainfall results in recharge to the consolidated aquifers.

The proponent has installed automatic groundwater level data loggers in several of the dedicated groundwater monitoring bores to continue to monitor seasonal groundwater level fluctuation **Figure 17-6**, **Figure 17-7** and **Figure 17-8** show the groundwater level variation in bores BYGW05, BYGW07A and BYGW09 for an eight month period from December 2011 to August 2012.

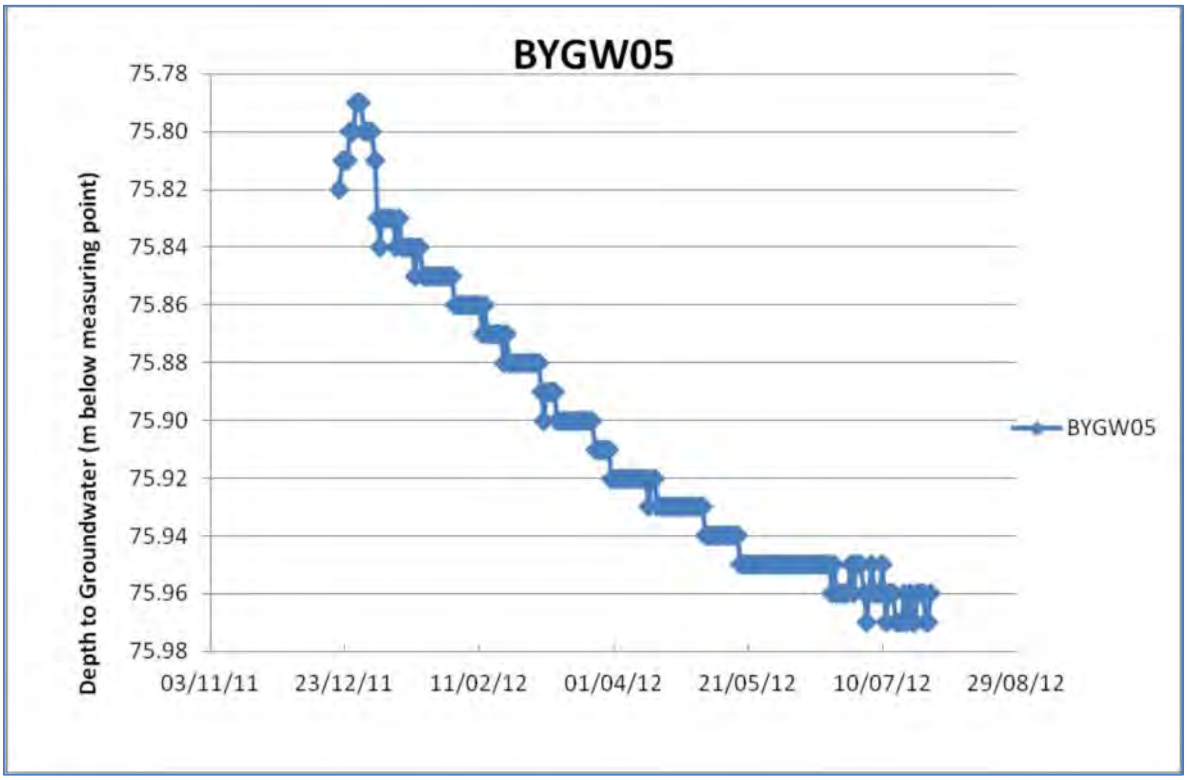


Figure 17-6 Depth to Groundwater Chart BYGW05 December 2011 to August 2012

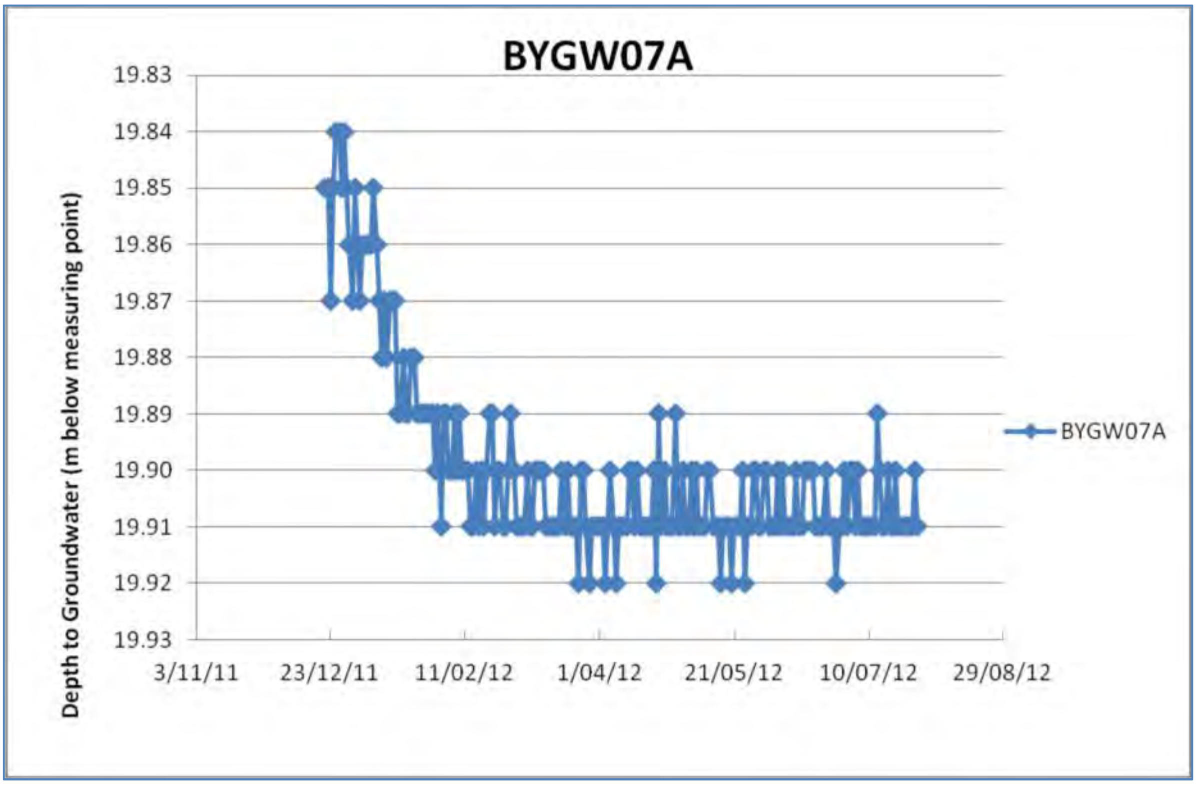


Figure 17-7 Depth to Groundwater Chart BYGW07A December 2011 to August 2012

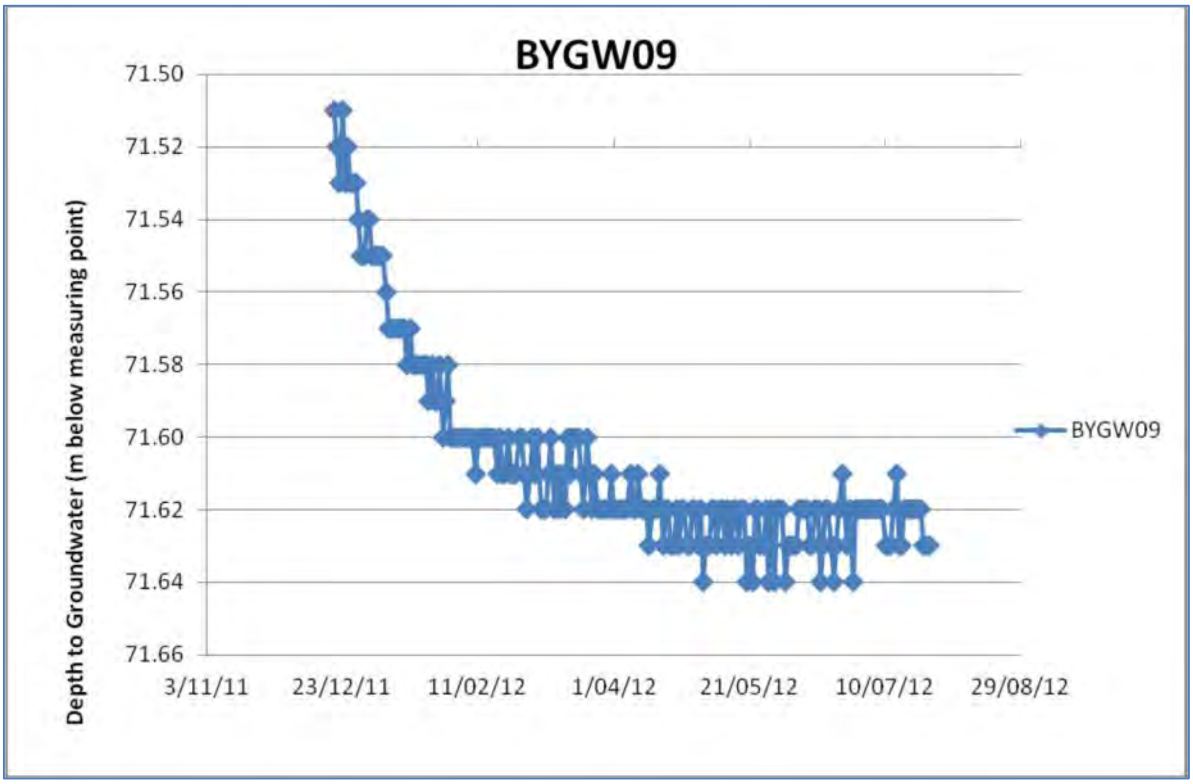


Figure 17-8 Depth to Groundwater Chart BYGW09 December 2011 to August 2012

It can be seen that the seasonal decline in groundwater level in each of these three bores ranges from 0.08 m to 0.16 m. Such small amplitudes of seasonal groundwater level variation are typical of low hydraulic conductivity aquifers. Significantly it is noted that these results for bores across the project area are directly comparable to the fluctuation of groundwater levels measured, over an approximate 10 year period, in bore RN 12030094 located in the Suttor Formation 8 km to the west of the project (see **Section 17.4.3.2**).

Given the lack of hydraulic connectivity between various aquifers or between aquifers and the quaternary alluvium, as well as the extremely slow recharge rates, any predicted localised drawdown within specific aquifers is considered unlikely to affect the hydrogeological recharge regime in any aquifer, outside the predicted drawdown.

17.4.14 Groundwater Chemistry in Dedicated Groundwater Monitoring Bores

Groundwater from the dedicated groundwater bores is monitored in an ongoing programme. Water samples are collected in alignment with the Queensland Water Quality Guidelines 2009 (DERM, 2009) unless circumstantial departures (such as equipment failure) preclude data gathering in the prescribed manner. Such circumstances prevailed in August 2012 when dedicated groundwater monitoring bores were measured for SWL. During that sampling round, effective purging could not be achieved due to equipment failure and as a consequence, samples collected on that occasion were of standing water rather than "fresh formation water", as such the existing water sample analysis results will be compared to subsequent confirmatory sampling and monitoring results.

Tabulated analyses of the groundwater from the groundwater monitoring bores taken in October and December 2011 are included in **Appendix 18**.

BYGW04 has not yielded sufficient water to permit a valid groundwater sample to be obtained. The electrical conductivity of the water from it was measured at 2,720 µS/cm at time of drilling, indicating that the groundwater in that bore is brackish.

As with scientific data collection of any kind, a larger data set will enable more robust analyses and interpretation, in comparison to smaller data sets. As such, a more robust statistical analysis of data will be available for water quality parameters with data collected from ongoing sampling in the early stages of project development

In summary chemical analysis of the groundwater monitoring bores data showed the following:

- The natural electrical conductivity (EC) and the total dissolved solids (TDS) content of the groundwater ranges from moderate to high.
- The groundwater across the project area is moderately to highly alkaline with pH in excess of 10.0 being measured in BYGW05, BYGW06, BYGW08 and BYGW10, while BYGW01 recorded a pH of 9.44. These bores are also high in electrical conductivity, TDS and ammonia. This groundwater chemistry is invariably associated with the coal seams.
- Dissolved arsenic concentrations have been below the ANZECC/ARMCANZ 2000 stockwater guideline value of 0.5 mg/L;
- Dissolved cadmium concentrations have been below the ANZECC/ARMCANZ 2000 stockwater guideline value of 0.01 mg/L;
- Dissolved copper concentrations have been below the ANZECC/ARMCANZ 2000 stockwater guideline value of 1 mg/L;
- Dissolved lead concentrations have generally been below the ANZECC/ARMCANZ 2000 stockwater guideline value of 0.1 mg/L except for the water from bores BYGW07B and BYGW09 in December 2011;
- Dissolved zinc concentrations have been below the ANZECC/ARMCANZ 2000 stockwater guideline value of 20 mg/L;
- Nitrate concentrations have been below the Australian Drinking Water Guideline value of 50 mg/L which is the most stringent guideline value for water in Australia;
- Nitrite concentrations have been below the Australian Drinking Water Guideline value of 3 mg/L;
- Sulphate concentrations in the groundwater are within the generally accepted stock watering guideline value of 1,000 mg/L except for the groundwater from BYGW02.

The groundwater in its natural state is generally brackish to saline and of poor quality.

17.4.15 Ionic Speciation of Groundwater

Data on major cations and anions, as well as the physico-chemical parameters EC and pH were used to assess the ionic speciation of the groundwater by using the graphical Piper Diagram method.

Figure 17-9 shows the Piper Diagram for the Byerwen groundwater from October 2011. The groundwater from all formations beneath the project area is of the sodium chloride type.

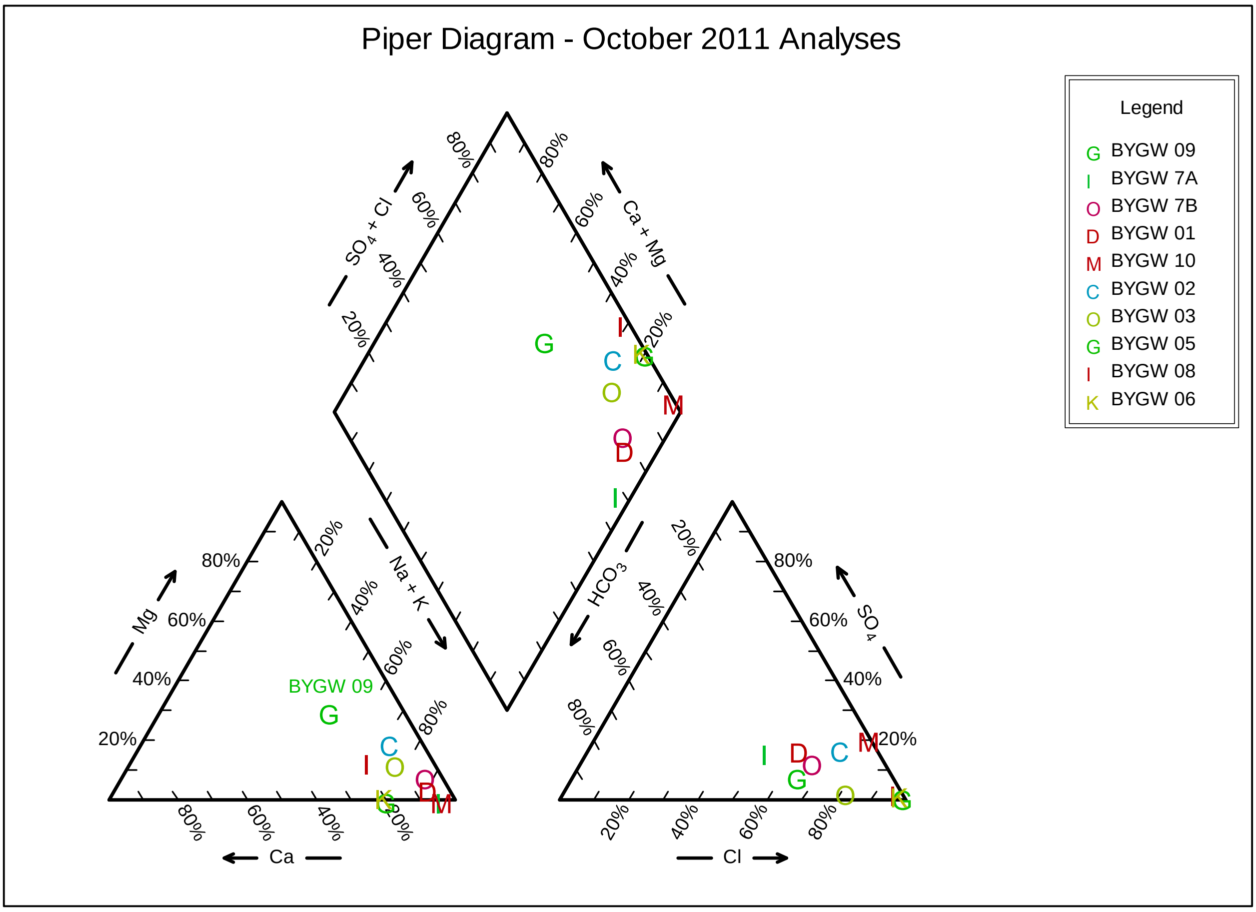


Figure 17-9 Piper Diagram for October 2011 Groundwater Chemical Analyses

17.4.16 Hydrocarbons in Groundwater

No groundwater related industries other than extraction for mine dewatering or agricultural use, exist in the project area or adjacent to the project area within the coal measure aquifers. As such, the presence of anthropogenic dissolved hydrocarbons within the groundwater in the area is considered extremely unlikely. Furthermore groundwater is in some instances being used for livestock watering and no naturally occurring hydrocarbons have been reported.

Accordingly hydrocarbon data was not prioritised as part of the initial baseline data set; however confirmatory groundwater sampling will be undertaken prior to commencement of mining to verify the absence of dissolved hydrocarbons in groundwater.

17.4.17 Pit Groundwater Inflow Initial Estimates

Groundwater inflow estimates into open pits were based on data from widely distributed bores. The results from these bores are noted as being of the appropriate order of magnitude for similar coal measures elsewhere in the Bowen Basin. Given the highly conservative methodology and assumptions, the inflow estimates are therefore considered suitable for interpretation and water management planning.

An additional measure of conservatism within the flow estimates is that the inflow estimates are based on pristine water table conditions and are therefore high. Inflow rates will almost certainly decrease (to be less than the calculated estimates) as the potentiometric surface declines with development of the site.

It is noted that depressurisation of the potentiometric surface will occur as the pits develop.

An analytical hydrogeological model using equations developed by Marinelli and Niccoli (2000) were used to assess the impact on groundwater levels and the radius of influence of this impact for each scenario to be tested. Marinelli and Niccoli present modelling equations for estimation of the radius of influence of an open pit or excavation and groundwater inflow rates. This requires a simplification of the hydrogeological environment that can be used to provide a range of potential drawdown and pit inflow estimates.

For Zone 1 (Pit Wall) the analytical solution considers steady-state, unconfined, horizontal, radial flow and assumes that:

- the excavation walls are approximated as a circular cylinder
- groundwater flow is horizontal; the Dupuit-Forchheimer approximation is used to account for changes in saturated thickness due to depression of the water table
- the static (pre-mining) water table is approximately horizontal
- uniform distributed recharge occurs across the site as a result of surface infiltration from rainfall; all recharge within the radius of influence (cone of depression) of the excavation is assumed to be captured by the excavation
- groundwater flow toward the excavation is axially symmetric.

Inflows from Zone 2 (Pit Floor) were not assessed as the majority of the groundwater inflow to the pits will occur within Zone 1 during pit development.

17.4.17.1 Hydraulic Conductivity (Permeability)

The data from the hydraulic conductivity tests discussed in **Section 17.4.6** were used for the initial estimates of groundwater inflow to the proposed pits.

The dedicated project groundwater monitoring bores range in depth from 52 m bgl to 120 m bgl with ALY ranging from 0 L/s to 10 L/s.

ALY data also exists for 25 coal exploration bores. These bores range in depth from 104 m bgl to 297 m bgl. The ALY from those 25 bores range from 0 L/s to 8.25 L/s.

The ranges of ALY in the dedicated groundwater monitoring bores and in the coal exploration bores are similar. It is therefore reasonable to adopt the calculated hydraulic conductivity values from the dedicated groundwater monitoring bores as being representative for the purposes of this assessment.

Table 17-6 shows that the permeability values for all lithologies tested are relatively low (10^{-7} m/s to 10^{10} m/s) with the only exceptions being the Tertiary sand below the basalt in BYGW07A and the sandstone in BYGW03. These are regarded as being the exception rather than the rule.

The variations in calculated permeability explain the wide variations in ALY obtained by the exploration bores and reinforce the conclusion that fracture porosity, not primary porosity, is the dominant mechanism for groundwater accumulation and flow.

For the purposes of this assessment the geometric mean of the values for BYGW03, BYGW04, BYGW05, BYGW06 and BYGW08 (2.45×10^{-8} m/s) was used for inflow estimation to the South and East Pits and the geometric mean of the values for BYGW02, BYGW03 and BYGW08 (7.81×10^{-7} m/s) was used for inflow estimation to the West Pits.

It should be noted that bores BYGW03 and BYGW08 are common to both sets of bores used for calculating the geometric means. As the geometric means from each data set are one order of magnitude different, it was considered valid that inflow estimates should be carried out according to a low hydraulic conductivity scenario (using 2.45 x 10^{-8} m/s as the value for this scenario), and also according to a high hydraulic conductivity scenario (using 7.81 x 10^{-7} m/s as the value for this scenario), for the East, West and South Pits as they are all in reasonable proximity. This methodology provides a conservative basis of assumptions for inflow calculations.

For the purposes of the inflow estimates to North Pit the geometric mean of the values for BYGW01, BYGW09, and BYGW10 was used. This geometric mean is 1.28 x 10^{-7} m/s. As only these three bores were used for calculation of the geometric mean, only one hydraulic conductivity scenario (using 1.28 x 10^{-7} m/s as the value for this scenario) has been undertaken for North Pit.

In summary, the hydraulic conductivity values used for the groundwater inflow scenarios for the project pits are as shown in **Table 17-8**.

Table 17-8 Hydraulic Conductivity Values used for Inflow Estimates

	Low Hydraulic Conductivity	High Hydraulic Conductivity
North Pit	Not applicable	1.28 x 10^{-7} m/s
South Pits	2.45 x 10^{-8} m/s	7.81 x 10^{-7} m/s
East Pits	2.45 x 10^{-8} m/s	7.81 x 10^{-7} m/s
West Pits	2.45 x 10^{-8} m/s	7.81 x 10^{-7} m/s

17.4.17.2 Inflow Estimates

Inflow estimates were assessed for the various pits according to their floor levels for successive stages of development.

The inflow estimates for the East, West and South Pits, calculated using the methodology described in **Appendix 18**, are shown in **Table 17-9** for the low hydraulic conductivity case and **Table 17-10** for the high hydraulic conductivity case.

Table 17-9 Pit Inflow Estimates for the Low Hydraulic Conductivity Case

Mine Year	Pit	Bottom level mAHD	Inflow m^3/day	Inflow L/s
Year 25	East Pit 1	270*	0	0.00
Year 46	East Pit 2	191	13	0.15
Year 03	South Pit 1	205	9	0.10
Year 05	South Pit 1	135	44	0.51
Year 10	South Pit 1	80	84	0.97
Year 25	South Pit 1	25	135	1.57
Year 46	South Pit 1	-80	260	3.01
Year 10	South Pit 2	220	4	0.05
Year 25	South Pit 2	70	92	1.06
Year 01	West Pit 1	240	4	0.04
Year 03	West Pit 1	230	6	0.07
Year 05	West Pit 1	185	24	0.28

Mine Year	Pit	Bottom level mAHD	Inflow m^3/day	Inflow L/s
Year 10	West Pit 1	90	90	1.04
Year 25	West Pit 2	50	14	0.16
Year 25	West Pit 3	220	9	0.10
Year 46	West Pit 3	82	96	1.12

* Above water table

Table 17-10 Pit Inflow Estimates for the High Hydraulic Conductivity Case

Mine Year	Pit	Bottom level mAHD	Inflow m^3/day	Inflow L/s
Year 25	East Pit 1	270*	0	0.00
Year 46	East Pit 2	191	76	0.88
Year 03	South Pit 1	205	116	1.34
Year 05	South Pit 1	135	750	8.67
Year 10	South Pit 1	80	1,547	17.90
Year 25	South Pit 1	25	2,630	30.42
Year 46	South Pit 1	-80	5,307	61.39
Year 10	South Pit 2	220	44	0.51
Year 25	South Pit 2	70	1,712	19.80
Year 01	West Pit 1	240	33	0.39
Year 03	West Pit 1	230	76	0.88
Year 05	West Pit 1	185	392	4.54
Year 10	West Pit 1	90	1,688	19.52
Year 25	West Pit 2	50	22	0.25
Year 25	West Pit 3	220	129	1.49
Year 46	West Pit 3	82	1,822	21.08

* Above water table

It is considered that the low permeability case is more pertinent to the East, West and South Pits.

Table 17-11 shows the inflow estimates for North Pit.

Table 17-11 Pit Inflow Estimates North Pit

Mine Year	Pit	Bottom level mAHD	Inflow m^3/day	Inflow L/s
Year 16	North Pit	175	70	0.81
Year 25	North Pit	100	256	2.97
Year 46	North Pit	80	320	3.70

17.5 Potential Impacts and Mitigation Measures

Potential impacts on groundwater environmental values which could arise from project activities are described below:

- Open cut coal mines will be developed in the project area and will excavate to a maximum depth of approximately 350 m (South Pit 1) and have the potential to drawdown groundwater levels, thereby affecting private groundwater bore levels or flows to groundwater dependent ecosystems (if any).
- Contamination of groundwater may occur through seepage from waste rock dumps and in-pit rejects disposal facilities.
- If final void water levels exceed the local groundwater levels, final void water may be released to groundwater.
- Pollution of groundwater from surface activities may occur from seepage from co-disposal facilities and accidental release of hydrocarbons (e.g. fuels and oils) or other contaminants.

Impacts on groundwater are associated with project operations. Construction is unlikely to impact groundwater as activities are limited to surface or near surface works and therefore will not intercept any aquifers (refer **Section 17.4.7**).

The project is open cut mining with residual voids and final shaped rehabilitated landforms remaining, following decommissioning activities. No activity is anticipated to intercept groundwater bearing units and affect the gross porosity or permeability of those units, except for the pits themselves, which have been specifically modelled and addressed as final voids. This lack of an anticipated affect is further reinforced by the conclusion in **Appendix 18** that fracture porosity, not primary porosity, is the dominant mechanism for groundwater accumulation and flow.

The interaction between final voids and groundwater is described in **Section 17.5.5**.

17.5.1 Drawdown of Regional Groundwater Levels

The Marinelli and Niccoli method (refer **Section 17.4.17**) is considered a highly suitable analytical hydrogeological model for the estimation of potential drawdown associated with the project dewatering activities. The suitability of this model for project planning is further reinforced by the highly conservative mathematical assumption that groundwater inflow to the pit is axially symmetric. In reality this is an oversimplification of the data, where the ALYs show that the aquifers are evidently not symmetric, but rather they appear highly heterogeneous. This is reinforced by groundwater inflow observations to most open pit coal mines in the north Bowen Basin where it has been observed and recorded that often many metres separate discrete pit inflows.

Based on the mine planning calculations, South Pit 1 in Year 46 will have a maximum depth of 380 m bgl which is nominally 320 m below the existing water table. This is the deepest and most extensive of all of the project pits and as such is considered to be the 'worst-case scenario'.

The dimensions of the deepest bench of South Pit 1 in Year 46 are approximately 3,600 m long and 160 m wide. Therefore, the assumed effective radius of the disk sink is about 1,200 m (being the radius at which the circumference of the assumed exposed disk approximates the actual planned bench/wall distance as a rectangle). Given the highly conservative nature of this model as well as the previous conservative assumptions made, this assumed radial value is considered suitable.

As stated above it is considered that the low permeability case is more pertinent to South Pit 1. **Figure 17-10** is a chart of the estimated drawdown from the pumping sump of South Pit 1 at its full development. As this pit will be progressively developed and deepened from west to east, the pumping sump will be at the furthest eastern extent of South Pit 1. **Figure 17-11** is a representation of the estimated extent of maximum drawdown under this scenario.

Drawdown will be at its maximum, i.e. 320 m below the existing water table, at the pumping sump within the pit, and will gradually diminish as distance from the pit increases. Based on these calculations South Pit 1 will induce drawdown to a distance of 2,300 m.

Raw data on ALY and permeability for the key aquifer lithologies was obtained from groundwater monitoring bores and coal exploration bores, which showed similar low permeabilities for the majority of lithologies tested. Given the highly conservative assumptions made for other modelling parameters, the assumed permeability for modelling was taken as the geometric mean for each aquifer which was represented by bores considered within a proximity to the modelled pits. A conservative maximum extent of drawdown of 2,300m can therefore be applied to all aquifers intercepted by the pits.

There are no groundwater users, GDE or hydraulic connections to the Suttor River within that radial distance of South Pit 1; however **Sections 17.5.2** to **17.5.6** discuss potential impacts to all groundwater values, within that conservative extent.

Ultimately the dedicated groundwater monitoring bores (refer **Section 17.5.7**) will be used to accurately measure any actual drawdown impacts of the pits as they are developed.

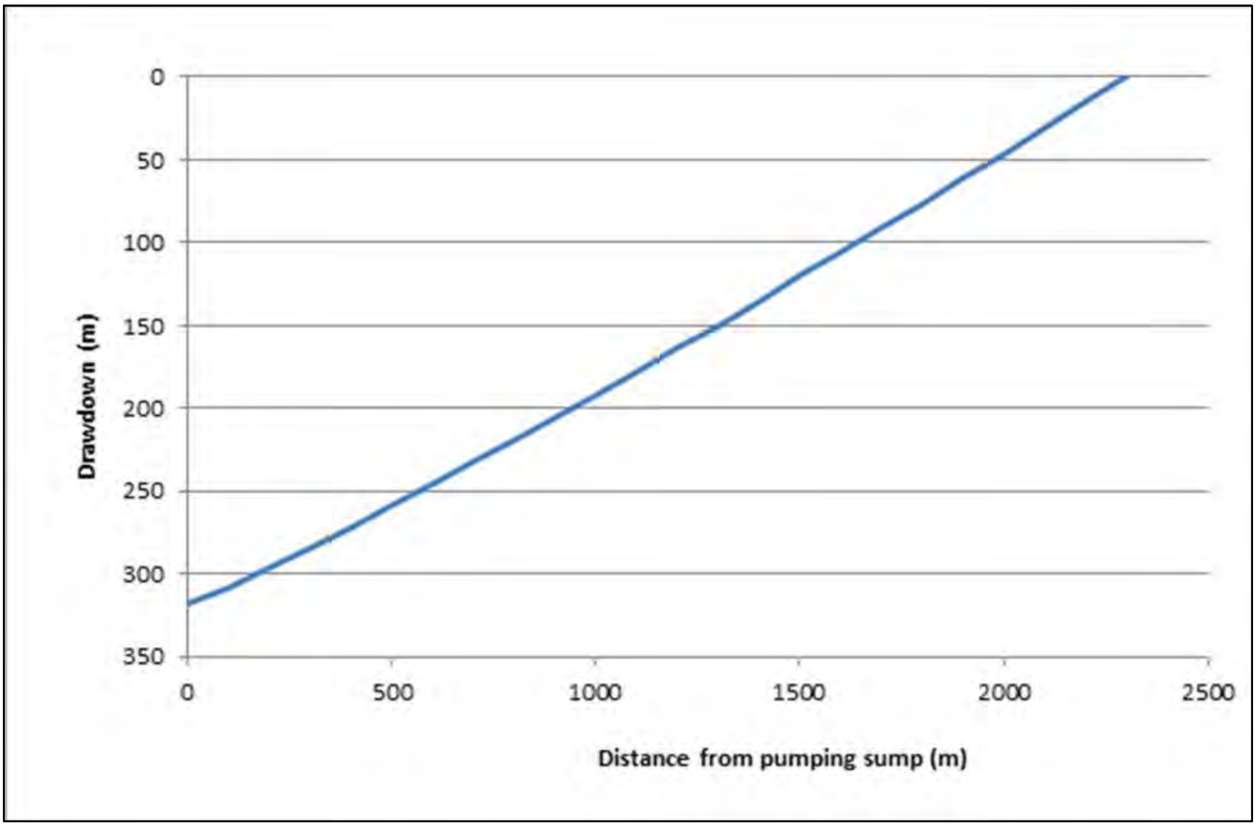
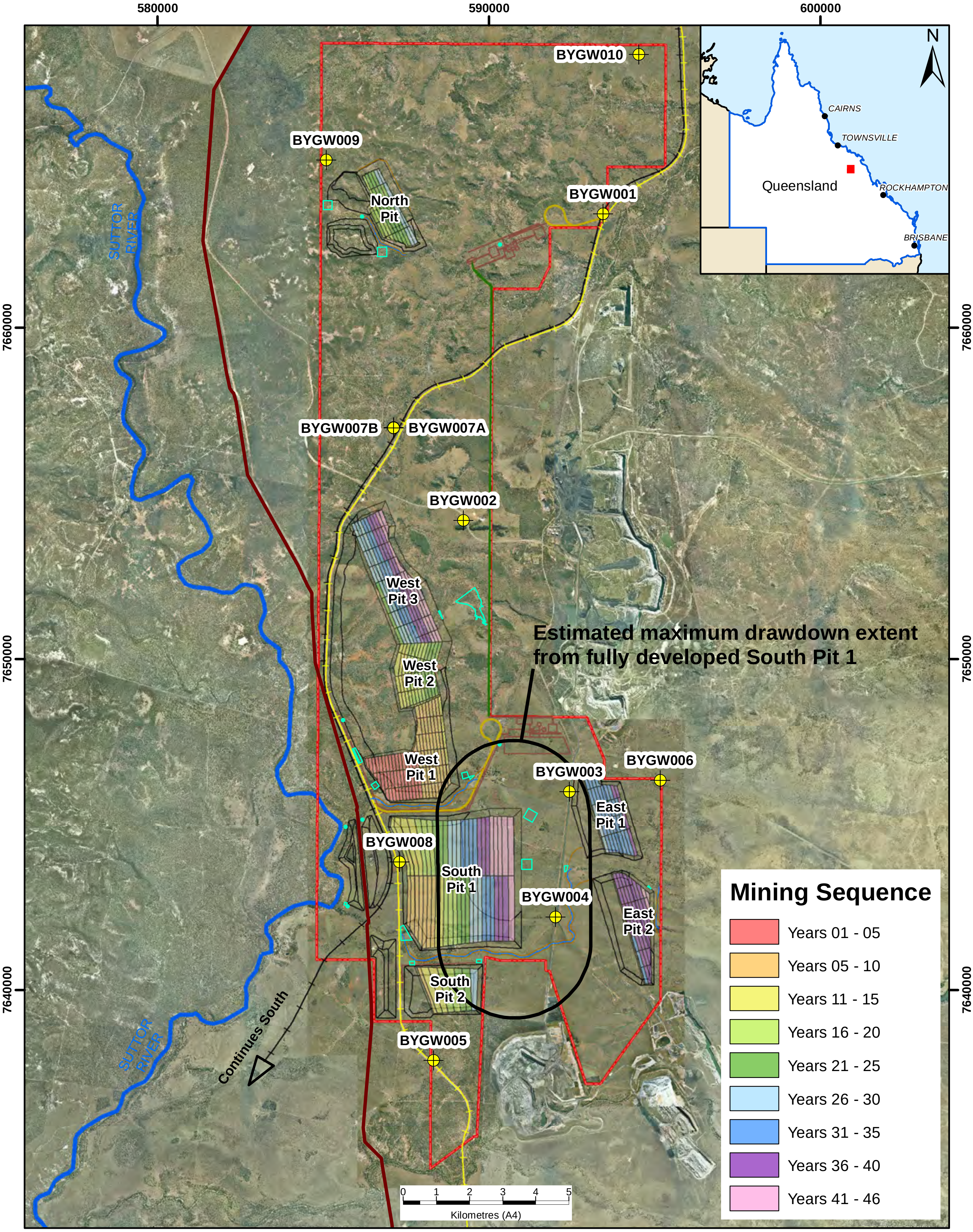


Figure 17-10 Estimated Drawdown with Distance from South Pit 1 at Full Pit Development



Legend

- Project Area
- Waste Rock Dumps and Pits
- Burdekin to Moranbah Pipeline
- GAP Rail line
- Alpha Coal Project Rail Line
- Train Loading Facilities
- Central Infrastructure Corridor
- Dam (mine affected, sediment affected, clean water)
- Suttor River
- Drainage Bund
- Drainage Diversion
- Mine Infrastructure
- Groundwater Monitoring Bore

Estimated Drawdown Impact of South Pit at Full Pit Development

QCOAL GROUP

Figure 17-11

Byerwen Coal Project

Date: *29/01/2013*

Author: samuel.ferguson

Map Scale: 1:150,000

Revision: R1

Coordinate System: GDA 1994 MGA Zone 55

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environmental and licensing professionals pty ltd

17.5.2 Private Boreholes

Owing to their proximity to the project area there is potential for bores RN 25633, 25636, 25638, 25686, 60458, 60459, 100092 and 100274 (shown in **Figure 17-2**) to be impacted by the project. The groundwater discharge from these bores is limited and would only sustain domestic or stock water uses.

As demonstrated in **Section 17.5.1**, the maximum expected radius of drawdown is 2,300 m from South Pit 1; all other pits are expected to have a lesser radius of drawdown Therefore applying that maximum radial extent to the other pits is a conservative measure which shows that other than RN 25686, none of the private boreholes is within 2,300 m of any of the project's open pits and therefore would not be impacted by drawdown, with the exception of RN 25686. RN 25686 is approximately 1,950 m from East Pit 2 following Year 35 of mining operations.

The expected impact on each of the bores is discussed below:

- RN 25633 is located approximately 10 km to the north-north-east of proposed North Pit on Lot 2 CP866147. The bore is only 18.3 m deep and extracts groundwater from a 'rock hole'. It is considered to be too far away from North Pit to be impacted by that pit. Groundwater levels in this area will be detected by BYGWB10.
- RN 25636 is located approximately 9 km to the north-east of proposed North Pit on Lot 2 CP866147. The bore is only 37.2 m deep and extracts groundwater from coal measures aquifers. It is considered to be too far away from North Pit to be impacted by that pit. Groundwater levels in this area will be detected by BYGWB10.
- RN 25638 is located approximately 8 km to the north-east of proposed North Pit on Lot 2 CP866147. The bore is only 16.4 m deep and probably extracts groundwater from basalt aquifers. It is considered to be too far away from North Pit to be impacted by that pit. Groundwater levels in this area will be detected by BYGWB10.
- RN 25686 is approximately 1,950 m east of East Pit 2 (on Lot 682 CP906890), at year 35 of mining and may therefore may be considered within a distance to experience potential drawdown. However, any potential impact to the SWL in this bore is unlikely as it is only cased to a shallow depth of 6.4 m. The groundwater quality from RN 25686 is generally only suitable for stock watering, being naturally too high in chloride and sulphate for human consumption.
- RN 60458 is located on the eastern boundary of the project on Lot 3 SP171922. It was formerly a mineral exploration bore. It is located approximately 5 km to the east-north-east of proposed West Pit 3. This bore may experience affects from potentially existing water table depression associated with the Xstrata Newlands mine. This bore could be potentially be affected by depression associated with the project as it is mid way between the Xstrata Newlands coal mine pits to its east and proposed West Pit 3; however this is considered unlikely due to the distance of this bore from the project's pits. In addition groundwater monitoring bore BYWWB02 is well located to monitor groundwater level and groundwater quality impacts on RN 60458.
- RN 60459 is located well to the east of the project on Lot 3 SP171922. It was formerly a mineral exploration bore. Its use status has not been confirmed; however, it is located on the eastern side of the Newlands mine pits (hydraulically isolating the project from this bore). It is assessed that RN 60549 will not be impacted by the project.
- RN 100092 and RN 100274 are located about 5 km to the east of the proposed East Pits on Lot 682 CP906890. Their use status is not known. They were formerly mineral exploration bores. They are also located in close proximity to each other and would have potential to overlap when pumping

simultaneously, if they are equipped. Existing water table depressurisation may have occurred in the area of these bores as a result of the existing mining related dewatering operations at the adjacent mining projects; as such, there may be some resultant existing effect on these bores. There is some potential for these bores to also be affected by development of the East Pits of the project; however, due to the distance from the East Pits this is considered unlikely. Furthermore groundwater monitoring bore BYGW06 is ideally located to assess potential for groundwater level and groundwater quality impacts on these bores.

As groundwater use in the vicinity of the project is for stock-watering use only and the modelled drawdown extent does not predict drawdown of groundwater levels at private groundwater bores (other than potentially at RN 25686), dewatering from project mining activities is expected to have negligible or no impact on private groundwater bores. However, in the unlikely event of regional depressurisation of the water table, the dedicated project groundwater monitoring bores are well located to measure those impacts.

Where practicable, RNs 25633, 25636, 25638, 25686, 60458, 60459, 100092 and 100274 will be measured for their groundwater level and groundwater quality before project mining commences to establish their baseline groundwater status, with regular monitoring undertaken thereafter. More frequent quarterly monitoring of project groundwater monitoring bores (which are located in close proximity to these bores) will be undertaken for level and quality to provide comparative data on the groundwater in the areas of these bores.

Groundwater monitoring, impact assessment and reporting requirements for project related monitoring bores are discussed in **Section 17.5.7**, along with an approach to developing any mitigation and management requirements in the event of project related impacts in excess of allowable criteria. The project bores are well located to delineate any project related groundwater impacts (changes in quality and level) between the project and private groundwater bores and will therefore detect any project related changes in groundwater prior to private bores.

Should impact in private bores be detected that have the potential to be related to project activities, an investigation into the cause will be undertaken. Depending on the issue investigations may include confirmatory water quality sampling, comparison against private bore baseline levels, project bore water level trends, project activities and any known third party activities, as well as make recommendations as to short, medium or long terms impacts, as well as required management or mitigations.

17.5.3 Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDE) fall into four categories:

- Terrestrial GDE (woodlands dependent on shallow groundwater, and vegetation along dry riverbeds). There are no terrestrial GDE in the project area although they may exist along the Suttor River to the west of the project area. It is considered that there is no groundwater - surface water interaction between the aquifer sequences beneath the project area and the Suttor River alluvium so project mining activities will have no impact on terrestrial GDE.
- River Baseflow GDE (ecosystems reliant on groundwater discharging to streams, springs, seeps and swamps). No springs, seeps or swamps are known in the project area and there is no groundwater - surface water interaction between the aquifer sequences beneath the project area and the watercourses that traverse the project area. Project mining activities will have no impact on river baseflow GDE.

- Aquifer GDE (ecosystems that exist in the subsurface, entirely dependent on groundwater). Stygofauna are the subject of a separate study (see **Chapter 20**).
- Wetland GDE. There are no records of wetland GDE in the Belyando Suttor river systems.

With the exception of stygofauna (refer **Chapter 20**) it is concluded that there are no GDE which can be impacted by the project's mining activities.

17.5.4 Waste Rock and Rejects

Chapter 9 provides characterisation for waste rock and rejects. In summation:

- there is a low risk of acidity forming for waste rock or coal rejects
- there is moderate to high risk of salinity and dispersion from the weathered material if left exposed in the final landform; if covered by unweathered material the risk is low, as is the case for the Byerwen project
- there are low concentrations of metals and metalloids.

With respect to in-pit rejects management facilities, whilst pits are being dewatered there will always be a hydraulic gradient into the pit where water is collected and managed, as such, seepage into the groundwater around the pits is extremely unlikely.

Waste rock management is described in **Chapter 9,** including the development of a Mine Waste Management Plan (MWMP). Waste rock will be characterised and placed within waste rock dumps to limit dispersion and erosion.

The quality of groundwater is described in **Section 17.4**. In summary, the groundwater is generally brackish to saline and of poor quality. Therefore potential seepage from waste rock dumps or in-pit rejects management facilities into groundwater would have minor potential impacts on groundwater quality and negligible impacts on groundwater values. Preventative measures, such as selective placement of waste rock within waste rock dumps will assist in reducing any potential impacts on groundwater.

17.5.5 Final Void Water Interaction with Groundwater

Modelling of final void water levels and quality is presented in **Chapter 11**. In summary, there is an overwhelming likelihood (85-95% probability), that final void water levels in all pits will stabilise at levels below the surrounding water table, providing a permanent hydraulic gradient into the void and preventing excursions into the surrounding groundwater.

Salinity of final void water is expected to increase and range between 1,000 mg/L and 10,000 mg/L over time. Waste rock geochemistry testing suggests that there is a very low risk of acid generation, and the water quality entering the voids from the pit walls would not adversely affect void water quality. The salinity of near surface pit water is expected to be much lower that at depth, with high dissolved oxygen, neutral to slightly alkalinity, with low to very low dissolved metal concentrations.

As there is minimal likelihood of final void water flowing into the surrounding groundwater (i.e. stabilising above the surrounding groundwater level), and the existing groundwater is generally brackish to saline and of poor quality, the potential for final void water to impact on the surrounding groundwater is excepted to be minor. Furthermore any potential impacts to groundwater values which might occur would themselves be minor.

17.5.6 Groundwater Vulnerability to Pollution

In accordance with the EPP (Water), contamination of groundwater through construction, operation and decommissioning will be avoided through design of facilities to prevent release of contaminants. The proponent will adopt hydrocarbon and chemical handling, storage and spill response procedures for all phases of the project that will minimise the risk of contaminant release and contain any accidental releases.

In order to prevent contamination of groundwater and to minimise seepage from the base and basal edges of the facility (refer **Chapter 9**), the co-disposal dams will be constructed in accordance with the requirements of the Manual for Assessing Hazard Categories and Hydraulic Performance of Dams (DERM, 2012) (the Manual) by a Registered Professional Engineer Queensland (RPEQ). The construction of co-disposal dams will include seepage detection mechanisms systems based on the RPEQ design, which can include, regular surveyed level monitoring, dam specific water balances and monitoring bores installed near co-disposal dams to detect seepage and measure seepage quality, if any.

If installed monitoring bores indicate seepage the proponent will take the appropriate remedial action. This will be determined at the time and will be based on the advice of an RPEQ to address seepage.

If contamination from seepage has occurred, as with contamination on any area of the project, an investigation will be undertaken, with management or remediation as required. This may involve engaging a suitably qualified person (SQP) approved by EHP as a contaminated land specialist[1], where required, and will fully depend on the nature and extent of contamination.

The vulnerability to pollution of any aquifer is directly related to:

- hydraulic condition (confined or unconfined)
- proximity to the pollutant source
- hydraulic conductivity of the subsurface sequence.

17.5.6.1 Alluvium

It has been demonstrated in **Section 17.4.7** that there are no alluvial aquifers of note in the project area. Pollution of the groundwater in this aquifer formation from surface activities is therefore not possible.

17.5.6.2 Suttor Formation

The unconfined to semi-confined Suttor Formation is predominantly clayey and therefore of low bulk hydraulic conductivity. It contains naturally saline groundwater (as evidence by DNRM groundwater monitoring bore RN 12030094). The groundwater quality in the bore is very poor with total dissolved solids content of 6,200 mg/L, which is typical of groundwater from the Suttor Formation.

The vulnerability to pollution of the groundwater in this aquifer formation from surface activities is considered to be low.

17.5.6.3 Tertiary Sands below Basalt

The confined Tertiary sands below the basalt occur in 'shoestring' aquifers. The groundwater quality in BYGW07A is mildly brackish with total dissolved solids content of 300 to 1,300 mg/L. The Tertiary sands are confined beneath a significant thickness of fresh basalt acting as an aquitard and providing a barrier to direct rapid ingress of pollution from surface activities.

[1] For the purposes of preparing site investigation and validation reports and draft site management plans, an SQP is defined in the *Environmental Protection Regulation 2008*.

The vulnerability to pollution of the groundwater in this aquifer formation from surface activities is considered to be low.

17.5.6.4 Coal Seam Aquifers

The confined coal seam aquifers are both discontinuous and of low hydraulic conductivity. The groundwater quality in the coal seam aquifers is naturally very poor. The vulnerability to pollution of the groundwater in this aquifer formation from surface activities is considered to be low.

17.5.7 Groundwater Monitoring

The following groundwater monitoring strategy will be implemented by the proponent during construction, operations and decommissioning:

- The groundwater monitoring bore suite will consist of the following bores:
  - BYGW01
  - BYGW02
  - BYGW03
  - BYGW04
  - BYGW05
  - BYGW06
  - BYGW07A
  - BYGW07B
  - BYGW08
  - BYGW09
  - BYGW10.
- Monitoring of project groundwater monitoring bores will be undertaken on a quarterly interval basis for water level and water quality. This will provide data on the groundwater in the areas of operation, data on groundwater around private bores (several bores have been located to allow delineation of any potential project related impact on private landholder bores) and data on regional groundwater for comparison (several bores are located well outside of potential impact).
- Automatic water level data loggers will remain in BYGWB05, BYGW07A and BYGW09 to capture daily groundwater levels which will enable sufficient temporal resolution for trend analysis on groundwater level fluctuations.
- Groundwater samples will be retrieved during monitoring to allow more robust statistical analysis of water quality and comparison against contaminant trigger limits.
- The dedicated groundwater monitoring bores will continue to be sampled in accordance with the Water Quality Sampling Manual produced by the former Department of Environment and Resource Management.
- All groundwater samples will be submitted to a NATA accredited laboratory for analysis.
- Daily rainfall will be measured and recorded.
- The data from the groundwater monitoring bores will be reviewed at minimum six-monthly intervals.

The proponent will develop a groundwater monitoring plan, incorporating the strategies described above and incorporating standards and indicators against which groundwater impacts can be measured.

Specifically if monitoring indicates a change in groundwater elevation > 2m compared to the previous quarterly monitoring event, results will be reported to the regulatory authority, which will include an investigation into the cause, potential short, medium or long term impacts and any required management or mitigations.

Water quality criteria will also be monitored for change and compared against a range of investigation level criteria based on baseline data. This will include physiochemical parameters, metals and hydrocarbons. Groundwater contaminant parameters and trigger levels (i.e. indicators) will be finalised based on a background groundwater monitoring program and be submitted to the administering authority by commencement of mining operations.

If groundwater contaminant trigger levels are exceeded then the proponent will complete an investigation into the potential for environmental harm and notify the administering authority within 30 business days of receiving the analysis results. Any required remedial action will be agreed upon with the relevant regulator and would be undertaken within an agreed timeframe.

In addition bore performance will be reviewed annually for function and suitability, and recommendations made for maintenance or replacement of bores where required.

A groundwater monitoring program will be implemented within the project area for the life of the project which includes frequency and location of monitoring, and the parameters to be monitored. The monitoring requirements for groundwater are included in the EMP (**Appendix 9**).

17.6 Conclusions

Information on the hydrogeology and groundwater in the study area was obtained from publically available records, previously existing mineral exploration bores and the dedicated groundwater monitoring bores. The hydraulic conductivity values for all lithologies tested are generally relatively low (10^{-7} to 10^{-10} m/s).

There are no alluvial aquifers of any significance in the project area. Tertiary sequence aquifers do not appear to be in hydraulic connectivity with the deeper Permian sequence aquifers. The aquifers within the sandstones contained in the Permian coal seams are discontinuous. Therefore the hydraulic connectivity within the coal seam aquifers will be at best very limited. There are no aquifers of significance in the basement.

An assessment of the regional potentiometric surface for the Permian sequences indicates that groundwater flow is both to the north east and to the south with a groundwater divide running east west across the centre of the project area.

The aquifers within the project area are not hydraulically connected to the Suttor River or any of the major watercourses. There is little or no groundwater - surface water interaction across the project area, as the standing water levels are deep and there is generally a significant thickness of low permeability material above any aquifers that are encountered.

Tertiary aquifers cannot contribute recharge to the Permian aquifers. The majority of the recharge to the Permian coal sequence aquifers probably derives from slow infiltration through the Suttor Formation. There is no recharge from the alluvium to the Permian sequence aquifers.

Groundwater chemistry in the 11 dedicated groundwater monitoring bores indicated that:

- electrical conductivity (EC) and the total dissolved solids (TDS) content of the groundwater ranges from moderate to high
- groundwater across the project area is moderately to highly alkaline

- metal and sulphate concentrations are below ANZECC/ARMCANZ 2000 stockwater guideline values except for two bores with higher lead concentrations and one bore with higher sulphate concentrations
- nitrate and nitrite concentrations are below Australian Drinking Water Guidelines.

The presence of anthropogenic dissolved hydrocarbons within the groundwater in the area is considered extremely unlikely and confirmatory sampling will be undertaken to verify the absence of hydrocarbons.

Groundwater inflow was estimated for the open pits, using a low permeability and high permeability case, with the low permeability case considered more pertinent. Inflow estimates under the low permeability case were between 0 and 320 m^3/day across all pits.

Groundwater drawdown contours were modelled for South Pit 1 as it is the deepest and most extensive pit and therefore the worst case scenario for radius of drawdown. The maximum expected radius of drawdown from South Pit 1 is 2,300m. All other pits are expected to have a lesser radius of drawdown and as such, applying that maximum radial extent to the other pits is a conservative measure.

There are 8 privately owned groundwater facilities close to the project area. Other than bore RN 25686, none of the private boreholes is within 2,300 m of any of the project's open pits. RN 25686 is approximately 1,950 m east of East Pit 2 at Year 35 of mining operations. RN 25686 is generally only suitable for stock watering, being naturally too high in chloride and sulphate for human consumption. Dewatering from any mining activities in the project area is expected to have negligible or no impact on privately owned groundwater facilities.

No springs, seeps or swamps are known in the project area and there is no groundwater - surface water interaction between the aquifer sequences beneath the project area and the watercourses that traverse the project area. With the exception of stygofauna (which is specifically addressed in **Chapter 20**) it is concluded that there are no groundwater dependent ecosystems which can be impacted by the project's mining activities.

There is minimal likelihood of final void water stabilising above the surrounding groundwater level and as such the potential for seepage into the surrounding groundwater is minor. Furthermore the groundwater is generally brackish to saline and of poor quality; as such and based on the characterisation of waste rock and rejects, any potential seepage from waste rock dumps and in-pit rejects management facilities to groundwater, is likely to have a minor impact on groundwater quality and negligible impact on groundwater values.

The potential for final void water to impact on the surrounding groundwater is expected to be minor and any potential impacts to groundwater values which might occur would themselves be minor.

The vulnerability of groundwater aquifers to surface pollution is considered low as:

- the Suttor Formation has low hydraulic conductivity and already contains saline groundwater
- the Tertiary Sands below the basalt are mildly brackish and confined beneath a significant thickness of fresh basalt (acting as an aquitard) preventing direct ingress of pollution
- coal seam aquifers are both discontinuous and of low hydraulic conductivity with poor water quality.

In addition, the proponent will implement management measures to prevent and control the release of surface contaminants.

A groundwater monitoring strategy will be implemented, comprising the existing dedicated groundwater monitoring bores. Groundwater levels will be measured and recorded in all the groundwater monitoring bores at quarterly intervals. The monitoring data will be reviewed at minimum six-monthly intervals. In the unlikely event of regional depressurisation of the water table, the dedicated project groundwater monitoring bores are well located to measure those impacts.

Water level monitoring data will be reported to the relevant authority on a quarterly basis only if a change of >2 m (higher or lower than the previous quarterly monitoring event) to the standing water level is detected; however, all groundwater level monitoring results will be reported as part of the annual return.

If groundwater contaminant trigger levels are exceeded then the proponent will complete an investigation into the potential for environmental harm and notify the administering authority within 30 business days of receiving the analysis results. Any required remedial action will be agreed upon with the relevant regulator and would be undertaken within an agreed timeframe.